SYSTEMS ENGINEERING

The part-time Systems Engineering program provides students with in-depth knowledge and technical skills that prepare them to further their careers within industry and government. The program addresses the needs of engineers and scientists engaged in all aspects of analysis, design, integration, production, and operation of modern systems. Instructors are practicing systems engineers who employ lectures and readings on theory and practice, and present realistic problem scenarios in which students, individually and collaboratively, apply principles, tools, and skills.

Program Committee

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Programs

- Systems Engineering, Graduate Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/systems-engineering/systems-engineering-graduate-certificate/)
- Systems Engineering, Master of Science (https://e-catalogue.jhu.edu/engineering/engineering-professionals/systems-engineering/systems-engineering-master-science/)
- Systems Engineering, Master of Science in Engineering (ABET-accredited) (https://e-catalogue.jhu.edu/engineering/engineering-professionals/systems-engineering/systems-engineering-master-science-engineering/)
- Systems Engineering, Post-Master's Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/systems-engineering/systems-engineering-post-masters-certificate/)

Courses

EN.645.621. Engineering and Measuring Influence. 3 Credits.
Systems engineering requires an understanding of how people interact with complex systems. Often times, human interaction makes up a substantial portion of system variance and controlling this variance is critical for system performance. Engineers must design interventions to influence people through all aspects of the system. Emerging technology can be used to understand, measure, and assess the effectiveness of interventions to influence human behavior and performance. This course will introduce students to theories of behavior change and provide hands on experience using technologies to measure human-system interaction and influence. Technologies will include biometric, psycho-physiological, and neuroimaging systems.

EN.645.631. Introduction to Model Based Systems Engineering. 3 Credits.
The Introduction to Model Based Systems Engineering course provides an overview of what Model Based Systems Engineering (MBSE) is and how MBSE techniques can be applied to the Systems Engineering process to manage complexity, reduce risk, and potentially streamline the engineering design and development effort. Students will utilize an industry-leading system modeling tool and develop artifacts applied to real-world case studies that reinforce the MBSE concepts of methodology, language, and tools.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering OR EN.655.662 Introduction to Healthcare Systems Engineering

EN.645.632. Applied Analytics for Model Based Systems Engineering. 3 Credits.
This course is a continuation of Introduction to Model Based Systems Engineering (MBSE), and provides in-depth exposure to building and using industry-leading system modeling tools to apply and analyze real-world case studies. This course will focus on the application of Model Based Systems Engineering through the use of a modeling language, a modeling method and a system modeling tool as part of the systems engineering process to support requirements, design, analysis, specification, and verification and validation activities of the system. Concepts that were developed from the previous course are now analyzed to assist the systems engineer to explore the solution space using MBSE.
Prerequisite(s): EN.645.631 Introduction to Model Based Systems Engineering.

EN.645.650. Foundations of Human Systems Engineering. 3 Credits.
Systems are designed, built, and used by humans. Their purpose is to help people meet their goals and perform their tasks. This course introduces the foundations of HSE from which system requirements and design elements are derived. The objective is to provide students with the knowledge of human capabilities and introduce human systems engineering concepts and design principles. Human capabilities include visual, auditory, and touch senses, motion, cognitive processing, and decision making. Human systems engineering concepts and design principles include human factors engineering; training; maintenance; environmental, safety, and health; survivability; habitability; manpower; and personnel.

EN.645.651. Integrating Humans and Technology. 3 Credits.
This class provides a hands-on introduction to human and cognitive systems engineering. Students will learn and apply user-centered research and innovation methods that are used to discover, document and integrate human capabilities, limitations and needs into the systems engineering process, improving the likelihood that the resulting systems are intuitive, efficient, effective and useful. Topics include needs elicitation, workflow analysis, functional allocation, decision making, prototyping, and performance measurement.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering OR EN.655.662 Introduction to Healthcare Systems Engineering OR EN.675.600 Systems Engineering for Space

EN.645.662. Introduction to Systems Engineering. 3 Credits.
This course introduces students to the fundamental principles of systems engineering and their application to the development of complex systems. It describes how the systems engineering viewpoint can be brought to bear to address engineering challenges as well as the essential role of systems engineering in project management. Topics include defining systems, the system development life cycle, and the systems engineering method. These primary topics are decomposed into requirements analysis, functional design, physical design, design validation, concept development, engineering development, and post development. In addition, the tools and methods at the systems engineer's disposal are also covered. These include risk analysis, configuration management, design trade-offs, modeling and simulation, and interface management, as well as how these subjects are linked to systems program management activities. More advanced Systems Engineering topics such as Software Systems, System of Systems, Enterprise Systems, and Agile Systems Engineering are introduced. The course defines the breadth and depth of the knowledge that the systems engineer must acquire concerning the characteristics of the diverse components that constitute the total system. Students will work as a group to develop and present a conceptual system architecture chosen from a list of existing systems in order to gain familiarity with architecting, system modeling, and the relationship between requirements, activities, hardware/software, interfaces, and other system elements.

EN.645.667. Management of Systems Projects. 3 Credits.
The course addresses the management of a technical project from concept to operational use, with emphasis on the functions, roles, and responsibilities of the project manager. From the development of a proposal to the delivery of a product to a customer, the efforts to conceive, plan, budget, schedule, monitor, control/direct, and report the progress of the project are discussed. Throughout the project life cycle, the need for good communications, interface and configuration management, and conflict resolution is emphasized. Students assume the role of project managers who must use management tools such as WBS, EVM, and CPN and who must address typical problems that arise in the conduct of a high-technology systems project.

EN.645.669. Systems Engineering of Deployed Systems. 3 Credits.
Systems engineering theory typically focuses on the early design and development phases of a system's life cycle, yet over the life of a system, the bulk of engineering effort and the associated costs are not realized until the operations and support (O&S) phase. This course will examine the importance of designing O&S considerations early in a system's life cycle by identifying the appropriate logistic elements and measures, while introducing the necessary analytical processes and tools to support end-to-end life cycle engineering requirements. Manufacturing and production operations will be presented along with the elements that support a system once it is fielded (maintenance planning, reliability prediction, supply support, training, shipping, and system disposal). The course will also explore the requirements and processes associated with major upgrades to deployed systems and the logistics management techniques that must be implemented during initial fielding and deployment. A class project and real-world case studies will underscore the theory and techniques associated with deployed systems engineering.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering or EN.645.667 Management of Systems Projects. College-level Statistics (College-level Calculus preferred but not required).

EN.645.711. Systems Engineering of Radar and Missile Technologies. 3 Credits.
This course emphasizes the key systems engineering processes involved in missile design. Missile technologies including electro-optical and radio-frequency sensors used for target detection; aerodynamics; navigation, guidance, and control; propulsion; warheads; fuzes; and signal and image processing are discussed in conjunction with the critical tradeoffs and methods used to meet operational requirements. The course objectives are demonstrated through a system cost-as-an-independent variable trade and design study that is based on trades of sensor type, guidance type, operational constraints and implementation, and how the system is segregated into different sub-system configurations.

EN.645.742. Management of Complex Systems. 3 Credits.
Traditional systems engineering is usually applied to closed, precise, and recursive systems with the assertion that the methodologies used can be scaled up to more elaborate systems of systems. This course addresses the more realistic and emerging field of complex systems, where multiple current development efforts with disparate and nonlinear attributes characterize the system components. Managing complex systems must account for the likelihood of multiple disciplines, differing scales, often unpredictable future states, irreducible uncertainty, and nonlinear behavior. Customers, corporations, governments, technologies, and systems now must be considered on a global scale with a mix of new and legacy systems. The student will be encouraged to think differently and creatively about the approaches to managing complex systems and to use adaptive strategies and tools. Special attention will be given to risk assessment and management for dynamic systems. Case studies and examples will be drawn from commercial industry and DoD/government systems. Students will be expected to discuss several readings and complete academic papers to explore in depth one or more of the concepts discussed.
Prerequisite(s): EN.645.769 System Test and Evaluation or EN.655.769 Healthcare System Test and Evaluation or advisor and instructor approval.

EN.645.753. Enterprise Systems Engineering. 3 Credits.
Enterprise Systems Engineering is a multidisciplinary approach to the application of systems engineering principles and systems thinking to large sociotechnical enterprises as complex adaptive systems. Health, energy, food, disaster response, and global transportation systems are all examples of such systems. Systems engineering has been a critical enabler of development, and is key, to addressing the complexities of the evolution of complex systems and systems of systems.?In this course, we explore systems thinking and systems engineering approaches that can be applied to this new class of broad sociotechnical enterprise.? We will examine the characteristics of this class of enterprise and the challenges for applying systems engineering to this type of complex adaptive system. These enterprises are comprised of multiple independent organizations with their own objectives, resources, and authority structures without top-level cross cutting authority and may possess conflicting objectives. A process model will be created to describe the activities of key enterprise elements and interactions which, along with external factors, influence the evolution of such enterprises. This model will be used to understand the current enterprise composition and dynamics and evaluate the impact of issues or actions as the basis for systems engineering trades or recommendations.
Prerequisite(s): EN.645.769 System Test and Evaluation or advisor and instructor approval.

EN.645.755. Methods in Human-System Performance Measurement and Analysis. 3 Credits.
This course focuses on human-systems performance measurement (HsPM) methods used to determine whether human-system requirements are met and if the system's design provides effective and efficient human-system performance. Students will gain knowledge of HsPM study design protocols, data collection tools and methods, analysis techniques and processes, and procedures required to execute studies with human participants. The course will provide students with an understanding of HsPM in the context of system design; workplace design; environment, safety, and occupational health; training; and maintenance. Students will be exposed to heuristic evaluations; modeling and simulation of human tasking, including tools for measuring physical limitations, cognitive load, and fatigue; and system testing with the human element.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering OR EN.655.662 Introduction to Healthcare Systems Engineering.

EN.645.756. Metrics, Modeling, and Simulation for Systems Engineering. 3 Credits.
This course takes an integrated, in-depth view of foundational statistical concepts, modeling, and simulation techniques. Knowledge of typical system-level key performance parameters and their stochastic characterization is critical to the systems engineering process as the basis for decision-making from early system conceptualization through retirement. Relevant probability and statistics concepts are covered in context of SE decision points. Techniques in experimental design, data collection, analysis, and modeling of system metrics as a function of system use and environment are explored as they pertain to characterizing system, subsystem, and component performance. Finally, implementing models in analytic simulations to support requirements, design, upgrade, and replacement/retirement phases of the SE process provides the systems engineer with a solid foundation for making and justifying difficult decisions.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering, EN.645.667 Management of Systems Projects, and EN.645.767 System Conceptual Design.

EN.645.757. Foundations of Modeling and Simulation in Systems Engineering. 3 Credits.
This course provides an introduction to the field of modeling and simulation (M&S) from the perspective of M&S as an essential tool for systems engineering. The course presents an overview of the M&S discipline, the model/simulation development process, the types of models and simulations used in the various phases of the systems engineering life cycle, and the verification, validation, and accreditation of models and simulation. The strengths and limitations of M&S are explored with respect to the application of M&S use in systems engineering. Examples are given for several types of systems, including both military and civilian systems. Statistical methods used in applying M&S in systems engineering are explained. The Arena process modeling tool is used for some examples, an individual assignment, and a team-based project. Upon completion of the course, the student will be able to explain when M&S will provide meaningful support to a technical program, select the appropriate modeling techniques for a given task, plan the development of a model/simulation and the modeling of its input data, and analyze the results of its execution to support decisions at key milestones of a system's life cycle.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering OR EN.655.662 Introduction to Healthcare Systems Engineering.

EN.645.758. Advanced Systems Modeling and Simulation. 3 Credits.
This course provides in-depth exposure to the field of modeling and simulation (M&S) from the perspective of M&S as an essential tool for systems engineering. Advanced statistical methods are used to conduct requirements-driven simulation analysis and experimentation. The course provides treatment of advanced M&S topics, including methods for simulation interoperability and composability; modeling of the system environment, both natural and man-made; modeling of system costs; and the establishment of collaborative M&S environments. The course also explores continuous and real-time simulation. Students are exposed to the techniques used to form conceptual models of mechanical (both translational and rotational), electrical, fluid, thermal, biological, and hybrid systems. The conceptual models are transformed into mathematical models and implemented in a modern simulation package. State-of-the-art tools are explored, and each student is given the opportunity to conduct a simulation study of a complex system. Each student will present a case study and complete a project. Upon completion of the course, the student will be able to conduct or lead the development of the model of a complex physical system, model the input data, and analyze the results to support decisions at key milestones of a system's life cycle.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering

EN.645.761. Systems Architecting. 3 Credits.
As the systems that systems engineers face become more complex, it is no longer sufficient to use "good engineering practices." The complex systems of today need to be architected before design work can begin. This course examines the principles and art of systems architecting when developing both individual systems and systems that are components of a system or federation of systems. The objective is to provide students with the principles, techniques, and hands-on experience of architecting modern, complex systems. Students will learn the latest architecture development techniques using DoD and commercial architectural frameworks, then extend those frameworks to specific problems involving unique systems development environments. Topics include the management of underlying system and data models and the special architecting requirements of command, control, and communications systems. Special attention will be placed on visualizing architecture artifacts-qualitatively and quantitatively evaluating architectures and the systems model they represent-and utilizing system architectures for investment decisions. Case studies from actual experiences will be presented. Course Note(s): Selected as one of the electives in the MSE or MS program or a required course for the post-master's certificate.
Prerequisite(s): EN.645.769 System Test and Evaluation or advisor and instructor approval OR EN.655.769 Healthcare Systems Engineering Test and Evaluation or advisor and instructor approval.

EN.645.764. Software Systems Engineering. 3 Credits.
This course for systems engineers covers software engineering principles, artifacts, and approaches for the development of software systems. Topics include software engineering processes and metrics; real-time, distributed, configurable, and object-oriented software; alignment of software systems with overall system design; software-unique aspects of planning, requirements, architecture analysis, design, implementation, testing, and maintenance; understanding important software engineering constraints (performance, security, networking, etc.); and technology trends in software engineering today.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering or EN.655.662 Introduction to Healthcare Systems Engineering and EN.645.667 Management of Systems Projects or EN.655.667 Management of Healthcare Systems Projects or permission from the student's academic advisor and the course instructor

EN.645.766. Systems Engineering Advanced Technology. 3 Credits.
This course emphasizes the impact on society of recent technological advances on new products, processes, and needs in systems engineering. The roles of the technical manager, program manager, and especially the systems engineer in these rapidly-evolving technologies are addressed as well. Subject areas and lecture content tracks current topics of interest, including but not limited to, trends and developments in hypersonics, artificial intelligent, nanotechnology, robotics, and genetic engineering. Advanced technologies in application areas such as transportation, space, manufacturing, and biotechnology are also discussed. This course also includes a discussion on the ethics of lethal autonomous weapons. Students are encouraged to explore new technology areas and share information with each other. Students' mastery of concepts culminates in a term paper on a new or emerging technology area as it relates to systems engineering.
Prerequisite(s): EN.645.768 System Design and Integration

EN.645.767. System Conceptual Design. 3 Credits.
This course addresses in detail the systems engineer's responsibilities and activities during the conceptual phases of a system development program. Systems engineering tools commonly employed at this stage of a program are presented along with selected problems that illustrate both the applicability and limitations of commonly employed tools and procedures. The course steps through conceptual design beginning with analysis of needs and objectives and proceeding to the exploration of alternative concepts and the selection of a concept that best meets goals of performance, timeliness, and affordability. Topics include definition of operational scenarios, functional analysis, risk assessment, system tradeoffs, measures of effectiveness, and requirements formulation. Emphasis is on the application of these systems engineering techniques in a team environment to a class project. Students apply systems engineering methods learned from reading and lectures to the development of a realistic system in an ongoing project in a team format.
Prerequisite(s): EN.645.764 Software Systems Engineering or permission of the student's advisor and the course instructor.

EN.645.768. System Design & Integration. 3 Credits.
This course addresses the systems engineering objectives, responsibilities, and activities during the demonstration and validation and the engineering and manufacturing development phases of a system development program. Systems engineering procedures and tools employed during these phases are identified and their use illustrated. Topics include the relationship between a system specification and the system design, systems engineering management plans, risk management, system development models, customer integration into the design process, and design disciplines and practices. The course uses a system problem scenario extensively to illustrate systems engineering principles and specific product design issues.
Prerequisite(s): EN.645.767 System Conceptual Design or permission of the student's advisor and the instructor.

EN.645.769. System Test & Evaluation. 3 Credits.
This course focuses on the application of systems engineering principles to the test and evaluation of system elements and, ultimately, of the total system. Test requirements, selection of critical test parameters, analysis of test results, and determination of remedial action in the event of discrepancies are all systems engineering functions. Topics include validation and verification, similarities and differences in the nature of hardware and software testing, test tools and test procedures, testing during hardware-software integration, quality assurance test, environmental test, and operational test and evaluation. Student problems include scenario case studies using examples developed in the several previous courses.
Prerequisite(s): EN.645.768 System Design and Integration or permission of the student's advisor and the instructor.

EN.645.771. System of Systems Engineering. 3 Credits.
This course addresses the special engineering problems associated with conceiving, developing, and operating systems composed of groups of complex systems closely linked to function as integral entities. The course will start with the underlying fundamentals of systems' requirements, design, test and evaluation, and deployment, and how they are altered in the multi-system environment. These topics will then be extended to information flow and system interoperability, confederated modeling and simulation, use of commercial off-the-shelf elements, and systems engineering collaboration between different organizations. Advanced principles of information fusion, causality theory with Bayesian networks, and capability dependencies will be explored. Several case studies will be discussed for specific military systems of systems, including missile defense and combatant vehicle design, as well as selected commercial examples.Course Note(s): Selected as one of the electives in the MSE or MS program or a required course for the post-master's certificate.
Prerequisite(s): EN.645.769 System Test and Evaluation OR EN.655.769 Healthcare Systems Engineering Test and Evaluation or advisor and instructor approval.

EN.645.772. Systems Innovation. 3 Credits.
Systems thinking and systems engineering are fundamentally problem-framing and problem-solving approaches that help provide more comprehensive solutions by considering the broader context, vigorously investigating and designing alternatives and interfaces, and exhaustively verifying requirements and operational outcomes. However, the systems approach is also inherently innovative because it leverages unique adaptable systems tools, tailorable approaches, and limitless dimensional frameworks and analyses. This course will show the student how to explore and mine key features of the systems process with the goal of demonstrating innovative techniques and innovative problem identification and solution approaches. You will see in this course that innovation is not just new technology or basic science discoveries, but the practice of successfully creating and adapting ideas, methods, or processes with the goal of delivering breakthrough value and impact for stakeholders and customers. The more complete form of innovation used in this course will enable the student to directly harness the systems principles more creatively through innovation exemplars, design thinking techniques, reflective thinking, and brainstorming techniques; and, by demonstrating at each of step of the systems lifecycle there are opportunities to be innovative.

EN.645.780. Agile Systems Engineering. 3 Credits.
The development of large, complex, software-intensive hardware systems has become extremely challenging for systems engineers. Some examples are virtually all modern military systems, commercial automotive and aeronautical industries, even medical devices, each containing an extensive set of interconnected, software-driven electrical and mechanical components and are digitally connected to the outside world. This course will show you how to effectively lead teams capable of addressing this complexity using deliberate, incremental learning intervals throughout the system's development and improvement lifecycles. You will explore how to successfully lead your team in executing these learning intervals using Agile methods, modular hardware and software architectures, integrated descriptive and analytic modeling, Lean and Design Thinking all integrated with the foundational principles of systems engineering. This course will show you how the increasingly ubiquitous, cross-industry digital transformation supports these learning intervals using Digital Threads, Digital Twins and development pipelines called DEVSECOPS. All of the lectures in this course are available asynchronously as recorded videos along with a textbook and other learning material. This course's most popular feature has been highly collaborative teamwork requiring some Zoom-based student/instructor conferences. During these conferences, student teams present their work to other student teams and instructor(s) in highly engaged, spirited discussions.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering

EN.645.781. Systems Thinking and Systems Dynamics. 3 Credits.
Systems thinking is the ability to perform insightful and comprehensive problem solving of complex systems. Fundamental to systems thinking is system dynamics, an approach used to understand the nonlinear behavior of complex systems over time using stocks, flows, internal feedback-loops, a variety of functions, and time-delays. This course will investigate the needs, motivations, and frameworks of systems thinking employing causal-loop diagram archetypes, as well as establish foundational concepts and approaches for systems thinking problem construction. From these foundations, system dynamic approaches, analytical models-tools, and simulations will be constructed to mature foundational systems thinking problem frameworks for quick, insightful, and quantitative impact-analysis. A variety of systems thinking problems will be addressed through the assembly of causal-loop diagrams, followed by the construction of system dynamics models, with a specific focus on emerging challenges of supply management and healthcare systems engineering and delivery. The course concludes with a series of reflective and inspirational challenges and opportunities, with the goal of solidifying comprehensive systems thinking acumen. This course will use The Fifth Discipline by Peter M. Senge, Thinking in Systems – A Primer by Donella H. Meadows, and Systems Thinking Tools – A User's Refence Guide by Daniel H. Kim as course textbooks. Also, a variety of relevant articles, papers, and recorded video material will be used. Vensim © (freeware version: https://vensim.com/) will be the system dynamics modeling tool used in the course.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering and EN.645.767 System Conceptual Design

EN.645.782. Foundations of Digital and Mission Engineering. 3 Credits.
This course provides an introduction to Digital Engineering and Mission Engineering, both of which are topics of emerging emphasis, particularly in the U.S. Defense community. The course begins with a review of the systems engineering process, with its technical and technical management processes, as it is applied in the U.S. Department of Defense (DoD) acquisition lifecycle. It then provides an overview of the DoD Digital Engineering Strategy, and discusses key competencies needed for Digital Engineering. As Modeling and Simulation (M&S) and Model Based Systems Engineering (MBSE) are key to the implementation of Digital Engineering, the course discusses fundamental concepts of M&S and how models and simulations are used in the various phases of the systems engineering process. Key MBSE concepts are then presented, along with an overview of the Systems Modeling Language (SysML) and its constituent diagrams, followed by an overview of the Object-Oriented Systems Engineering Method (OOSEM). The course then discusses how to apply these MBSE concepts to analyze several selected real-world case studies. A generic framework for a collaborative environment to support digital engineering is presented, along with how it might be used to support the development of digital twins and digital threads for a system. The underlying concepts and the key methodology elements of Mission Engineering are then described, based on the DoD Mission Engineering Guidebook. Finally, the course examines how and why Digital Engineering supports the implementation of Mission Engineering.
Prerequisite(s): EN.645.662 Introduction to Systems Engineering

EN.645.783. Systems Engineering Process Improvement. 3 Credits.
Through lectures and facilitated teamwork, this course presents the fundamental concepts of continuous process improvement in the context of systems engineering. Students will explore how to define, map, model and simulate, assess, manage, and improve a systems engineering process. This will enable students to lead or contribute to a systems engineering process improvement effort on the job, and to be better prepared for certifying their systems engineering expertise.

EN.645.784. Decision Science & Analytics in Systems Engineering. 3 Credits.
Through lectures, readings, and projects, this course imparts the fundamental concepts of decision science and analytics in the context of Systems Engineering. Topics include objectives hierarchies, influence diagrams, measures of effectiveness, measures of performance, morphological analysis, methods for mitigating combinatorial explosion, Pareto frontiers, sensitivity analyses, uncertainty analyses, information visualizations, and multiple objective selection methods. The course is not intended to provide students with extensive training in particular software packages. However, hands-on computer laboratory sessions re-enforce critical concepts.

EN.645.800. Systems Engineering Master's Project. 3 Credits.
This course provides the experience of applying systems engineering principles and skills learned in the formal courses to a specific practical project that is suggested by the student and is presented in a formal proposal. The product of the system project is a final report; also required are interim reports and an oral presentation to permit review of the project objectives and approach. This is an independent course that has no formal classes; the student is responsible for developing their own project timeline and works to complete it within one semester. A student typically has a mentor who is a member of the systems engineering faculty. The program chair, vice chair, and mentor review proposals and reports. The total time required for this course is comparable to the combined class and study time for the formal courses. Course Note(s): Students who plan to register for this course will need to contact the Systems Engineering Program Coordinator (annie.cranston@jhuapl.edu) at least four to six weeks prior to the semester start date for access to the Capstone website. Students must connect with a projectmentor (via capstone website) and have an approved topic prior to beingregistered manually by the course instructor
Prerequisite(s): EN.645.769 System Test and Evaluation and an approved project concept from their project mentor and project instructor.

EN.645.801. Systems Engineering Master's Thesis. 3 Credits.
This course is the first of a two-semester requirement designed for students in the Systems Engineering Master's program. Thesis students will conduct independent research in the field of systems engineering, under the guidance of an advisor. The intent of the Master's Thesis research is to advance the body of knowledge and the understanding of systems engineering practices, the improvement of systems engineering practices in industry and in government, the evolution of systems engineering tools and techniques, and the solution of systems development issues in the acquisition of advanced systems. In this course, students will gain a foundation in conducting graduate-level, academic research, including an introduction to research paradigms and methodologies, problem/research question formulation, research design, literature search and critique, proposal preparation, data collection and analysis, research ethics, and the canons of research for engineering and science. At the end of this semester, the student will present their research proposal to their thesis committee. Students interested in pursuing a doctoral degree should enroll in the Thesis Option. Prerequisite(s): Completion of all other courses applicable to the Systems Engineering master's degree. Course Note(s): Students who plan to register for this course will need to contact the Systems Engineering Program Coordinator(annie.cranston@jhuapl.edu) four to six weeks prior to the semester start date. Students must connect with a thesis advisor and have an approved topic prior to being manually registered for the course by the instructor.

EN.645.802. Systems Engineering Master's Thesis. 3 Credits.
This course is the second of a two-semester requirement designed for students in the systems engineering master's program. Thesis students will conduct independent research in the field of systems engineering, under the guidance of an advisor. The intent of the Master's thesis research is to advance the body of knowledge and the understanding of systems engineering practices, the improvement of systems engineering practices in industry and in government, the evolution of systems engineering tools and techniques, and the solution of systems development issues in the acquisition of advanced systems. In this semester, the student will conduct the research outlined in the research proposal developed during EN.645.801, with guidance and oversight from their thesis advisor. At the end of the semester, the student will deliver their thesis paper acceptable for publishing in a professional peer-reviewed journal and will present a defense of their research to their Thesis Committee. Students interested in pursuing a doctoral degree should enroll in the Thesis Option. Prerequisite(s): Completion of EN.645.801 Systems Engineering Master's Thesis, the first semester of this two-semester course.