Division of Engineering and Weapons

Aerospace Engineering Department
Electrical Engineering Department
Mechanical Engineering Department
Naval Architecture and Ocean Engineering Department
Weapons and Systems Engineering Department

Commander Robert L. Curbeam, Jr., USN
U.S. Naval Academy
Class of 1984

The U.S. Naval Academy produces more astronauts than any other university in the country.

Aerospace Engineering Department

Aerospace Engineering Major

The aerospace engineering department offers one of the most exciting and challenging academic programs at the Naval Academy. The program is structured to produce naval officers who will serve in the forefront of the inception, development and employment of Navy air and space assets. The curriculum provides a background in engineering fundamentals through courses in chemistry, physics, mathematics, engineering mechanics, thermodynamics and electrical engineering. With these subjects as a base, students undertake aerospace engineering topics including aerodynamics, propulsion and aerospace structures. The major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

In the area of aeronautics, students extend their study of aerodynamics, flight structures and flight mechanics. The astronautics track allows students to study astrodynamics, satellite attitude dynamics and control, and the space environment. Both tracks conclude with a design course, which allows midshipmen to apply their engineering knowledge to the design of an aero or space flight vehicle. Both tracks also involve thorough laboratory experimentation. The Naval Academy's aerospace laboratory facilities are some of the most advanced and extensive in the country. These facilities include structures, propulsion and rotor labs; variable stability aircraft simulator; spacecraft tracking and experimentation facilities; and various wind tunnels with flow velocities ranging from subsonic to supersonic.

While graduates of all majors are prepared for careers in naval aviation, the aerospace engineering major is intended for those who are not only fascinated by flight but want to understand the technology of making air and space flight work.

Graduates from the aerospace engineering major are also fully prepared to undertake postgraduate education programs in engineering disciplines either at the Naval Postgraduate School or any other academic institution. Naval officers with advanced degrees in the aerospace areas may be assigned to billets involving the research, development, test and evaluation of Navy aircraft or spacecraft projects. Locations for these challenging technical billets include the Naval Air Systems Command, Naval Research Laboratory, Test Pilot School, the Navy's Space Command, the Unified Space Command, the Navy Space Support Activity and perhaps as a naval astronaut with the National Aeronautics and Space Administration.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM212, SM221;
Science: SP211, SP212;
Humanities: HH215, HH216, two electives including one at the 300/400 level;
Engineering: EE331, EE332, EM211, EM217, EM232, EM321, EM319, ES300, ES410;
Major: Aeronautics Track - EA203, EA204, EA301, EA303, EA304, EA308, EA322, EA332, EA401, EA413, EA429, EA440, plus two major electives; Astronautics Track - EA203, EA204, EA305, EA308, EA322, EA362, EA364, EA365, EA461, EA465, EA466, EA467, EA470, plus one major elective.

Aerospace Engineering Courses

EA203 Principles of Aerospace Engineering I (2-2-3). First course of a two-course sequence covering the fundamentals of aerospace engineering. Topics in the sequence include the earth's atmosphere, the space environment, aerospace structures, atmospheric flight, space flight, attitude dynamics, propulsion and communications. Knowledge of spreadsheet, calculator, and computer programming fundamentals are developed. This sequence prepares beginning aerospace engineering students for further studies and develops sound engineering practices. *Prereq: SM122 or SM162.*

EA 204 Principles of Aerospace Engineering II (2-2-3). Second course of a two-course sequence covering the fundamentals of aerospace engineering. See EA203 for the topics covered. *Prereq: EA203 or approval of department chair.*

EA300 Introduction to Aeronautics (3-0-3). Introduces students to the applied science of air-breathing atmospheric flight. The course describes airplanes and how they fly from a design and application perspective. Included are topics in fluid dynamics, airfoil and wingtheory, aircraft performance, stability, and aircraft design.
Prereq: Calculus II (SM122 or SM162).

EA301 Aerodynamics (3-0-3). Covers essentials of fluid mechanics and topics in aerodynamics including potential flow and thin airfoil theory. *Prereq: SM221and EA203.*

EA303 Wind Tunnel (1-2-2). A laboratory course in wind tunnel test techniques. *Coreq: EA301.*

EA304 Aerodynamics II (3-0-3). Discussion of 3-D finite wings, lifting surface theories, and vortex lattice methods. Introduction to viscous flow and boundary layer. *Prereq: EA301.*

EA305 Aero/Gas Dynamics (2-2-3). Covers essentials of fluid mechanics and kinematics with an introduction to potential flow. Basic one-dimensional compressible flow including thermodynamics of perfect gases in subsonic and supersonic flows. Introduction to nozzle flow. *Prereq: EA203&EA204; Coreq: EM319.*

EA308 Engineering Analysis (1-2-2). Applications of numerical theory and analysis to relevant engineering problems are the focus of this course. Topics include: solutions of systems of nonlinear equations, iteration techniques, nonlinear root-solvers, numerical integration and differentiation, and curve-fitting techniques. Applications are used to develop the tools necessary to solve realistic problems. *Coreq: SM212.*

EA322 Aerospace Structures I (3-2-4). A second course following EM321, in the analysis and synthesis of air and space vehicle structures. Topics include further study of axial loading, torsion, bending and traverse loading; design for strength; internal force determination for plane and space structures using statics and matrix methods; displacement of structural systems using differential equation and strain energy methods; statically determinate and indeterminate structures using compatability and strain energy; wind bending and shear analysis; semi-monocoque open and closed structures; multi-cellular sections; and introductory composite structure analysis. Laboratory work and demonstrations are integrated to show the relevance of the topics and to give a practical insight to the behavior of aerospace structures. *Prereq: EM321.*

EA332 Gas Dynamics (2-2-3). Compressible flow of one-dimensional subsonic flows. Methods of gas dynamics in internal flow systems. Shock waves, waves in supersonic flow, linearized flows. *Prereq: EA301, EM319.*

EA362 Astrodynamics I (3-0-3). Introduction to the principles of planetary and satellite motion. Topics include the classical two-body problem, orbital parameters, orbit determination and maneuvers, remote sensing geometry, types of orbits and their uses, constellation design, orbit changes, perturbations and atmospheric drag effects, rendezvous, ballistic missile trajectories, and lunar and interplanetary travel.
Prereq: EM232 or (SM212 + SP212).

EA364 Spacecraft Attitude Dynamics and Control (3-0-3). Rigid body dynamics and control of spacecraft. Euler angles, inertial properties of rigid and semi-rigid bodies, body-centered equations of motion, torque-free motion. Passive, active, and semi-active attitude controls. Gyroscopes and stable platforms. *Prereq: EA362.*

EA365 Rocket Propulsion (2-2-3). The principles of fluid mechanics and thermodynamics are applied to the problem of propulsion of aircraft and space vehicles. Cycle analysis, ramjets, jets and rockets. Air-breathing propulsion. Solid and liquid propellant rockets, fuels and applications. *Prereq: EA305 or equivalent.*

EA401 Applied Aero and Design (3-0-3). The basic principles for lift and drag calculations are extended to entire flight vehicle analysis. Static and dynamic point performance analysis. Introduction to energy methods with selected optimum climb and trajectory problems. Mission analysis and carpet plots leading to design selection criteria. *Prereq: EA304.*

EA413 Stability and Control (3-0-3). The aerodynamic and inertial forces and moments acting on the flight vehicle and its component parts are analyzed to determine their effect on static and dynamic stability. *Prereq: EA301.*

EA414 Airplane Simulation and Control (3-0-3) Implementation of linear and non-linear airplane models for man-in-the-loop and batch simulation of airplane flight dynamics. Application of modern control methods to the design of airplane Stability Augmentation Systems and autopilots. *Prereq: EA413; Coreq: ES410 or equivalent.*

EA417 Elements of Flight Test Engineering (2-2-3). A lecture and laboratory course designed to provide practical applicaton of theoretical principles learned in courses in flight performance, aerodynamics, and stability and control. Topics include flight test theory and purpose, engineering test planning, flight test instrumentation, data analysis, and report writing. Activities include flight simulation, several flights in an aircraft, as well as interaction with naval flight test facilities for test data acquisition and analysis. *Prereq: EA401, EA413, and approval of dept. chair.*

EA421 Aerospace Structures II (3-0-3). Introduction to the finite element methods of structural analysis as applied to atmospheric flight and space flight vehicles. Topics include formulation of the element stiffness matrices, assembly of the global structural matrix, formulation of equivalent loads, energy methods and matrix equation solution methods. A design project using a finite element computer program is carried out. *Prereq: EA322.*

EA424 Structural Dynamics (3-0-3). An introductory course in structural dynamics as applied to atmospheric flight and space flight vehicles. Topics include the analysis of free, damped and forced vibrations of systems with one or many degrees of freedom; vibrations of strings, beams and rectangular plates; matrix formulation of equations of motion; introduction to the finite element method of structural dynamic analysis. *Prereq: EA322.*

EA425 Viscous Flow (3-0-3). An advanced course covering viscous flow problems including laminar, turbulent, incompressible and compressible boundary layers with heat transfer. *Prereq: EA304.*

EA427 Aerodynamics III (3-0-3). An advanced course continuing the study of compressible high-speed flow including general conservation laws for inviscid flows, unsteady flow problems, numerical techniques for supersonic flows and real gas effects. *Prereq: EA304.*

EA428 Computational Aerodynamics (3-0-3). Introduction to the major numerical techniques used in computational aerodyna-mics. Topics include mathematical methods, boundary conditions, stability, panel methods, lattice methods, nonlinear problems, time dependent solutions and transonic flow problems. *Prereq: EA304.*

EA429 Flight Propulsion (2-2-3). The principles of fluid dynamics and thermodynamics are specialized to the problem of propulsion of aircraft. *Prereq: EA332.*

EA430 Propulsion II (3-0-3). The second propulsion course covers turbomachinery theory including compressors, turbines, pumps, application and design methods. Combustion and cooling techniques in modern engines are introduced. *Prereq: EA429 or EA365.*

EA435 The Aerodynamics of V/STOL Aircraft (3-0-3). An advanced course covering the aerodynamics of vertical and short takeoff and landing aircraft, including fixed wing and rotary wing types, with major emphasis on the helicopter. *Prereq: 1/C, aeronautical track major.*

EA439 Special Aircraft Design (1-4-3). This course, along with EA440, provides a two-semester sequence in aerospace design for selected midshipmen. *Prereq: 1/C standing in aerospace engineering.*

EA440 Aerospace Vehicle Design (1-4-3). Preliminary design of a flight vehicle. Includes preliminary layout, weight and balance estimates, performance analysis, stability analysis and structural analysis. *Prereq: 1/C, aeronautical track major.*

EA461 Space Environment (3-0-3). Introduction to the environment of the upper atmosphere, near Earth space, and interplanetary space. Topics include: properties of the upper atmosphere and ionosphere, the geomagnetic field, radiation belts and magnetosphere of the Earth, the solar wind and interplanetary medium, remote sensing of the atmosphere and oceans, environmental implications for spacecraft design. *Prereq: SP212.*

EA462 Astrodynamics II (3-0-3). Advanced topics in astrodynamics including potential of an arbitrary body and of the earth, orbit determination from observations including numerical techniques for data smoothing, special and general perturbations of orbits and interplanetary trajectories, drag effects on low altitude orbits. Special projects. *Prereq: EA362.*

EA463 Space Operations (3-0-3). This course investigates the relationship between mission operations and the other elements of a space mission. It defines a process for translating mission objectives and requirements into a viable mission operations concept. The course focuses on how we get information to and from space and then to the user in a usable format. *Prereq: EA362.*

EA465 Spacecraft Communications and Power (3-0-3). This course is intended to develop communications fundamentals with emphasis on digital communications, link budget analysis, and power subsystems. Secondary topics include: computer and data bus operations, command and data handling, telemetry, and tracking and control. *Prereq: EA362; Coreq: EE302 or EE332.*

EA467 Spacecraft System Laboratory (0-4-2). Laboratory analysis of the major system elements of space systems to include ground control and power, attitude control, communications, propulsion and thermal control. Constraints imposed by system application launch vehicles and environment are considered. Introduction to the engineering design process as well as its computer adaptations. *Prereq: EA364.*

EA469 Special Spacecraft Design (1-4-3). This course, in conjunction with EA470, provides a two-semester spacecraft design program for selected midshipmen. *Prereq: approval of department chair.*

EA470 Spacecraft Design (1-4-3). Preliminary design of a spacecraft. Includes: preliminary layout, weight and moment of inertia estimates, specifications of on-board systems, power subsystem requirements and design, and constraints imposed by launch vehicle and mission requirements. *Prereq: 1/C, astronautical track major or IT (Space Ops) major.*

Electrical Engineering Department

Electrical Engineering Major

The Electrical Engineering Department offers one of the cornerstone disciplines that will shape many aspects of the Navy for the foreseeable future. The major offers a solid grounding in the fundamentals of electrical engineering, as well as the opportunity to investigate concepts of advanced specialties in communication systems, digital computer systems, fiber optic systems, microwaves, and instrumentation. Two elective course options are available within the major. One emphasizes the fundamentals of conventional electrical engineering and the other emphasizes digital microcomputers. The Navy needs officers trained in these engineering concepts to lead in the development, integration, and operation of advanced systems. The electrical engineering major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET) and leads to a bachelor of science in electrical engineering.

Electrical engineering majors apply classroom concepts in the laboratory throughout the program. The Department has extensive well-equipped laboratories to provide excellent hands-on support of every course in the EE major. Dedicated laboratories support EE courses in fiber optics, electronics, digital and analog communications, operation and integration of digital hardware and software, electro-mechanical energy conversion, and advanced electrical engineering project design. The Department emphasizes individual lab station learning to ensure thorough understanding of required skills as well as the team approach to solving design problems. EE labs are constantly updated with leading edge technology.

The electrical engineering capstone senior design laboratory sequence (EE411 and EE414) integrates all required critical aspects of complete significant professional design. Two midshipmen per year are awarded the EE Department's Steinmetz Prize for innovative work in this design laboratory course sequence. The Captain Boyd R. Alexander Prize in electrical engineering is presented during Commissioning Week to the outstanding graduate in the EE major.

Graduates of the electrical engineering program are very well prepared for any of the many jobs they may be assigned in the fleet. The major also provides an excellent fundamental background and foundation for continued, more specialized study in electrical engineering at the graduate level on active duty after commissioning at the Naval Postgraduate School or any other academic institution.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM221, SM212;
Science: SP211X, SP212X;
Humanities: HH215, HH216, and two elective courses including one at the 300/400 level;
Engineering: EM318, EM319, ES300, ES410;
Major: SI204, SM313, EE221, EE228, EE242, EE322, EE341, either EE342 and EE372 or EE461, SI220, EE411, EE414, plus three major electives.

Electrical Engineering Courses

EE221 Introduction to Electrical Engineering I (3-2-4). Terminal characteristics of passive linear and nonlinear devices, ideal energy sources (including dependent sources), and the basic laws of circuit analysis are introduced. Analysis of networks comprised of these devices including: steady-state DC/AC response, transient response of first-order circuits, methods of network analysis, and the concept of equivalence. Computer software is used to support concept development, analysis, and understanding of homework problems. *Prereq: Calculus I.*

EE228 Introduction to Electrical Engineering II (3-2-4). Continued development of various fundamental concepts of basic circuit theory including: behavior of second-order circuits; various concepts of AC power; coupled coils; and signal representation in the frequency domain, including frequency response and filtering. Basic principles of operation of electromechanical energy conversion devices are introduced, and circuit models are developed to predict performance. Computer software is used to support concept development, analysis and understanding of homework problems. *Prereq: EE221.*

EE242 Digital Systems (3-2-4). Fundamentals in realizing a digital system. Topics covered include: Boolean algebra, Karnaugh mapping, flip-flops, state diagrams for system minimization and analysis of sequential and logic function circuits, binary arithmetic, decoders, encoders, multiplexers and demultiplexers, as well as counter and register design. An introduction to complex programmable logic device (field programmable gate array) systems is provided with applications to projects. *Prereq: EE221.*

EE 301 Electrical Fundamentals and Applications (3-2-4). Provides an introduction to AC and DC circuit theory appropriate to model shipboard systems. Circuits of resistors, capacitors, inductors and sources are analyzed to predict steady state and first-order transient voltage, current, and power. Impedance matching, filters, transformers, motors/generators, and three-phase power distribution systems are introduced in the context of shipboard application. Laboratory exercises use tools and equipment found in the fleet and allow for a comparison of theoretical and actual circuit performance. *Prereq: Physics II (SP 212 or SP222).*

EE302 Electronic Communication Systems and Digital Communications (3-2-4). This course is a follow-on to EE301, Electrical Engineering Fundamentals. This course begins with the basic principles of digital logic circuitry followed by an introduction to computer architecture. The principles of Analog and Digital Communications are presented to include the most common digital modulation techniques and a study of Amplitude Modulation. Radio Wave propagation and the fundamentals of Antennas are also presented. The course ends with a study of the engineering fundamentals of networking including topology, connectivity, routing, bandwidth, subnetting, the OSI Model, TCP/IP, and the Internet as an application of networking concepts. *Prereq: EE301 or EE331.*

EE313 Logic Design and Microprocessors (3-2-4). This is an introductory level project course in digital electronics for non-EE majors. It begins with the design, analysis and minimization of both combinatorial and sequential circuits and their realization in both discrete components and programmable logic devices. The course progresses into the use of MSI devices and digital arithmetic. Finally, an introduction to assembly level programming and microprocessor/microcontroller-based systems design is also provided. *Prereq: EE302 or EE332 or approval of department chair.*

EE322 Signals and Systems (2-2-3). The principles of circuit analysis are extended to the transmission of signals through linear systems. The approach is based on determination and interpretation of natural frequencies, pole-zero diagrams, and their relation to the governing system equations. Transform techniques are applied to the analysis of circuits. Both continuous-time and discrete-time systems are discussed. Computer software is used to model and analyze signals and systems. *Prereq: EE228 or approval of department chair.*

EE331 Electrical Engineering I (3-2-4). A study of DC and AC electrical elements and circuits, including Thevenin equivalence, natural and forced responses of first-order systems, AC power, and AC three-phase systems. Amplifiers, diodes and transistors are introduced and drive discussion of applications in power regulation and machine control. AC and DC machines are investigated and discussed in the context of a shipboard environment. *Prereq: SP212 or SP222.*

EE332 Electrical Engineering II (3-2-4). Modeling and analysis techniques are applied to rotating machines, diodes, op amps, transistors and amplifiers. Amplitude modulation and demodulation and combinational and sequential digital logic are introduced. *Prereq: EE331.*

EE334 Electrical Engineering and IT Systems (3-2-4) This course is a follow-on to EE331, Electrical Engineering I. In this course, modeling and analysis techniques are applied to electronic communication systems including both analog and digital modulation/demodulation techniques. Also in the course, students design and analyse combinational and sequential digital logic circuits. An in-depth study of computer networking is included with specific emphasis on the OSI model and wireless systems. *Prereq: EE331.*

EE341 Electronics I (3-2-4). The physics of semiconductor devices (p-n junction diode, bipolar and field effect transistors) is introduced. Device characterization in terms of appropriate external variables then leads to construction of small-signal and large-signal models. Emphasis is on small-signal applications of these device models. Applications in basic amplifier and switching circuits are emphasized in laboratory exercises. *Prereq: EE221, EE311 or EE331.*

EE342 Electronics II (3-2-4). BJT and MOSFET amplifiers are studied. This includes the analysis of differential amplifiers, current mirrors, multistage amplifiers, feedback amplifiers, power amplifiers, and integrated circuit amplifiers. Feedback and frequency analysis of amplifiers is emphasized. Applications include active filters and oscillators. *Prereq: EE341 or approval of dept. chair.*

EE354 Modern Communication Systems (3-2-4). Digital signal implementation and processing techniques are introduced. Various digital modulation methods as well as AM and FM methods are studied. Baseband and bandpass modulation and demodulation techniques are introduced. Probability theory is applied to determine the error performance of a binary phase-shift keying system. *Prereq: EE322 or approval of department chair.*

EE 372 Engineering Electromagnetics (3-0-3). Fundamentals of electromagnetic theory and modern transmission systems. Basic transmission line theory is introduced. Maxwell's equations are formulated and applied to static and dynamic electromagnetic problems including plane-wave propagation and reflection and transmission at discontinuous boundaries. *Prereq: SP212 or SP222.*

EE411 Electrical Engineering Design I (2-2-3). A series of design problems are presented to take the student through the total design process from specification to verification of performance. In addition to technical design, factors such as safety, economics, and ethical and societal implications are considered. A small project is executed and evaluated. Each student chooses a project and develops and submits a proposed design to be completed in EE414. The proposal is presented to the student's peers and project advisors in lieu of a final exam. *Prereq: 1/C standing or approval of dept. chair.*

EE414 Electrical Engineering Design II (0-4-2). This course provides practice in engineering design, development, and prototype testing. Following approval of the project by the instructor, the student develops a prototype, troubleshoots, and gathers performance data, and completes construction and packaging of the final design. A formal briefing to peers and EE Department faculty follows a written final project report on the completed project in lieu of a final exam. *Prereq: EE411.*

EE426 Fundamentals of Electronic Instrumentation (2-2-3). A practical introduction to the design of electronic instrumentation. Common to all instruments is input from the physical world. Many instruments also entail control of external devices. Students examine a wide range of sensors and actuators. Labs support a broad study of the major components of electronic instrumentation systems: sensors, data acquisition, signal conditioning, computer control, and actuators. *Prereq: EE302 or EE332.*

EE431 Advanced Communication Theory (3-2-4). Digital and analog communication systems and concepts. Fourier analysis, sampling theorem, autocorrelation function, power spectrum, cross-correlation function, cross-spectrum, pseudonoise sequences, matched-filters, spread-spectrum, coding, PCM, TDM, and FDM are defined and applied. Probability, random variables, and random-signal principles are used to compute the information content of a message and to compute the error rates in digital communication systems. *Prereq: EE354, EE332, or approval of chair.*

EE432 Digital Signal Processing (3-2-4). Digital signal processing principles are studied and applied to modern radar, sonar and communications systems. The DFT is introduced, its properties are explored and the FFT algorithm is developed. Discrete correlation, convolution, spectral analysis, matched filter detection problems, complex demodulation techniques, the Z transform, and stability of discrete systems are explored. Properties of FIR and IIR digital filters are studied. Digital filters are designed and applied to random and deterministic signals. *Prereq: EE322 or EE332, or approval of chair.*

EE433Wireless and Cellular Communications Systems I (3-2-4). An in-depth study of wireless and cellular systems. This study includes system design, mobile radio propagation (large-scale path loss, small-scale fading, and multipath), and modulation techniques for mobile radio. A working knowledge of the characteristics of the three major cellular/PCS systems in use in the U.S. today is also developed. Technical discussions of recent topics/publications related to the course material are also conducted. Laboratory experiments emphasize indoor and outdoor RF propagation measurements. A final project is required in lieu of a final examination. *Prereq: EE354 or approval of chair.*

EE434 Wireless and Cellular Communication Systems II (3-2-4). A continuation of the in-depth study of the wireless and cellular systems. This study includes modulation techniques for mobile radio, equalization, diversity, and channel coding. Small group research projects are conducted in lieu of a final exam. *Prereq: EE433 or approval of chair.*

EE451 Electronic Properties of Semiconductors (3-0-3). This course develops an understanding of semiconductor properties and how they determine the performance of semiconductor devices. Hole and electron conduction and charge carrier distribution models are developed. Charge carrier generation and recombination and carrier dynamics leading to drift and diffusion are used to study semiconductor transport phenomena. The p-n junction, the bipolar junction transistor, and field-effect transistor are studied in detail. *Prereq: (SP212 or SP222) or EE341 or approval of chair.*

EE452 Semiconductor Electronics (3-2-4). This course continues on the foundations developed in EE451 for discrete semiconductor devices. This course will focus on basic analog and digital transistor circuits, and how transistor design affects their performance. Computer-aided transistor circuit design and simulation are emphasized. Solar cells, light-emitting diodes, microfabrication techniques, and microelectro-mechanical systems (MEMS) are also introduced. The laboratory involves an individual student research project. *Prereq: EE451 or permission of chair.*

EE461 Microcomputer-Based Digital Design (3-2-4). A principles-based foundation to the concepts and techniques used in analyzing and designing systems using combinations of discrete logic, programmable logic devices, and microprocessors. The student will acquire a detailed understanding of state-machine design; the system bus; the architecture and interfacing of various processor, memory, and input-output (I/O) elements; serial I/O protocols; and architecture and instruction set of a representative microcontroller; assembly-language programming for circuits based on that microcontroller; and the use of interrupts. Emphasis is on concepts that will have long-term value. *Prereq: EE242, EE313, or EE332.*

EE462 Microcomputer Interfacing (2-4-4). This course provides a strong foundation in techniques for connecting computers to peripheral and communications devices and in the methodology for programming the computer to control external devices in real time. This course is supported by a project-oriented laboratory with an opportunity to use a wide variety of computer-controlled peripheral devices. The student will learn the architecture of a representative digital signal processor (DSP) and how to use assembly language to program it. A major emphasis of the course is the in-depth study of interrupt processing, polling, direct memory access, parallel input/output (I/O) protocols, interprocess communication, and modular techniques for designing hardware and software. *Prereq: EE242, EE313, or EE332.*

EE464 Introduction to Computer Networks (3-2-4).This course provides a foundation in the fundamentals of data and computer communications. Emphasis is placed on protocol and network design. Critical technical areas in data communications, wide-area networking, and local area networking are explored. *Prereq: EE354 or approval of chair.*

EE471 RF Power Electronics (3-2-4). This course leverages the student's previous study in electronics and eletromagnetics to examine RF power concepts and devices. Some of the topics include: electron dynamics, electron beam-wave interaction, vacuum RF power devices and high frequency semi-conductor devices. The course draws upon current research at the Naval Research Laboratory and invited speakers to present timely and practical applications in U.S. Navy weapons systems and sensors. The various threads of course material come together in the study of the microwave power module (MPM) and the millimeter wave power module (MMPM), an integration of vacuum and semiconductor electronics to produce light-weight, high power, high frequency devices used to power the current unmanned aerial vehicle (UAV) sensors. Laboratory work includes power and frequency measurements on a variety of devices, as well as the use of simulation software to model the performance of RF power devices. *Prereq: EE372*

EE472 Fiber Optical Communications (3-2-4). An introduction to the nature of optical waveguides and fiber optical communications systems. Fiber propagation modes, dispersion and attenuation are studied. Lightwave transmitters and receivers, optical amplifiers, and components for wavelength division multiplexing are discussed, and a complete optical communication network is analyzed. *Prereq: EE354 or approval of department chair.*

Mechanical Engineering Department

Mechanical Engineering Major

The mechanical engineering major, accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, offers one of the most diversified engineering programs available at the Naval Academy. In addition to an education in mechanical engineering, the program prepares its graduates to assume responsibilities in any of the warfare specialties of the U.S. Navy and U.S. Marine Corps. Graduates will be in positions of responsibility involving the operation and maintenance of high technology weapons systems. As officers progress through their careers, many will assume positions of responsibility as managers of weapons systems development and procurement. This dictates a program that emphasizes a broad spectrum of undergraduate studies. The program thus includes required courses in solid and fluid mechanics, dynamics, thermodynamics and energy systems, materials engineering and a significant emphasis on electrical engineering and control systems fundamentals. This broad background in the fundamentals of mechanical engineering prepares midshipmen to select elective courses in any of the five tracks within the mechanical engineering program. These tracks are energy systems, engineering mechanics, marine propulsion, materials engineering and nuclear engineering. A midshipmen can choose to specialize in a particular area by selecting all of their electives in one track, or a more general approach can be taken by selecting electives across several tracks.

The program takes seriously the need to develop graduates who have a sound understanding of the design process and its importance in the success of engineering activity. Design education in the program is focused through a sequence of five courses, beginning in the first semester of the sophomore year (EM215, EM375, EM371, EM477, EM472), which make up the design backbone. Each semester, other courses that are more often identified with engineering science support the backbone through problems and small projects that build on concepts and tools developed in the design backbone. This approach weaves the subjects of design and design tools into the program as an integrated engineering activity. A Navy or Marine Corps officer with a bachelor's degree in mechanical engineering is well prepared for a wide variety of career assignments both ashore and afloat. Operational sea billets in surface ships, submarines, and aircraft squadrons provide many opportunities for a mechanical engineer to develop practical experience in a warfare or engineering specialty area while contributing to fleet engineering and material readiness. The operational environment enables a junior officer to rapidly develop sound leadership and managerial abilities while refining mechanical engineering capabilities acquired at the Naval Academy. Ashore, the mechanical engineer has a wide range of opportunities in sub-specialty billets with naval applications. These include such areas as ship and aircraft design, propulsion systems, environmental systems, advanced engineering education, major project management and weapons systems acquisition. There is an abundant and continuing need for mechanical engineers throughout today's naval service.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM212, SM221;
Science: SP211 and SP212;
Humanities: HH215, HH216, and two electives including one at the 300/400 level;
Engineering: EE331, EE332, EM211, EM217, EM232, EM313, EM319, EM324, ES300, ES410;
Major: EM215, EM320, EM371, EM375, EM415, EM472, EM477, plus three major electives.

General Engineering Major

The general engineering major provides a basic technical education in mathematics, science, engineering and naval professional subjects. It offers a broad engineering background for future naval service and for additional advanced technical training and education. Midshipmen completing the general engineering major receive a designated bachelor of science degree.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM221, SM230;
Science: SP211, SP212;
Humanities: HH215, HH216 plus two electives including one at the 300/400 level;
Engineering: EE301, EE302, EM300, EN200, ES419;
Major: EE313, EM211, EM232, EM214, EM318, EM319, EN200, SM212, plus eight major electives

Mechanical Engineering Courses

EM211 Statics (3-0-3). An initial course in applied vector mechanics with emphasis on static equilibrium. Topics include forces, moments, couples, equivalent force-couple systems, centroids, distributed forces, and Coulomb friction. The application of the free body diagram in the analysis of static equilibrium of frames, machines and trusses is stressed. *Coreq: Calculus III and Physics I.*

EM215 Introduction to Mechanical Engineering (2-2-3). This is an overview course that introduces the student to the main areas of mechanical engineering, mechanics, materials, and thermoscience. In addition, it provides background in visualization skills and the design process. Projects are used to enhance the understanding of mechanical engineering and the design process. *Prereq: none.*

EM217 Strength of Materials (3-2-4). A first course in mechanics of deformable bodies with emphasis on the engineering approach to the responses of these bodies to various types of loadings. Topics include stress-strain relationships, stress-strain analysis, stress and strain transformation (Mohr's circle), load-deflection, bending, torsion, buckling, and temperature effects. *Prereq: EM211; Coreq: SM212.*

EM232 Dynamics (3-0-3). Course in classical vector dynamics. Topics include vector algebra and calculus, kinematics and kinetics of particles and rigid bodies, as well as energy and momentum methods. Extensive problem solving involving particle and rigid body motion is required. *Prereq: EM211; Coreq: SM212.*

EM300 Principles of Propulsion (3-2-4). A study of naval engineering systems, including the principles of energy conversion and the basic operation of steam, gas turbine and internal combustion engine power plants. *Prereq: SP211 or SP221.*

EM300N Principles of Propulsion/Nuclear (3-2-4) Study of engineering systems principles of energy conversion via steam, gas turbine and internal combustion. Covers nuclear power propulsion principles. *Prereq: SP211, 3/C cruise.*

EM313 Materials Science (3-2-4). An introductory course in the physical and mechanical properties of engineering design materials including metals, ceramics and plastics, their structures, use in engineering applications and failure phenomena. All laboratory projects are structured to provide strong physical illustrations for the topics covered in lectures. *Prereq: EM217.*

EM318 Applied Fluid Mechanics (3-0-3). A first course in incompressible fluid mechanics. Topics include properties of fluids, fluid statics, integral conservation equations, differential field analysis, dimensional analysis and similitude, incompressible boundary layers, viscous flow in conduits and flow about immersed bodies. *Prereq: SM212.*

EM319 Engineering Thermodynamics (3-0-3). A basic thermodynamics course in which the first and second laws of thermodynamics are studied primarily from the classical macroscopic viewpoint and applied to both closed and open systems. Working substances include perfect gases, real gases and vapors in addition to solids and liquids. Naval applications are emphasized. *Coreq: SM212.*

EM320 Applied Thermodynamics (2-2-3). Laboratory equipment which operates on principles of thermodynamics and fluid mechanics is used to reinforce analyses and design of gas and vapor power cycles, refrigeration and air conditioning, ship and aircraft propulsion systems, combustion, energy conversion and compressible flow. *Prereq: EM319 or equivalent.*

EM321 Mechanical and Materials for Aerospace Engineers (3-2-4). A first course in materials and mechanics. Topics include: aerospace materials properties; treatments; manufacturing and fabrication processes including jointing; design and selection considerations, including durability, reparability, maintainability, corrosion and protective treatments; fatigue and creep phenomena; basic elasticity; simple structural element behavior for rods, beams, shafts and plates. Laboratory work and demonstrations are integrated to show the relevance of topics and to give practical insight to the behavior of aerospace structural materials and structures. *Prereq: EM211.*

EM324 Fluid Dynamics (3-2-4). An introductory course in fluid dynamics stressing both the integral and differential forms of the conservation laws of fluid flow. Engineering applications are made to hydrostatics and to ideal and real fluid flows. Laboratory experiments and problems sessions complement the lectures. *Coreq: EM319 or equivalent.*

EM362 Reactor Physics I (3-0-3). An introductory course in radiation physics and nuclear reactors. Course covers topics in atomic models, different types of radiation and their interaction with matter, radioactivity, fission process, neutron diffusion, and reactor criticality concepts for bare and reflected homogeneous systems. Prereq: SM212 or SP222.

EM371 Introduction to Design (2-2-3). Fundamentals of mechanical design, with emphasis on the design of pertinent machine elements. Topics such as fasteners, springs, anti-friction bearings, lubrication and journal bearings, gearing and shafts are covered. Also included are static and fatigue failure theories. *Prereq: EM217, EM232.*

EM375 Mechanical Engineering Experimentation (2-2-3). A design course that emphasizes the theory and practical considerations associated with contemporary experimental procedures, methods and design strategies. Topics include measurement error and its propagation, equation fitting and plotting, signal acquisition and validation, instrument response and elements of experimental design. Emphasis includes computer aided data reduction, modeling of a system and report writing. *Prereq: SM212, EM217 and EM232.*

EM380 Engineering Review (0-2-0). A comprehensive review course to prepare students to take the Engineer-In-Training (EIT) or Fundamentals of Engineering (FE) examination. Topics include mathematics, chemistry, computers, electrical engineering, engineering economics, statics, dynamics, thermodynamics, fluid mechanics, and mechanics of materials. *Prereq: 1/C engineering major.*

EM415 Heat Transfer (3-2-4). Study of thermal radiation, steady and transient conduction, laminar and turbulent convection, internal and external flow, boundary layers and empirical correlations. Applications address fins, nuclear reactor cooling, heat exchangers and interactive computing. *Prereq: EM319 and EM324.*

EM423 Mechanical Vibrations (2-2-3). The treatment of vibration fundamentals including free, damped and forced harmonic vibrations of linear single and multi-degree of freedom systems, modal analysis, continuous systems and a practical project. *Prereq: EM217 and EM232.*

EM432 Computer Methods in Structural Mechanics (3-0-3). Structural design and analysis; matrix formulation employing flexibility and stiffness methods of analysis, computer languages and techniques in structural design. Topics include temperature effects, effects of settlement of supports and misfit of structural parts. *Prereq: EM217.*

EM433 Computer-Aided Manufacturing (2-2-3). This course examines how computers and automation are used in modern manufacturing processes. Topics include machining processes, CNC programming, process planning, dimensioning, and tolerancing. Students participate in a manufacturing project, which utilizes CAD/CAM software to design and manufacture a component using CNC machining equipment. *Prereq: EM477.*

EM434 Advanced Mechanics of Materials (3-0-3). Topics include theories of elasticity and plasticity, stress and strain as tensors, compatibility and constitutive relationships, energy methods, stability, yield functions, behavior of time dependent materials, plasticity limit theorems, plastic design. *Prereq: EM217.*

EM436 Mechanics of Composite Structures (2-2-3). An introductory course that emphasizes the mechanics of structures containing composite materials. Topics covered include the generalized Hooke's Law, lamina constitutive relationships, mechanics of fiber reinforced lamina, lamina strength analysis, and the mechanics of composite laminates. Analysis is accomplished through computer lab assignments. *Prereq: EM217.*

EM443 Energy Conversion (3-0-3). Introduction to energy conversion and utilization. Terrestrial and thermodynamic limitations, direct energy conversion devices, alternative energy sources, present and future energy research design and development and energy usage and economy are presented. *Prereq: EM319 or equivalent.*

EM446 Heating, Ventilation and Air Conditioning: Design (3-0-3). Principles of thermodynamics, heat transfer, and fluid mechanics as applied to the design and control of thermal environments. Cycles and equipment for heating, cooling and humidity control. Air transmission, distribution and cleaning are also considered. *Prereq: EM319 and EM320 or equivalent.*

EM450 Compressible Flow and Turbomachinery (3-0-3). Fundamental principles of fluid dynamics and thermodynamics are applied to one-dimensional compressible flows. Topics include varying-area isentropic flow, flow with friction, flow with heat transfer and normal and oblique shock waves. Introductory concepts in the design and analysis of turbomachinery are covered. *Prereq: EM320, EM324 or equivalent.*

EM453 Materials: Processing and Fabrication (3-0-3). State-of-the-art and advanced process and fabrication techniques are examined for metallic, polymeric and composite materials. Aspects of the production of the basic components of material systems are examined. Also, post processing and fabrication thermal treatments to improve the material system will be discussed. The course is directed to proper process and fabrication selection for efficient and safe design of mechanical systems. *Prereq: EM313 or EM214.*

EM454 Mechanical Behavior of Materials (3-0-3). Treatment of mechanical behavior from a materials viewpoint. In addition to metallic materials, engineered materials, such as metallic, polymeric and ceramic composites are included. Elastic and elastic-plastic behavior are treated, as well as modes of fracture, including brittle and ductile. Scanning electron microscopy is performed for fractography. Ductile-to-brittle transition, elastic fracture mechanics, fatigue and creep are considered. *Prereq: (EM214 or EM313) and EM217.*

EM456 Corrosion and Corrosion Control (3-0-3). A course dedicated to the study of various types of corrosion including the electrochemical and metallurgical mechanisms responsible for each and their prevention. The course concentrates principally on the structural alloys used in the marine environment. Laboratory sessions involve demonstrations and hands-on experiments, which complement the lecture material. *Prereq: EM313 or EM214.*

EM458 Failure Analysis (2-2-3). A course designed to introduce the student to the principles, tools and techniques used in the analysis of materials failures. Laboratory skills in non-destructive testing, optical and electron microscopy, mechanical testing, corrosion and wear testing are developed. Emphasis is placed on actual case histories and the student is required to complete analysis of a failed component. *Prereq: EM217, EM313 or EM214.*

EM461 Engines: Principles, Design and Applications (2-2-3). The course objective is to provide a fundamental understanding of reciprocating internal-combustion engine design and operation. This is achieved by linking existing engine hardware design and performance analysis to concepts and disciplines studied in the mechanical engineering curriculum. *Prereq: EM320 or approval of department chair.*

EM463 Reactor Physics II (2-2-3). The topics covered include neutron generation times, reactor period, delayed neutrons, negative temperature coefficient, xenon poisoning, control rod theory, shielding and a reactor kinetics case problem. *Prereq: EM362.*

EM468 Nuclear Energy Conversion (3-0-3). Principles of the conversion of nuclear energy into useful power are covered. Various types of nuclear power plants, their design, cycles, load following characteristics, etc., are studied. Advanced nuclear energy conversion systems, including fusion, are also studied. *Prereq: EM362.*

EM472 Mechanical Design (2-2-3). A capstone study of the engineering design process emphasizing the integration of objectives, analysis of alternatives and synthesis of components. Practical experience is gained by participation in team projects. *Prereq: (EM371 and EM477) or approval of department chair.*

EM474 Gas Turbines: Design and Analysis (2-2-3). A course designed to acquaint the student with the design and analysis of modern gas turbine engines currently employed by the U.S. Navy. The emphasis is on the constraints and limitations of the various components that comprise shaft power gas turbine engines such as axial and centrifugal compressors, combustors, axial and radial turbines, intercoolers, reheaters, regenerators and inlet/exit diffusers and nozzles. In addition, component matching and the problems associated with it will be studied. Also, future concepts in turbo machinery propulsion will be discussed. The course assumes a basic knowledge of thermodynamics and will add to the student's knowledge in such areas as compressible flow in turbo machinery, combustion analysis and emissions control. The culmination of the course is a final design project. *Prereq: EM320.*

EM476 Undersea Power Systems (3-0-3). The principles of design of undersea power systems are presented. Topics include batteries, fuel cells, thermoelectrics, magnetohydrodynamics, thermophotovoltaics, and OTEC. *Prereq: EE332 and (EM318 or EM324 or approval of department chair).*

EM477 Computer-Aided Design (2-2-3). A design course using the workstation environment and selected software in mechanisms. Solid modeling and finite element analysis are used to generate solutions based on performance related objectives. *Prereq: EM371.*

Naval Architecture and Ocean Engineering Department

Naval Architecture Major

The naval architecture major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. This major came into being as an engineering discipline because of a unique and complex end-product, the ship. A special combination of knowledge and experience is needed to design and build a ship. Variety exists not only in the kinds of work (research, design, cost-estimation, fabrication, and management), but also in the types of craft involved—from sailboats to aircraft carriers, hydrofoil boats to catamarans, and submarines to surface-effect vehicles.

Naval architects use both art and engineering in designing ships. Armed with imagination and experience, they convert functional requirements into a suitable, cost-effective design. They analyze and select the best dimensions and hull form, calculate the power requirements, and estimate the weights of the principal components. They design and analyze the hull structure and decide on the location of military sub-systems, machinery spaces, habitability and support spaces, and tankage. Additionally, the ship must be subdivided into watertight compartments so that, if damaged, the chances of survival are maximized. Weighing and resolving the many conflicting requirements in the design of a ship are the creative and challenging responsibilities of the naval architect.

Naval architecture at the Naval Academy approaches these topics in a fully integrated program of classroom sessions, hands-on laboratory work, field trips, and the latest in computer-aided ship design and analysis techniques. A naval architecture design room, two towing tanks, a circulating water channel, and a static stability tank are some of the many facilities available to midshipmen majoring in naval architecture. A distinguished and innovative faculty complement these excellent facilities and contribute to making this an outstanding undergraduate engineering major. A bachelor of science in naval architecture is awarded.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM212, SM221;
Science: SP211, SP212;
Humanities: HH215, HH216 plus two electives including one at the 300/400 level;
Engineering: EE331, EE332, EM211, EM217, EM232, EM318, EM319, ES300, ES410;
Major: EN246, EN342, EN353, EN358, EN380, EN455, EN471, EN476, plus two major electives

Ocean Engineering Major

Ocean Engineering holds the key to the last frontier on earth, the ocean depths. While marine scientists provide us with a basic knowledge of the ocean environment, the ocean engineer enables us to use this environment more effectively. By blending the fundamentals of mathematics, physics, chemistry and oceanography with knowledge of the engineering sciences, including ocean materials and wave mechanics, the ocean engineer plans, designs and builds a variety of coastal, harbor, and offshore structures; unmanned underwater vehicles and diver-support equipment; underwater acoustic systems; ocean energy and other marine-related environmental systems. Multi-disciplinary in nature, ocean engineering will appeal to civil, electrical, environmental and mechanical engineers who wish to practice in the ocean realm.

The ocean engineering major is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The major offers an integrated program of study, using a balance between classroom theory, laboratory work and practical application providing midshipmen with the background to work effectively as ocean engineers. Laboratory experiments are conducted in the 120-foot and 380-foot wave and towing tanks and coastal engineering basin. These are equipped with electro-hydraulic wave-makers and instrumented with sophisticated sensors and on-line data acquisition and analysis equipment. A circulating water channel, hyperbaric test facility and an environmental chamber are also available. The Naval Academy's computer systems are used in solving design problems and preparing computer-aided designs. Supervising, directing and teaching this program is a team of professionals recognized for providing one of the finest undergraduate majors in ocean engineering available in the country. A bachelor of science in ocean engineering is awarded.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM212, SM221;
Science: SP211, SP212;
Humanities: HH215, HH216, and two electives including one at the 300/400 level;
Engineering: EE331, EE332, EM211, EM217, EM232, EM318, EM319, ES300, ES410;
Major: EN245, EN380, EN441, EN461, EN462, EN475, SO221, plus four major electives.

Naval Architecture and Ocean Engineering Courses

EN200 Principles of Ship Performance (3-2-4). This course is an introduction to ship systems, including basic methods of ship procurement, construction and power plant selection. Principles of ship stability and operability as related to preventive and corrective damage control. *Prereq: NS100 and Physics I (SP211 or SP221), and 3/C cruise.*

EN245 Principles of Ocean Systems Engineering (2-2-3). This course introduces new ocean engineering majors to the general problems and dsign practices in the areas of the ocean environment, coastal engineering, offshore structures, ocean materials, ocean acoustics, and underwater systems. Basic naval architecture principles are also covered, including hydrostatics, stability and buoyancy, and powering. The use of laboratory experiments and computer-aided drafting (CAD) are ephasized. *Prereq: EOE major or approval of chair. Coreq: EM211.*

EN246 Principles of Naval Architecture (2-2-3). This course, which is intended for midshipmen majoring in naval architecture, provides an overview of topics paramount to ship design. Topics include introductions to engineering design, engineering graphics, numerical methods, buoyancy, ship structures, and marine propulsion systems. A design project is used to provide students with a hands-on experience in designing a simple vessel. *Prereq: ENA major or approval of chair.*

EN330 Probabilities and Statistics with Ocean Applications (3-0-3). Covers the basic concepts of probability and statistics with the aim of providing an understanding of the probabilistic nature of the forces acting on a marine structure. A statistical representation of the sea surface is developed in order to determine design values for structural loading and vehicle motion. *Prereq: SM212 and (EN200 or EN245 or EN246).*

EN342 Ship Hydrostatics and Stability (3-2-4). Theories and procedures for predicting a ship's hydrostatic response to various conditions are addressed. Methods for computing the stability characteristics of both intact and damaged ships are studied. Floodable length computations are taught. Stability and subdivision criteria are explained. The lines plan for a hull form is developed and analyzed. *Prereq: EN245 or EN246.*

EN353 Resistance and Propulsion (3-2-4). Topics include dimensional analysis, similitude, wave and viscous resistance of ships, ship-model testing techniques, full-scale performance prediction, momentum theory of propulsive devices and propeller vibrations and design. The course also covers the experimental aspects of marine vehicle resistance and propulsion. *Prereq: (EN245 or EN246) and (EM318 or EM324).*

EN358 Ship Structures (3-2-4). A course in structural theory and practice. Topics include longitudinal and transverse strength of the hull girder, bending moments in a seaway, plate theory, development of ship structural design, finite element analysis, and applications of shipbuilding materials. *Prereq: EM217; Coreq: EN353.*

EN380 Naval Materials Science and Engineering (3-0-3). The course addresses the optimal use of materials in ocean systems with emphasis on corrosion prevention, fracture mechanics and basic materials science. *Prereq: SC112 or SC151; Coreq: EM217.*

EN411 Ocean Environmental Engineering I (2-2-3). An introduction to basic principles and current issues in environmental engineering as applied to the ocean environment. Topical coverage includes chemical and biological considerations in water quality, diffusion and dispersion in estuaries and oceanic environments, engineering methods used to analyze and mitigate the effects of marine pollution, and environmental ethics and regulatory statutes. *Prereq: 1/C engineering major or approval of chair.*

EN412 Ocean Environmental Engineering II (3-0-3). Basic principles and current issues in environmental engineering as applied to the ocean environment are introduced. Principal focus is on ocean resources: their identification, recovery and utilization. Topical coverage includes the technological aspects of alternate energy sources; deep-ocean oil and gas recovery; desalinization; dredging and uses for dredge spoil; mineral exploitation; ocean depositories; wetlands, reefs and other coastal developments; and environmental economics, ethics, and regulatory statutes. *Prereq: 1/C engineering major or approval of chair.*

EN420 Coastal Engineering (2-2-3). This coursse provides an overview of the methods used to design both shore protection systems and port and harbor structures. Topics include sea level fluctuations, wind-wave forecasting, shallow water wave transformation, sediment transport, littoral processes, "soft engineering" approaches like beach nourishment, and structural design of revetments, groins, jetties, and breakwaters. Emphasis is on the design process using Army Corps of Engineers design manuals. *Prereq: En475, 1/C EOE major or approval of chair.*

EN425 Ocean Thermal Systems (3-0-3). Applies the concepts of thermodynamics, fluid dynamics, psychrometrics and heat transfer to ocean systems and ocean environmental systems. Includes thermal energy conversion to power cycles, including internal and external combustion engines and gas turbines. Topics include: refrigeration, air conditioning, heat pumps, incompressible and compressible flow, mass and energy balances and heat exchanger designs. *Prereq: EM319; Coreq: EM324.*

EN430 Underwater Work Systems (3-0-3). This course acquaints the student with design and operational considerations for working in the subsea environment. Topic coverage includes manned submersibles, unmanned remotely-operated vehicles, autonomous underwater vehicles, and deep-dive systems. *Prereq: 1/C engineering major or approval of chair.*

EN440 Design of Foundations for Ocean Structures (3-0-3). This course covers basic soil mechanics principles and then applies these to the design of foundation systems, with an emphasis on the unique nature of coastal and ocan conditions. Topics include recommended practices and procedures for planning, designing and constructing adequate foundations for marine structures, including shallow foundations, deep pile foundation, vertical retaining walls, and anchoring systems. *Prereq: EM217, 1/C EOE major or approval of chair.*

EN441 Ocean Engineering Structures I (3-0-3). Structural design considerations for fixed ocean structures, such as docks, piers, and steel-jacket structures, are analyzed. Design techniques including matrix methods and finite element analysis are introduced. Boundary conditions, wave effects, foundations, loading and materials considerations are studied. *Prereq: EM217.*

EN442 Ocean Engineering Structures II (2-2-3). In this course in structural design theory and practice, basic structural elements of offshore and coastal structures are designed using current engineering design codes. Topics include material properties, connection methods, and design of steel, timber, and concrete structures. *Prereq: EN441.*

EN445 Marine Fabrication Methods (2-2-3). This course presents some of the basic techniques used to fabricate offshore structures and ships. Lecture and lab topics develop an understanding of metal, concrete and composite construction and quality control methods through the manufacturing and testing of small components representative of those used in the marine environment. An understanding of fabrication specifications is developed through group projects in each material category. *Prereq: EN380.*

EN450 Engineering Economic Analysis (3-0-3). Basic methods and reasons for conducting an engineering economic study are presented. Economic criteria are developed. Procedures for making a selection from among a set of technically feasible alternatives are studied. Assumptions and implications associated with these decision-making procedures are discussed. *Prereq: 1/C engineering major or approval of chair.*

EN451 Analytical Applications in Ship Design (3-0-3). The design process and analytical tools required for effective decisions in the design of marine systems are studied. Methods for the analysis and transformation of available data are evaluated. Once procedures for establishing the technical feasibility of a design have been addressed, emphasis shifts to the proper resolution of decisions dominated by economic considerations. *Prereq: 1/C standing as naval architecture major or approval of chair.*

EN452 Structural Reliability (3-0-3). This course provides an understanding of how reliability methods are used to account for the random nature of the sea when designing ocean and ship structures. Methods for the reliability assessment of structures are presented. The role of reliability methods in the design of structures and as the basis for design codes is discussed. Case studies on the use of reliability methods provide the student with real world applications to complement theroretical studies. *Prereq: EN358 and EN455, or EN461 and EN475.*

EN455 Seakeeping and Maneuvering (3-2-4). Topics include ship steering, maneuvering, motion and seakeeping. The basic equations of motion for a maneuvering ship and for ship motions in a seaway are developed, and various methods of solution are discussed. The course also covers the experimental aspects of seakeeping and maneuvering. *Prereq: EN353.*

EN456 Advanced Methods in Ship Design (3-0-3). An introduction to computer-aided ship design is presented. Topics include numerical procedures applied to form, stability, resistance, propulsion, motion, maneuvering and strength. *Prereq: EN353 or approval of chair.*

EN457 Hydrofoil and Propeller Design (3-0-3). The analysis and design of hydrofoils and marine propellers are presented. Lifting line and lifting surface theories are applied to naval devices. Design and towing tank work supplements recitations. *Prereq: EN353 or approval of chair.*

EN458 Advanced Marine Vehicles (2-2-3). Modern watercraft discussed include multihulls, planing boats, hydrofoil craft, and surface effect vehicles. Analysis and design features are investigated experimentally in the towing tank when appropriate. *Prereq: EN353.*

EN461 Ocean Systems Engineering Design I (3-0-3). Engineering design is introduced as an interdisciplinary activity coupling such subjects as applied probability and statistics, cost assessment, decision-making, economic evaluation, engineering ethics, and project planning. Instruction in hydrographic surveying and profiling, computer-aided drafting, and design report preparation and presentation is also included. *Prereq: 1/C standing in ocean engineering major.*

EN462 Ocean Systems Engineering Design II (1-4-3). The conceptual design of an ocean engineering system is accomplished by midshipmen teams. Projects are selected to match student interest and vary each semester, but normally incude such areas as coastal shore protection, marinas, offshore structures, tidal wetlands, artificial reefs, ocean energy systems, underwater vehicles, diving and life support systems. Design teams work independently and integrate detailed engineering design along with other project elements such as proposal writing, project management, cost estimating, report preparation, and oral presentations. *Prereq: EN461.*

EN470 Life Support Systems (3-0-3). The physiological and psychological aspects of man in the sea are presented with the related engineering requirements. Topics include hyperbaric physiology, saturation diving, life support equipment, deep dive systems, diving operations and hazards. *Prereq: 1/C engineering major or approval of department chair.*

EN471 Ship Design I (2-2-3). This course introduces the student to the requirements and procedures for accomplishing the design of a ship. The preliminary design of a small monohull displacement ship is developed. Relevant design resources and techniques are used. *Prereq: 1/C standing in naval architecture major.*

EN475 Ocean Engineering Mechanics (3-2-4). This course investigates the properties of ocean surface waves and the effects of ocean waves on fixed and floating ocean structures. Laboratory experiements are an integral part of the course and include measurements of wave heights, fuid velocities and pressures, wave-induced forces and structure motions in waves. Computational skills are also emphasized both through extensive spreadsheet applications and through programming in MATLAB. *Prereq: EM324, EN245 or approval of department chair.*

EN476 Ship Design II (0-6-3). In this course, which represents the culmination of an undergraduate naval architecture program, the student applies engineering skills to the design of a ship. *Prereq: EN471.*

EN478 Submarine Design Analysis (3-0-3). This course teaches naval architectural design methods specific to submarines, including generation of a concept design. Topics include surfaced and submerged hydrostatics, pressure hull design, resistance and propluson, hydrodynamics and ship handling, system integration, weight estimating, design margins, and operational envelopes. Additionally, midshipmen will gain insight into philosophies behind operating procedures, casualty procedures, and administrative quality controls which allow modern submarines to operate safely. *Prereq: 1/C Naval Architecture or Ocean Engineering majors.*

Weapons and Systems Engineering Department

Systems Engineering Major

Many modern products, from microwave ovens, stereos and automobiles to spacecraft, missiles and robots, are a complex system consisting of components from many engineering disciplines. The systems engineer seeks to combine and control the diverse components in order to meet specific design specifications.

The Naval Academy's systems engineering program, rated number one in the country for more than ten years, is accredited by the Accreditation Board for Engineering and Technology (ABET). It is an interdisciplinary major encompassing electronics, mechanics, automatic control, computers and simulation. An overall understanding of the analysis and design of complete engineering systems, including the interdisciplinary interfaces between systems, is the primary goal of the major. Systems engineering is particularly suited to those persons interested in the higher level interactions of engineering components rather than the detailed design of specific components. A bachelor of science in systems engineering is awarded. An honors program with a designated honors degree is available for selected students.

Since most modern systems contain automatic control functions using digital control techniques, the core of the systems engineering major is the study of feedback control theory, with digital control as a major element. Surrounding this core is the interdisciplinary part of the major, with advanced courses in digital technology and microprocessors, computer interfacing and engineering, analog and digital communications, analog and digital simulation and robotics. As a part of the interdisciplinary concept, portions of the systems engineering major may be fulfilled with advanced courses from all other engineering disciplines as well as mathematics, physics and computer science.

A systems engineer is particularly well prepared to operate and maintain the most sophisticated systems found in today's Navy. Knowledge gained in the major is directly applicable to missile, gun, sensor, guidance and propulsion systems. The systems engineering major also provides an excellent foundation for postgraduate education in any engineering discipline.

Curriculum Requirements (in addition to the requirements of plebe year)
Professional: NE203, NL302, NL400, NN204, NS310, NS40X;
Mathematics: SM212, SM221;
Science: SP211, SP212;
Humanities: HH215, HH216 and two electives including one at the 300/400 level;
Engineering: EE331, EE332, EM211, EM232, EM318, EM319, ES300;
Major: ES202, ES301, ES302, ES307, ES308, ES401, ES402, SI283, SM314, plus five major electives.

Systems Engineering Courses

ES202 Introduction to Systems Engineering (2-2-3). Introduction to the mathematics, programming and simulation tools of the Systems Engineer. Introduction to analog and digital simulation techniques and modeling of electrical, mechanical and hydraulic systems. Includes a simulation project, a briefing from the 1/C on design projects and a survey of the simulation and control laboratories and courses available in Systems Engineering. *Coreq:SM212.*

ES300 Naval Weapons Systems (3-0-3). An introduction to the theory of weapons systems through a study of the fundamental principles of sensor, tracking, computational and weapons delivery subsystems. *Prereq: Calculus II (SM122 or SM162), Physics II (SP212 or SP222), and Chemistry II (SC112 or SC151).*

ES301 Analog/Digital Computer Methods (2-2-3). Principles of computer simulation of linear and nonlinear multivariable systems are applied to the study of the behavior of realistic engineering control systems. Includes a hands-on hardware design and construction problem and a computer simulation design project. *Prereq: ES202 and EM232; Coreq: ES307.*

ES302 Applied Control Systems and Instrumentation (2-2-3). Computer controlled instrumentation is used to collect data for determination of mathematical model parameters of physical systems using statistical analysis. Comparisons of predicted and actual systems responses are made. Includes lab exercises with sensors, sensor operation and hardware design of DC and stepper motor controls. *Prereq: ES301 and ES307; Coreq: ES308.*

ES303 Linear Control Systems (3-0-3). Analysis and design of linear control systems in the time and frequencey domains. *Prereq: ES202 and EM232; Coreq: ES301.*

ES304 Advanced Control Systems (3-0-3). A study of advanced control methods for linear systems including frequency domain control system design, state feedback compensation, and state estimation. *Prereq: ES301 and ES303; Coreq: ES308.*

ES307 Linear Control Systems (4-0-4). Analysis and design of linear control systems in the time and frequency domains. *Prereq: ES202 and EM232; Coreq: ES301.*

ES308 Control Systems Design Laboratory (1-2-2). Applied control systems design. Implementation of analog and sample data controllers. *Prereq: ES303.*

ES401 Advanced Control Systems (2-2-3). A study of advanced topics of automatic control systems including compensation, modern control theory and nonlinear analysis and selected topics in research techniques. *Prereq: ES308 or ES410.*

ES402 Systems Engineering Design (2-4-4). Introduction to the macro-techniques of engineering design including performance, reliability, management control, redundancy, man-machine systems and testing techniques. Design, construction, test and evaluation of an approved project is accomplished in the lab. Two hours of lecture and two hours of laboratory are normally scheduled for this course. Each team also meets for an additional two hours of project work each week according to a schedule arranged to accommodate all those involved. *Prereq: ES308 and (ES405 or ES302).*

ES403 Engineering Design Methods (1-2-2). An introduction to the engineering design process and project management. Also includes the composition of the proposal for the senior design project. *Prereq: ES308; Coreq: ES405.*

ES405 Applied Control Systems (2-2-3). Computer controlled instrumentation is used to collect data for determination of mathematical model parameters of physical systems using statistical analysis. Comparisons of predicted and actual systems responses are made. Includes lab exercises with sensors, sensor operation, and hardware design of DC and stepper motor controls. *Prereq: ES304 and ES308.*

ES410 Control Systems and Their Application to Weapons (3-2-4). Linear control systems for engineering majors, using analytical, graphical and computer techniques. *Prereq: ES300, SM212 or SM222, and EE221 or EE331.*

ES413 Digital Control Systems (2-2-3). Analysis, design and simulation of digital filters. Analysis, design and laboratory testing of digital controllers for continuous processes using digital and analog computers and servo system hardware. *Prereq: ES308 or ES410.*

ES415 Nonlinear Control Systems (2-2-3). Analysis and design of control systems having nonlinear components. *Prereq: ES302 and ES308.*

ES418 Modern Control Systems (3-0-3). Analysis and design of control systems using modern control theory. *Prereq: ES304 or ES401.*

ES419 Weapons System Engineering (3-2-4). An introduction to weapons systems applications of RADAR, eletro-optics, SONAR, engagement systems, destruction systems and systems integration. An introduction to the engineering principles used in the control of weapons systems, including modeling of physical systems, analysis, and design. Applications of control systems is also addressed. *Prereq: EE301.*

ES421 Digital Information Systems (2-2-3). Introduction to the tools required to study digital and analog communications systems including Fourier analysis, sampling correlation, convolution and windowing. Analysis of different ways to encode digital communication signals. *Prereq: 1/C engineering major or approval of department chair.*

ES422 Analog Information Systems (2-2-3). Study of amplitude and frequency modulation techniques. Develop models of receiver structures for extracting signals from a noisy environment. System identification of unknown black boxes using time and frequency domain techniques. *Prereq: ES421.*

ES430 Introduction to Computer Engineering (2-2-3). An introduction to logic operations starting with Boolean algebra and switching circuits up to an introduction of the logical organization and internal functioning of computers. Lab exercises include combinatorial logic design, sequential logic design, computer functional simulation and a three-chip computer project.

ES432 Microcomputers in Control Applications (2-2-3). An introduction to the role of the microcomputer as a component in control systems, applying assembly language programming techniques and a variety of interface hardware. *Prereq: ES430 or approval of department chair.*

ES440 Environmental Systems Engineering (2-2-3). A survey of systems engineering topics related to the environment. Topics include environmental sensing, data processing, environmental modeling, alternate energy, and combustion emissions. Environmental engineering issues are explored through student research projects. Design and analysis of environmental sustems are explored through laboratory exercises. *Prereq: 1/C engineering major or approval of department chair.*

ES450 Introduction to Robotic Systems (2-2-3). Fundamentals of robotic systems including historical development, applications, basic configuration and design considerations, control principles of robot systems, computer vision processing and a group design project. *Prereq: 2/C engineering major or approval of department chair.*

ES451 Mobile Robot Design (1-4-3). An experimentation-based course in the design, analysis, construction, control and programming of autonomous mobile robots. Special topics include: locomotion methodologies (including walking machine design), design for terrain, analog robot designs, alternative actuation techniques (Shape Memory Alloys, etc.) microprocessor selection and integration, motion planning, behavior-based program structures, and power supply systems. Eight to ten robots are constructed by each team throughout the semester using standard robotic construction kits. All topics are investigated through experimentation in the laboratory. *Coreq: ES450.*

ES452 Advanced Topics in Robotics (2-2-3). Individual and group open-ended investigations of selected advanced topics in the field of robotics, such as: advanced computer vision processing techniques, multiple robot manipulator systems, and artificial neural network systems. Utilizes networked PCs, laboratory robots, computer vision systems. *Prereq: ES450 or approval of department chair.*