MARYLAND HIGHER EDUCATION COMMMISSION
ACADEMIC PROGRAM PROPOSAL DEC 16 2015

PROPOSAL FOR:

✓ NEW INSTRUCTIONAL PROGRAM

____ SUBSTANTIAL EXPANSION/MAJOR MODIFICATION **(for online delivery)**

____ COOPERATIVE DEGREE PROGRAM

✓ WITHIN EXISTING RESOURCES or ____ REQUIRING NEW RESOURCES

(For each proposed program, attach a separate cover page. For example, two cover pages would accompany a proposal for a degree program and a certificate program.)

Johns Hopkins University
Institution Submitting Proposal

Spring 2016
Projected Implementation Date

Master of Science	**Financial Mathematics**
Award to be Offered	Title of Proposed Program
1703-03	**27.0301**
Suggested HEGIS Code	Suggested CIP Code

Financial Mathematics	**T.E. Schlesinger, Dean**
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12/15/2015
Signature and Date

President/Chief Executive Approval

12/1/2015
Date

Date Endorsed/Approved by Governing Board

The Johns Hopkins University
Whiting School of Engineering
Proposal for New Academic Program

Master of Science in Financial Mathematics

A. Centrality to institutional mission statement and planning priorities

1. Program description and alignment with mission

The Johns Hopkins University Whiting School of Engineering proposes to launch a new Master of Science in Financial Mathematics, building on the existing and previously endorsed Master of Science in Engineering in Financial Mathematics (HEGIS code 170302, CIP code 270301), which is designed for full-time resident students. The newly proposed program would be delivered online and is intended for part-time students.

Financial Mathematics, also referred to as Financial Engineering, is a relatively new discipline, rooted in modern economic thought yet steeped in the classical intellectual disciplines of mathematical analysis, chance, and uncertainty. Tracing its origins to the early 1970s and to the introduction of the personal computer, financial engineering's early achievements include the development of structured mortgage-backed securities (now the biggest bond market) and a rationale for option pricing—the consequences of which are ubiquitous in modern investing and financial markets.

The Financial Mathematics program aims to equip graduates with the engineering-driven approaches widely used to construct and deploy the financial transactions and processes that, in their context, function as the international financial system and capital markets. These are the mechanisms that enable the creation and employment of wealth and for the worldwide distribution of well-being within the constraints and intent of global financial policy.

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 proposed program is consistent with the Johns Hopkins mission and the State of Maryland's goals for maintaining and strengthening a preeminent statewide array of postsecondary institutions recognized nationally for academic excellence and effectiveness in fulfilling the educational needs of students, the State and the nation; and for promoting economic growth and vitality through the advancement of research and the development of a highly qualified workforce.

The proposed program is part of the Johns Hopkins University Whiting School of Engineering's Engineering for Professionals (JHU-EP) program, initially designed to serve the part-time graduate degree program needs of the working engineering and science professionals in the central Maryland region. The Master of Science in Financial Mathematics program will prepare students to enter leadership positions in the financial

industry and government where they will use their financial mathematics knowledge, skills, and creativity to provide innovative solutions and develop new or improved financial products and services. This program will build on the existing instructional strengths of JHU-EP to provide a blend of graduate engineering knowledge with professional development education in areas such as financial risk management, portfolio management, trading and banking.

In order to provide the greatest opportunity for students to enroll in this program, and to capture the leverage offered by the resident program while conserving resources, it will be offered in an online mode of delivery. With transportation costs rising and the work and travel schedules of students becoming more intensive, students have been asking for more online courses. The JHU-EP online programs offer the same rigorous educational experience available to other graduate students at Johns Hopkins, as it is based entirely upon the same material and is taught by the same instructors as the classroom program. Thus this degree program will be available to students independent of geography, work environment, and schedule.

2. Alignment with institutional strategic goals

One of the Whiting School of Engineering's strategic priorities is to educate future leaders by providing students with an innovative and distinctive education of the highest quality, both at the undergraduate and graduate level, in a diverse and inclusive environment. One of the near-term goals within that priority is to develop a comprehensive suite of contemporary master's degree offerings, for full-and part-time students, with flexible formats that respond to the needs of industry in both the domestic and international markets. It is clear that this online program offers a flexible format and enables this program to more easily reach the broader markets cited in this goal.

Johns Hopkins University's 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. 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.

The educational objective of the Master of Science in Financial Mathematics program is to combine advanced, graduate coursework in a specialized technical field, requiring rigorous analytical skills, with professional education in financial risk management, portfolio management, trading, and banking. Our goal is to provide students with the

educational background to pursue increasingly responsible management roles in the financial industry and government.

B. Adequacy of curriculum design and delivery to related learning outcomes

1. Program outline and requirements

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

Applicants for the Master of Science in Financial Mathematics program must have:

- An undergraduate or graduate degree in a quantitative discipline (*e.g.*, mathematics or engineering) from a regionally accredited college or university and at least two years of experience in finance or a related field

Applicants must show competency (through their undergraduate transcripts) in the following areas:

- Calculus, through multivariable calculus
- Linear algebra
- Differential equations
- Probability and Statistics
- Competency in computer programming must be demonstrated through coursework (including MOOC course completion with verification) or work experience

The Financial Mathematics admissions committee will evaluate the prospective student's academic and professional record.

In order to earn a Master of Science in Financial Mathematics, 10 courses (30 credits) approved by an adviser, must be completed within five years. Four courses (12 credits) must be from the required Financial Mathematics (FM) core courses, with one additional elective (3 credits) chosen from the remaining Financial Mathematics (FM) core courses. In addition, five courses (15 credits) must be from the required core in Applied Mathematics (AM). No more than one course (3 credits) with a grade of C, and no course with a grade lower than C, may be counted towards the degree. The following summarizes these requirements and notes specific courses (described in Appendix A):

MS in Financial Mathematics

Courses (10)	
Financial Mathematics	Investment Science OR Mathematics of Finance
Financial Mathematics	Introduction to Financial Derivatives
Applied Mathematics	Statistical Methods and Data Analysis
Applied Mathematics	Introductory Stochastic Differential Equations with Applications
Financial Mathematics	Interest Rate and Credit Derivatives
Applied Mathematics	Monte Carlo Methods
Financial Mathematics	Financial Risk Management & Measurement
Applied Mathematics	Time Series Analysis and Dynamic Modeling
Applied Mathematics	Optimization Methods in Finance
Financial Mathematics	Quantitative Portfolio Theory & Performance Analysis OR Financial Engineering and Structured Products (ELECTIVE)

Students must meet the specific course and program requirements listed for each technical course they take. In the event that the student has transfer courses accepted, they must be equivalent to one of the financial mathematics curriculum courses.

2. Educational objectives and student learning outcomes

The educational objective of the Master of Science in Financial Mathematics program is to equip graduates with the engineering-driven approaches widely used to construct and deploy the financial transactions and processes that, in their context, function as the international financial system and capital markers. These are the mechanisms enabling the creation/employment of wealth and for the worldwide distribution of well-being within the constraints and intent of global financial policy.

Our goal is to provide students with the educational background to pursue increasingly responsible management roles in industry.

Graduates will be prepared to enter leadership positions in the financial industry and government where they will use their quantitative skills and creativity to provide innovative solutions and develop new or improved products and services.

3. General education requirements

Not applicable.

4. Specialized accreditation/certification requirements

Not applicable.

5. Contractual agreements with other institutions

Not applicable.

C. Critical and compelling regional or statewide need as identified in the State Plan

1. Demand and need for program

The Whiting School of Engineering has offered graduate degree programs that address both technical expertise and leadership skills for many years. The JHU-EP Program has offered the Master of Science in Technical Management since 1981. In 1991 the JHU-EP began offering a Master of Science in Systems Engineering to meet the demand from local Maryland companies and the federal government. While demand is still strong for both of those degree programs on the part of both students and employers, we have observed an increasing interest in a graduate degree program that addresses the particular needs of the financial industry. Other universities have also noticed this trend. This proposed Master of Science in Financial Mathematics program is a response to the demand from potential students and their employers for this kind of degree program.

For busy working professionals, flexibility is very important in enabling them to continue their education in the face of work demands. The online option for this program will create scheduling flexibility. They will also accommodate students who must suspend their studies due to temporary military deployment or relocation by their employer. Online offerings also give JHU-EP the opportunity to retain students with frequent business travel or job assignment outside of their home region as, well as those with personal commitments requiring schedule flexibility.

For these reasons, JHU-EP identified a need for online-based graduate education in Financial Mathematics leading to a Master of Science in Financial Mathematics.

2. Alignment with Maryland State Plan for Postsecondary Education

The 2013–2017 Maryland State Plan for Postsecondary Education articulates six goals for postsecondary education: 1) quality and effectiveness; 2) access, affordability and completion; 3) diversity; 4) innovation; 5) economic growth and vitality; and 6) data use and distribution. This degree program addresses most of these goals.

In offering the program via a distance education format, each candidate can tailor the program to suit his/her individual learning needs, which supports the access goal (Goal 2) in the State Plan. By leveraging technology, candidates can pursue "anytime, anywhere" learning opportunities, *i.e.,* candidates can undertake course-related activities at a time and a location most convenient to them, rather than what is most convenient to the instructor. The online program provides that emphasis and aligns with the innovation goal (Goal 4) articulated in the State Plan.

One of the goals of the Whiting School of Engineering is to prepare highly trained scientists and engineers to work in organizations where they can contribute to the needs of society. Typically, the part-time students with full-time jobs who enroll in our Engineering for Professionals programs represent a broader range of diversity than students in full-time degree programs. In targeting these part-time students, this program addresses the diversity goal (Goal 3) outlined in the State Plan. In turn, the program, through the preparation of highly qualified financial mathematicians/engineers, also

contributes to Goals 1 (Quality and Effectiveness) and 5 (Economic Growth and Vitality) by providing life-long learning to financial professionals so they can maintain the skills they need to succeed in the workforce.

D. Quantifiable and reliable evidence and documentation of market supply and demand in the region and State

1. Market demand

A recent survey through the job search-engine at Monster.com revealed more than 1,000 unfilled jobs in the mid-Atlantic/Baltimore region for various financial mathematics practitioners. The survey used search key-words such as financial mathematics (31), financial derivatives (158), financial risk (288), portfolio management (753), trading (110), and structured finance (482) to name a few, where all employment opportunities require advanced university education in financial mathematics.

2. Educational and training needs in the region

Professionals practicing financial mathematics are found at every financial services institution. Such firms include banks, whereby M&T and Bank One are but two major institutions with major installations in Maryland and the mid-Atlantic region (all firms mentioned in this section include only firms contacted about the proposed program); investment management firms, such as T. Rowe Price and Legg Mason; investment banks, such as Stifel and Bank of America Merrill Lynch. There are other industrial enterprises where interactions with markets (financial or otherwise) require highly skilled financial mathematics professionals, these being vital to their competitiveness (for example Consolidated Energy – trading in the global energy markets to ensure the best for Maryland). Additionally, graduates will be in demand by government entities (and governmental supra-agencies) such as at the Federal Reserve, the Government Sponsored mortgage Enterprises such as FNMA & FHLMC, the U.S. Treasury, the Social Security Administration, the World Bank, etc. If we were to include the burgeoning financial center in Wilmington, DE, such firms as J. P. Morgan Chase, Bank of America, ING, as well as Bloomberg, LLC, could be included in our list.

3. Prospective graduates

The residence program in the Whiting School of Engineering on the Homewood campus currently receives 500 applicants each academic year, accepts 25 to 30 students, and graduates the same number, annually. All these students are quickly placed in jobs, usually before graduation. A few stay in the Maryland area, but many go on to the financial centers in New York, London, Hong Kong, or Mainland China. There is tremendous demand for these skilled professionals, worldwide, and especially after the credit crisis of 2008.

The JHU-EP program is expected to produce a similar number of MS graduates. The majority of these graduates are not expected until 2018 given the normal pace of JHU-EP students in pursuit of their degree, though a few might choose an accelerated pace.

E. Reasonableness of program duplication

1. Similar programs

No other institution in the state of Maryland currently offers a Master of Science in Financial Mathematics or any program similar to the proposal herein.

2. Program justification

The proposed Master of Science in Financial Mathematics program is unique in its online options, its broad range of students, and its accompanying broad set of courses taught by highly-regarded researchers and practitioners. Students seek out JHU-EP programs for high quality and online, part-time convenience.

F. Relevance to Historically Black Institutions (HBIs)

1. Potential impact on implementation or maintenance of high-demand programs at HBIs.

Not applicable. Web searches of the HBIs in Maryland did not turn up any offerings like the one proposed here.

2. Potential impact on the uniqueness and institutional identities and missions of HBIs.

Not applicable.

G. Evidence of compliance with the Principles of Good Practice

See Appendix B for the evidence that this program complies with the Principles of Good Practice noted above.

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 at about any additional costs or charges that are associated with verification of student identity. In this graduate program, 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 their unique student ID and password they receive when they are admitted to the programs, 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.

H. Adequacy of faculty resources

The proposed Master of Science in Financial Mathematics engages faculty members from both the existing full-time program in Financial Mathematics as well as those from the part-time JHU-EP Applied and Computational Mathematics program. Each is a distinguished and experienced professional, and many have doctorates in their field of expertise. These faculty members have demonstrated a strong commitment to excellence in teaching. Most are practicing professionals in the financial industry or government, and many hold influential and leadership positions in their organizations. Please see Appendix C for a representative list of faculty who will teach in the program.

I. Adequacy of library resources

The Milton S. Eisenhower Library on the Homewood campus is ranked as one of the nation's foremost facilities for research and scholarship. Its collection of over three million bound volumes, several million microfilms, and over 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. The library offers a variety of instructional services, including electronic classrooms designed to explain the library resources available for research and scholarship. Librarians help students electronically and the library maintains an extensive web site to take visitors through all of its services and materials.

J. Adequacy of physical facilities, infrastructure and instructional equipment

As a JHU-EP program using existing courses as well as online technology, the Financial Mathematics program would not impact the JHU Whiting School of Engineering's physical facilities and infrastructure.

In terms of technology infrastructure and support, this online program will be delivered via the JHU-EP online offering infrastructure, which includes the Blackboard course management system and the Adobe Connect video conferencing system. Both of these systems are supported by the Whiting School and the University's IT infrastructure. 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. The Whiting School already successfully delivers all of its online and web-enhanced courses and programs using these platforms. As part of the program's development, the School's technical support team and business office have determined that we possess the necessary technology infrastructure and resources in place to support successful delivery of this online program.

The Johns Hopkins University is currently equipped with the technical infrastructure and a system server for the management of online courses using Blackboard and Adobe Connect software. Blackboard 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. The university is also outfitted with suitable technical and professional staff and a 24/7 technical help desk to provide technical assistance to the students taking online courses. All of the student services such as application processes, course registration, bookstore, ID service, and advising are currently provided online as well.

K. Adequacy of financial resources with documentation

JHU-EP now has more than 10 years of experience in developing and offering online courses. Based on that experience, JHU-EP will be able to sustain the proposed program through tuition generated by offering the courses during fall, spring, and summer terms each year. Details concerning the resources and expenses may be found in Appendix D.

L. Adequacy of provisions for evaluation of program

As part of the program design and approval process, student learning outcomes and assessments have been aligned with both the Whiting School of Engineering's Graduate Committee oversight and to applicable professional standards. Once the Master of Financial Mathematics program is launched, the program and courses will be evaluated using student surveys and program committee reviews on a regular basis. For example, feedback regarding the appropriateness of course content will be solicited from students every time a course is offered. The program committee will meet annually to assess course evaluations and other feedback provided by students, faculty and other stakeholders in the program. Based on these data, the program committee will implement changes to the program (in terms of curriculum content, course delivery mechanisms, etc.) as necessary.

M. Consistency with the State's minority student achievement goals

As discussed above, the JHU-EP program, the Whiting School of Engineering's part-time graduate program already draws students from the entire science and engineering work force in the central Maryland region. The diversity of Johns Hopkins's student body diversity reflects that of the regional work force. Including the online component of this program will also reflect the diversity of the work force on the national scale. This should serve to increase the accessibility of JHU-EP programs to a wider range of students in our diverse communities.

N. Relationship to low productivity programs identified by the Commission

Not applicable.

Appendix A

Course List and Descriptions

All courses listed below are 3 credit hours and are currently offered unless otherwise indicated.

Core courses in Financial Mathematics

555.442 Investment Science
This is the key introductory course for the financial mathematics program and introduces the major topics of investment finance. The investment universe, its context of markets, and the flow of global capital are introduced. Details of equities, interest, bonds, commodities, forwards, futures, and derivatives are introduced to varying degree. The concepts of deterministic cash flow stream, valuation, term structure theories, risk, and single- and multi-period random cash flows are presented. Here the neoclassical theory of finance is introduced including the topics of efficient markets, the risk-return twins leading to the mean variance Capital Asset Pricing Model (CAPM), the efficient frontier, the intertemporal models, and Arbitrage Pricing Theory (APT). Some introductory models of asset dynamics (including the binomial model), basic options theory, and elements of hedging are also included in this course. (This course is the same as 550.442 offered by the AMS department for the residence MSE in Financial Mathematics.)

625.441 Mathematics of Finance
This course offers a rigorous treatment of the subject of investment as a scientific discipline. Mathematics is employed as the main tool to convey the principles of investment science and their use to make investment calculations for good decision making. Topics covered in the course include the basic theory of interest and its applications to fixed-income securities, cash flow analysis and capital budgeting, mean-variance portfolio theory and the associated capital asset pricing model, utility function theory and risk analysis, derivative securities and basic option theory, and portfolio evaluation.

555.444 Introduction to Financial Derivatives
This is the first of a two-course sequence devoted to the mathematical modeling of securities and the markets in which they are created and exchanged. The basic cash, hybrid, and derivative instruments are reviewed and set in a rigorous mathematical context. This includes equities, bonds, options, forwards, futures, and swaps, as well as their dealer, over-the-counter, and exchange environment. Models of the term structure of interest rates, spot rates and the forward rate curve are treated; derived from cash instruments (*e.g.,* bonds and interest rates like LIBOR) as well as from derivatives (such as Eurodollar futures and swaps). Principles of static, discrete, continuous and dynamic probabilistic models for derivative analysis (including the Weiner process, Ito's Lemma and an introduction to risk-neutral valuation) are applied to develop the binomial tree approach to option valuation, the Black-Scholes-Merton differential equation, and the Black-Scholes formulas for option pricing. (This course is the same as 550.444 offered by the AMS department for the residence MSE in Financial Mathematics.)

555.445 Interest Rate and Credit Derivatives

This is the second of a two course sequence devoted to the mathematical modeling of securities and the markets in which they are created and exchanged. Focus turns to interest rate derivatives and the credit markets. The martingale approach to risk-neutral valuation is covered, followed by interest rate derivatives and models of the short rate process (including Heath, Jarrow, & Morton and the Libor Market Model); analysis of bonds with embedded options and other interest rate derivatives (*e.g.,* caps, floors, swaptions). Credit risk and credit derivatives, including copula models of time to default, credit default swaps, and a brief introduction to collateralized debt obligations. A major component of this course is computational methods. This includes data and time series analysis (*e.g.,* estimation of volatilities), developing binomial and trinomial lattices and derivative analysis schemes, and numerical approaches to solving the partial differential equations of derivatives. (This course is the same as 550.445 offered by the AMS department for the residence MSE in Financial Mathematics.)

555.446 Financial Risk Management and Measurement

This course applies advanced mathematical techniques to the measurement, analysis, and management of risk. The focus is on financial risk. Sources of risk for financial instruments (*e.g.,* market risk, interest rate risk, credit risk) are analyzed; models for these risk factors are studied and the limitation, shortcomings and compensatory techniques are addressed. Throughout the course, the environment for risk is considered, be it regulatory or social, *e.g.,* Basel capital accords. A major component of the course is the Value at Risk (VaR) measure for market risk in trading operations, including approaches for calculating and aggregating VaR, testing VaR, VaR-driven capital for market risk, and limitations of the VaR-based approach. Asset Liability Management (ALM), where liquidity risk as well as market risk can affect the balance sheet, is analyzed. Here, models for interest rate, spread, and volatility risks are applied to quantify this exposure. Another major component of the course is credit risk. Sources of credit risk, how measured risk is used to manage exposure, credit derivatives, techniques for measuring default exposure for a single facility (including discriminant analysis and Merton-based simulation), portfolio risk aggregation approaches (including covariance, actuarial, Merton-based simulation, macro-economic default model, and the macro-economic cash-flow model – for structured and project finance). Finally, there is a brief introduction to concepts and tools that remain valid for large and extreme price moves, including the theory of copulas and their empirical testing and calibration. (This course is the same as 550.446 offered by the AMS department for the residence MSE in Financial Mathematics.)

555.447 Quantitative Portfolio Theory & Performance Analysis

This course focuses on modern quantitative portfolio theory, models, and analysis. Topics include intertemporal approaches to modeling and optimizing asset selection and asset allocation; benchmarks (indexes), performance assessment (including, Sharpe, Treynor and Jenson ratios) and performance attribution; immunization theorems; alpha-beta separation in management, performance measurement and attribution; Replicating Benchmark Index (RBI) strategies using cash securities/derivatives; Liability-Driven Investment (LDI); and the taxonomy and techniques of strategies for traditional management Passive, Quasi-Passive (Indexing) Semi-Active (Immunization & Dedicated) Active (Scenario, Relative Value, Total Return and Optimization). In addition, risk management and hedging techniques are also addressed. (This course is the same as 550.447 offered by the AMS department for the residence MSE in Financial Mathematics.)

555.448 Financial Engineering and Structured Products
This course focuses on structured securities and the structuring of aggregates of financial instruments into engineered solutions of problems in capital finance. Topics include the fundamentals of creating asset-backed and structured securities – including mortgage-backed securities (MBS), stripped securities, collateralized mortgage obligations (CMOs), and other asset-backed collateralized debt obligations (CDOs) – structuring and allocating cash-flows as well as enhancing credit; equity hybrids and convertible instruments; asset swaps, credit derivatives and total return swaps; assessment of structure-risk interest rate-risk and credit-risk as well as strategies for hedging these exposures; managing portfolios of structured securities; and relative value analysis (including OAS and scenario analysis). (This course is the same as 550.448 offered by the AMS department for the residence MSE in Financial Mathematics.)

Core courses in Applied Mathematics

625.714 Introductory Stochastic Differential Equations with Applications
The goal of this course is to give basic knowledge of stochastic differential equations useful for scientific and engineering modeling, guided by some problems in applications. The course treats basic theory of stochastic differential equations, including weak and strong approximation, efficient numerical methods and error estimates, the relation between stochastic differential equations and partial differential equations, Monte Carlo simulations with applications in financial mathematics, population growth models, parameter estimation, and filtering and optimal control problems.

625.433 Monte Carlo Methods
The Monte Carlo method has proven to be an indispensable tool in any area of application involving stochastic modeling. The purpose of this course is to expose students to important ideas that arise when we employ the Monte Carlo approach. In the process, several key topics at the interface between numerical analysis, computing, probabilistic modeling, and statistics are covered, including: uniform random number generation, non-uniform random number generation, techniques for variance reduction, importance sampling, design of simulation experiments, Markov chain methods, applications to system reliability, and applications to error estimation for statistical methods. (This course is the same as 550.433 offered by the AMS department for the residence MSE in Financial Mathematics.)

625.403 Statistical Methods and Data Analysis
This course introduces commonly used statistical methods. The intent of this course is to provide an understanding of statistical techniques and guidance on the appropriate use of methodologies. The course covers the mathematical foundations of common methods as an aid toward understanding both the types of applications that are appropriate and the limits of the methods. MATLAB and statistical software are used so students can apply statistical methodology to practical problems in the workplace. Topics include the basic laws of probability and descriptive statistics, conditional probability, random variables, expectation and variance, discrete and continuous probability models, bivariate distributions and covariance, sampling distributions, hypothesis testing, method of moments and maximum likelihood point (MLE) estimation, confidence intervals, contingency tables, analysis of variance (ANOVA), and linear regression modeling.

625.495 Time Series Analysis and Dynamic Modeling

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 period-gram, spectral estimation techniques, multivariate time series, linear systems and optimal control, state-space models, and Kalman filtering and prediction. Additional topics may be to illustrate the usefulness of the techniques.

625.416 Optimization Methods in Finance

Optimization methods motivated by financial applications. Topics include linear and nonlinear programming, integer programming, dynamic programming, stochastic programming, and robust methods. Applications will include portfolio optimization, volatility modeling, immunization, identification of arbitrage, and index fund construction. (This course is the same as 550.461 offered by the AMS department for the residence MSE in Financial Mathematics.)

Appendix B

Principles of Good Practice (as outlined in COMAR 13B02.03.22C)

(a) Curriculum and instruction

(i) A distance education program shall be established and overseen by qualified faculty.

This online program will consist of courses drawn from or modeled after the well-established on-site programs in Financial Mathematics and Applied & Computational Mathematics. Faculty teaching in these existing programs will also serve as online instructors. Any new instructor recruited to teach online would be required to meet the same qualifications as those teaching in the existing programs.

(ii) A program's curriculum shall be coherent, cohesive, and comparable in academic rigor to programs offered in traditional instructional formats.

A Program Director with extensive subject matter expertise and practical experience will have oversight of the program curriculum. This individual, who also teaches in the residence program and serves as its Executive Director, will oversee the selection of course instructors and ensure that the academic rigor of the online courses are comparable to traditional instructional formats.

All the courses in the online program are offered in the traditional, site-based program in Financial Mathematics. Prior to a course being converted for online delivery, the course has typically been taught twice in-class. In addition, a formal online course development process is used to support the course conversion from in-class to online. The online course development process incorporates the Quality Matters™ research-based set of eight standards for quality online course design to ensure the academic rigor of the online course is comparable or better than the traditionally offered course. We are starting to experiment with straight-to-online developments in the expectation that we will get non-regional faculty to develop courses in the future.

(iii) A program shall result in learning outcomes appropriate to the rigor and breadth of the program.

The program learning outcomes for the distance education program are identical to the traditional on-site program. The program learning outcomes are derived from input from professionals within the discipline, the program instructors, program leadership and other program stakeholders.

(iv) A program shall provide for appropriate real-time or delayed interaction between faculty and students.

The online option for the Master of Financial Mathematics will be delivered via Blackboard, JHU's course management system. This platform supports asynchronous interaction between faculty and students. Students and faculty also have the option to participate in optional 'real-time' interaction through weekly web-conference office hours, supported by Adobe Connect.

(v) Faculty members in appropriate disciplines in collaboration with other institutional personnel shall participate in the design of courses offered through a distance education program.

The program has established a process for identifying the appropriate faculty to design an online course. All the faculty are selected based on domain expertise, program-related teaching experience and completion of a required online course development training course.

(b) Role and mission

(i) A distance education program shall be consistent with the institution's mission.

Refer to Section A.1 in the main body of the proposal.

(ii) Review and approval processes shall ensure the appropriateness of the technology being used to meet a program's objectives.

The development of online courses is supported by JHU-EP's Center for Learning Design and Technology (CLDT) professional staff, which includes instructional designers, instructional support specialists and other supporting staff. Each online course development is assigned an instructional designer. The course instructor(s) consults with the instructional designer during the course design process to determine the most effective learning technologies and strategies needed to meet the course learning objectives. The course design goes through multiple reviews by the instructional designer and program chairs. The program chairs are responsible for making sure the course design meets the program's expectations for online courses and that the course learning objectives reflect what your program expects students to achieve after completing this course. Once the online course launches, the assigned instructional designer continually monitors the courses, and consults with the instructor(s) to make adjustments to the course, if needed. All new online courses participate in a mid-term and end-of-term course evaluation process. The mid-term feedback is used to determine if any mid-point term corrections are needed. The end-of-term feedback is used to assess whether further course refinements are needed prior to the next time the course is offered.

(c) Faculty support

(i) An institution shall provide for training for faculty who teach with the use of technology in a distance education format, including training in the learning management system and the pedagogy of distance education.

Faculty development support for the development of online course is provided by JHU-EP's Center for Learning Design and Technology (CLDT) professional staff. Faculty have multiple opportunities to receive training in the learning management system, and pedagogy of online learning. These opportunities are presented at various times throughout the year at events such as fall/spring annual faculty meetings, Brown Bag workshops, webinars, and 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 on variety of online learning related topics.

(ii) Principles of best practice for teaching in a distance education format shall be developed and maintained by the faculty.

The JHU-EP CLDT has created a series of online teaching strategies resources. These resources are based best practices from research and other related sources. All new online course instructors are encouraged to review these resources prior to teaching their first online course. New online instructors also receive one-on-one coaching from instructional designers and peer mentors.

(iii) An institution shall provide faculty support services specifically related to teaching through a distance education format.

The JHU-EP CLDT provides a wide range of faculty support services for instructors engaged in online instruction. Instructors have access to multi-media specialists, instructional technologists, instructional designers, a training specialist and other institutional support staff to assist them in their role as online instructors. Some of the services provided include instructional technology training, course design support, learning management system training, course production support (*i.e.,* recording studio), video production, and a faculty support help line and email.

(d) An institution shall ensure that appropriate learning resources are available to students including appropriate and adequate library services and resources.

The students will have online 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 of its services and materials.

(e) Students and Student Services

(i) A distance education program shall 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.

JHU-EP maintains numerous web-based resources to inform prospective students on the information they may need as an online student. These resources include: EP main website (http://ep.jhu.edu); EP online catalog, which includes detailed programmatic information, academic support services, financial aid, costs, policies, etc. and specific information for online learning (refer to http://catalog.ep.jhu.edu/content.php?catoid=20&navoid=630). As new online students are admitted and enrolled, they receive timely emails with important information to help them prepare to become an online student. These emails include information on how to create their JHU login account for the course management systems, technical requirements, available academic support services and new online student orientation course.

(ii) Enrolled students shall have reasonable and adequate access to the range of student services to support their distance education activities.

JHU-EP online students have access to the following academic support services:

- **Academic Advising**: Students are assigned an advisor when accepted. Students 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. The advisor regularly contacts the students to check on progress and answer questions. Courses that deviate from the program plan and have not been approved by an adviser may not count toward degree requirements. A degree audit tool is provided so students verify their selections match degree requirements.

- **Library Services:** 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 web site to take visitors through all its services and materials.

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

- **Johns Hopkins Student Assistance Program:** The Johns Hopkins Student Assistance Program (JHSAP) is a professional counseling service that can assist students with managing problems of daily living. Stress, personal problems, family conflict, and life challenges can affect the academic progress of students. JHSAP focuses on problem solving through short-term counseling. Accessing the service is a simple matter of a phone call to arrange an appointment with a counselor. Online students may call a phone number for consultation and will be directed to the appropriate resource or office. JHSAP services are completely confidential. The program operates under State and Federal confidentiality legislation and is HIPAA compliant.

- **Transcript Access:** Official transcripts will be mailed upon written request of the student at no charge.

- **Student ID JCard:** The JCard serves as the student's University identification card. This card is mailed to the home address of every registered student. The JCard acts as the university library card, which enables students to check out books from the Homewood Eisenhower Library or at any of the campus center libraries, and provides access to many computer laboratories.

(iii) Accepted students shall have the background, knowledge, and technical skills needed to undertake a distance education program.

All accepted online students are required to have met the admission requirements stated for the degree program. New online students are strongly encouraged to complete the "New Online Student Orientation" course prior to beginning their first online course. This course covers a broad range of topics on how to be a successful online student such as: online student learning expectations, how to access the library, how to conduct online research, and how to participate in online discussions.

(iv) Advertising, recruiting, and admissions materials shall clearly and accurately represent the program and the services available.

All relevant program information is kept up to date on the JHU-EP web site (http://ep.jhu.edu).

(f) Commitment to Support

(i) Policies for faculty evaluation shall include appropriate consideration of teaching and scholarly activities related to distance education programs.

Faculty teaching online courses are strongly encouraged to participate in minimally one to two professional development opportunities annually to improve their online teaching skills.

(ii) An institution shall demonstrate a commitment to ongoing support, both financial and technical, and to continuation of a program for a period sufficient to enable students to complete a degree or certificate.

Please see sections J and K of the proposal.

(g) Evaluation and assessment

(i) An institution shall evaluate a distance education program's educational effectiveness, including assessments of student learning outcomes, student retention, student and faculty satisfaction, and cost-effectiveness.

Please see section L of the main body of the proposal.

(ii) An institution shall demonstrate an evidence-based approach to best online teaching practices.

The JHU-EP Center for Learning Design & Technology unit's instructional design and faculty support staff continually participates in professional development activities to keep abreast of evidence-based approaches to online teaching practices. These online teaching practices are then incorporated into the new online instructor training sessions.

(iii) An institution shall provide for assessment and documentation of student achievement of learning outcomes in a distance education program.

As part of the online course design process, course assessments are required to be aligned with stated course learning outcomes. The JHU-EP program, where appropriate, incorporates authentic-based learning assessments that demonstrate student's application of learned concepts.

Appendix C

Faculty

Name	Highest Degree	Field	Title	Courses Taught
David Audley	PhD	Financial Math	Senior Lecturer	Intro to Financial Derivatives; Interest Rate & Credit Derivatives; Financial Risk Management; Structured Securitization
James Spall	PhD	Applied & Computational Math	Research Professor	Stochastic Systems; Stochastic Optimization; Monte Carlo Methods; Investment Science
Beryl Castello	PhD	Applied Math & Statistics	Senior Lecturer	Linear Optimization; Nonlinear Optimization
Fred Torcaso	PhD	Applied Math & Statistics	Senior Lecturer	Time Series Analysis; Optimization in Finance; Stochastic Processes,
Barry Bodt	PhD	Mathematical Statistician	Lecturer	Statistical Methods & Data Analysis
Moustapha Pemy	PhD	Mathematical Finance & Stochastic Analysis	Associate Professor, Towson University	Mathematics of Finance; Introductory Stochastic Differential Equations with Applications

Appendix D

Finance Information

TABLE 1: RESOURCES	2015	2016	2017	2018	2019
1. Reallocated Funds	$0	$0	$0	$0	$0
2. Tuition/Fee Revenue (c + g below)	$0	$166,045	$636,230	$1,148,395	$1,515,882
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 Students	0	15	55	95	120
e. Credit Hour Rate	$1,177	$1,230	$1,285	$1,343	$1,404
f. Annual Credit Hour Rate	9	9	9	9	9
g. Total P/T Revenue (d x e x f)	$0	$166,045	$636,230	$1,148,395	$1,515,882
3. Grants, Contracts & Other Ext Sources	$0	$0	$0	$0	$0
4. Other Sources	$0	$0	$0	$0	$0
TOTAL (Add 1 – 4)	**$0**	**$166,045**	**$636,230**	**$1,148,395**	**$1,515,882**

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: Revenue is based on projected enrollments for the program. The Master of Science in Financial Mathematics and all related certificates are part-time programs, so no full-time students are expected.

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 sources.

Note: The resources and expenditures data for the Master of Science in Financial Mathematics is combined with those for the Post-Baccalaureate Certificate in Financial Risk Management, the Post-Baccalaureate Certificate in Securitization, and the Post-Baccalaureate Certificate in Quantitative Portfolio Management, as they share the same courses, and all resources and expenditures in these programs are course-based.

TABLE 2: EXPENDITURES	2015	2016	2017	2018	2019
1. Faculty (b + c below)	$27,524	$65,507	$124,088	$175,251	$218,479
a. # Sections offered	0	4	10	15	20
b. Total Salary	$25,485	$60,654	$114,897	$162,269	$202,296
c. Total Benefits	$2,039	$4,852	$9,192	$12,982	$16,184
2. Admin. Staff (b + c below)	$37,520	$38,270	$39,036	$39,817	$40,613
a. # FTE	0.25	0.25	0.25	0.25	0.25
b. Total Salary	$28,000	$28,560	$29,131	$29,714	$30,308
c. Total Benefits	$9,520	$9,710	$9,905	$10,103	$10,305
3. Support Staff (b+c below)	$28,669	$29,099	$29,535	$29,978	$20,285
a. # FTE	0.375	0.375	0.375	0.375	0.25
b. Total Salary	$21,315	$21,635	$21,959	$22,289	$15,082
c. Total Benefits	$7,354	$7,464	$7,576	$7,690	$5,203
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	$0	$59,516	$194,123	$299,920	$422,729
TOTAL (Add 1 – 7)	**$93,712**	**$192,392**	**$386,782**	**$544,966**	**$702,107**

Expenditures narrative

1. Faculty: The Engineering for Professionals lecturers are paid $8,495 (for FY15) per course taught or developed. For years 2–5, an additional 2% was added to the salary rate. The fringe rate is estimated at 8%.

2. Administrative Staff: Includes pro-rated salaries for the Program Chair.

3. Support Staff: Includes pro-rated salaries for F/T Instructional Designers 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 (per enrollment) are provided here.