DEPARTMENT OF MECHANICAL AND ASTRONAUTICAL ENGINEERING

Chairman:
Anthony J. Healey
Distinguished Professor
Code ME/Hy
Mechanical Engineering
Bldg, Room 338
(831) 656-3462/7533
DSN 756-3462/7533
FAX (831) 656-2238

Associate Chairman:
Knox T. Millsaps
Associate Professor
Code ME/Mi
Mechanical Engineering
Bldg, Room 321
(831) 656-3382
DSN 756-3382
FAX: (831) 656-2238

Academic Associate:
(570/571 Curricula)
Fotis A. Papoulias
Associate Professor
Code ME/Pa
Mechanical Engineering
Bldg, Room 323
(831) 656-3381
DSN 756-3381
FAX: (831) 656-2238

Academic Associate:
(591 Curriculum)
I. Michael Ross
Associate Professor
Code ME/Ro
Mechanical Engineering
Bldg, Room 306
(831) 656-2074
DSN 756-2074
FAX: (831) 656-2238

Brij N. Agrawal, Distinguished Professor (1989)*; Ph.D. Syracuse University, 1970.

Christopher M. Brophy, Research Assistant Professor (1998); Ph.D. University of Alabama-Huntsville, 1997.

Charles N. Calvano, Professor (1991); Ocean Engineer Massachusetts Institute of Technology, 1970.

Muguru S. Chandrasekhara, Research Professor (1987); Ph.D. University of Iowa, 1983.

Morris R. Driels, Professor (1989); Ph.D. City University of London, 1973.

Indranath Dutta, Professor (1988); Ph.D. University of Texas, Austin, 1988.

Ashok Gopinath, Associate Professor (1994); Ph.D. University of California, Los Angeles, 1992.

Joshua H. Gordis, Associate Professor (1992); Ph.D. Rensselaer Polytechnique Institute, 1990.

Anthony J. Healey, Distinguished Professor and Chairman (1986); Ph.D. Sheffield University, United Kingdom, 1966.

S. K. Hebbar, Senior Lecturer (1988); Ph.D. University of Maryland, 1976.

Garth V. Hobson, Professor (1990); Ph.D. Pennsylvania State University, 1990.

Isaac I. Kaminer, Associate Professor (1992); Ph.D. University of Michigan, 1992.

Matthew D. Kelleher, Professor (1967); Ph.D. University of Notre Dame, 1966.

Ramesh Kolar, Research Assistant Professor (1997); Ph.D. University of Arizona, 1984.

Young W. Kwon, Professor (1990); Ph.D. Rice University, 1985.

Terry R. McNelley, Professor (1976); Ph.D. Stanford University, 1973.

Knox T. Millsaps, Jr., Associate Professor and Associate Chair (1992); Ph.D./Sc.D. Massachusetts Institute of Technology, 1991.

Fotis A. Papoulias, Associate Professor and Academic Associate (1988); Ph.D. University of Michigan, 1987.

I. Michael Ross, Associate Professor and Academic Associate (1990); Ph.D. Pennsylvania State University, 1990.

Turgut Sarpkaya, Distinguished Professor (1967); Ph.D. University of Iowa, 1954.

Young S. Shin, Professor (1981); Ph.D. Case Western Reserve University, 1971.

Raymond P. Shreeve, Professor (1971); Ph.D. University of Washington, 1970.

* The year of joining the Naval Postgraduate School faculty is indicated in parentheses.

Jose O. Sinibaldi, Research Assistant Professor (1999); Ph.D. University of Michigan, 1999.

Oleg A. Yakimenko, Research Associate Professor (1989); Ph.D. Russian Academy of Sciences, 1991.

Professors Emeriti:

Robert E. Ball, Distinguished Professor Emeritus (1967); Ph.D. Northwestern University, 1962.

Oscar Biblarz, Professor Emeritus (1968); Ph.D. Stanford University, 1968.

Gerald H. Lindsay, Professor Emeritus (1955); Ph.D. California Institute of Technology, 1966.

Paul J. Marto, Distinguished Professor Emeritus (1965); Sc.D. Massachusetts Institute of Technology, 1965.

Paul F. Pucci, Professor Emeritus (1956); Ph.D. Stanford University, 1955.

David Salinas, Associate Professor Emeritus (1970); Ph.D. University of California, Los Angeles, 1968.

Luis V. Schmidt, Professor Emeritus (1964); PhD, California Institute of Technology, 1963.

Edward Ming-Chi Wu, Professor Emeritus (1984); Ph.D. University of Illinois, 1965.

OVERVIEW

The Department of Mechanical and Astronautical Engineering (MAE) provides a strong academic program, which spans the engineering disciplines of thermal-fluid sciences, structural mechanics, dynamic systems, guidance and control, materials science and engineering, propulsion, and systems engineering, including total ship systems engineering, spacecraft, and missile design. These disciplines are blended together with a strong emphasis on naval engineering applications required by surface vessels, submarines, and spacecraft. Furthermore, the department provides advanced education in classified topics in Astronautical Engineering. Programs leading to the degree Master of Science in Mechanical Engineering or Master of Science in Astronautical Engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). A specific curriculum must be consistent with the general minimum requirements for the degree as determined by the Academic Council. Any program leading to a degree must be approved by the Department Chairman at least two quarters before completion. In general, approved programs will require more than the stated minimum degree requirements in order to conform to the needs and objectives of the United States Navy, and satisfy the applicable subspecialty-code requirements.

OBJECTIVES

The overall educational objective of the Mechanical and Astronautical Engineering program is to support the NPS mission by producing graduates who have knowledge and technical competence, at the advanced level in Mechanical and Astronautical Engineering, in support of national security. In order to achieve this goal, the specific objectives are to produce graduates who have:

- The ability to identify, formulate, and solve technical and engineering problems in Mechanical and Astronautical Engineering and related disciplines using the techniques, skills and tools of modern practice, including modeling and simulation. These problems may include issues of research, design, development, procurement, operation, maintenance or disposal of engineering components and systems for military applications.

- The ability to provide leadership in the specification of military requirements, in the organization and performance of research, design, testing, procurement and operation of technically advanced, militarily effective systems. The graduate must be able to interact with personnel from other services, industry, laboratories and academic institutions, and be able to understand the role that engineering and technology have in military operations, and in the broader national and global environment.

- The ability to communicate advanced technical information effectively in both oral and written form.

DEGREE PROGRAMS

The following degrees are available. Consistent with NPS Academic Policy, with the exception of the Engineer's or Doctoral degrees, all degree requirements must be satisfied independently.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

A candidate shall have completed work equivalent to the requirements of this department for the Bachelor of Science degree in Mechanical Engineering. Candidates who have not majored in mechanical engineering, or who have experienced significant lapses in continuity with previous academic work, will initially take undergraduate courses in mechanical engineering and mathematics to fulfill these requirements in preparation for their graduate program.

The Master of Science degree in Mechanical Engineering requires a minimum of 48 quarter-hours of graduate level work. The candidate must take all courses in an approved study program, which must satisfy the following requirements: There must be a minimum of 32 quarter hours of credits in 3000 and 4000 level courses, including a minimum of 12 quarter hours at the 4000 level. Of the 32 quarter hours at least 24 quarter-hours must be in courses offered by the MAE Department.

A student seeking the Master of Science degree in Mechanical Engineering must also demonstrate competence at the advanced level in at least one of the available disciplines of Mechanical Engineering. These disciplines are the thermal-fluid sciences; solid mechanics, shock and vibration; dynamic systems and control; system design; and materials science. This may be accomplished by completing at least eight quarter-hours of the 4000 level credits by courses in this department and a thesis in one of these discipline areas.

An acceptable thesis for a minimum of 16 credits is also required for the Master of Science degree in Mechanical Engineering. An acceptable thesis for the degree of Mechanical Engineer may also meet the thesis requirement of the Master of Science in Mechanical Engineering degree. The student's thesis advisor, the Academic Associate, the Program Officer and the Department Chairman must approve the study program and the thesis topic.

MASTER OF SCIENCE IN ASTRONAUTICAL ENGINEERING

The Master of Science degree in Astronautical Engineering requires a minimum of 48 quarter-hours of graduate level work. The candidate must take all courses in an approved study program, which must satisfy the following requirements: There must be a minimum of 32 quarter hours of credits in 3000 and 4000 level courses, including a minimum of 12 quarter hours at the 4000 level. Of the 32 quarter hours at least 24 quarter-hours must be in courses offered by the MAE Department.

A student seeking the Master of Science degree in Astronautical Engineering must demonstrate knowledge of orbital mechanics, space environment, attitude determination, guidance and control, telecommunications, space structures, spacecraft/rocket propulsion, and spacecraft design. The student must also demonstrate competence at the advanced level in one of the above disciplines of Astronautical Engineering. This may be accomplished by completing at least eight quarter hours of the 4000 level credits by courses in this department and a thesis in one of these discipline areas.

An acceptable thesis for a minimum of 16 credits is also required for the Master of Science degree in Astronautical Engineering. An acceptable thesis for the degree of Astronautical Engineer may also meet the thesis requirement of the Master of Science in Astronautical Engineering degree. The student's thesis advisor, the Academic Associate, the Program Officer and the Department Chairman must approve the study program and the thesis topic.

MASTER OF SCIENCE IN ENGINEERING SCIENCE (MECHANICAL ENGINEERING)

Candidates with acceptable academic background may enter a program leading to the degree of Master of Science in Engineering Science (with major in Mechanical Engineering). Candidates who have not majored in mechanical engineering or closely related subject areas, or who have experienced significant lapses in continuity with previous academic work, will initially take undergraduate courses in mechanical engineering and mathematics to prepare for their graduate program.

The Master of Science in Engineering Science (with major in Mechanical Engineering) degree requires a minimum of 48 quarter hours of graduate level work. The candidate must take all courses in an approved study program, which must satisfy the following requirements: there must be a minimum of 32 quarter hours of credits in 3000 and 4000 level courses, including a minimum of 12 quarter hours at the 4000 level. Of the 32 quarter hours at least 24 quarter hours must be in courses offered by the MAE Department.

A student seeking the Master of Science in Engineering Science must also demonstrate competence at the advanced level in at least one of the available disciplines of Mechanical Engineering. These disciplines are the thermal-fluid sciences; solid mechanics, shock and vibration; dynamic systems and control; system design; and materials science. This may be accomplished by completing at least eight quarter hours of the 4000 level credits by courses in this department and a thesis in one of these discipline areas.

An acceptable thesis for a minimum of 16 credits is also required for the Master of Science in Engineering Science (with major in Mechanical Engineering) degree. The student's thesis advisor, the Academic Associate, the Program Officer and the Department Chairman must approve the study program and the thesis topic.

Under special circumstances as approved by Academic Associate, Program Officer and the Department Chair, students may take four additional courses in lieu of a thesis. Those four additional courses should be at least 3000 and 4000 level courses offered by the MAE Department, and among them at least 2 courses should be at the 4000 level.

Entrance into the 571 Reactors/Mechanical Engineering Curriculum program, leading to the degree Master of Science in Engineering Science (with major in Mechanical Engineering), is restricted to individuals who have successfully completed the Bettis Reactor Engineering School (BRES) and who have an academic profile code (APC) of 121 or better. All entrants must be nominated for the program by the designated program coordinator and primary consultant for Naval Reactors (SEA-08).

This program includes the following BRES courses: BRES 200 Mathematics; BRES 340 Applied Structural Mechanics; BRES 350 Heat Transfer and Fluid Flows; BRES 360 Reactor Dynamics, Control and Safeguards. The foregoing are equivalent to 16 credit hours of ME3XXX level courses. In addition, the BRES 370 Reactor and Power Plant Design Project and report must be successfully completed. In addition, the program must include 20 hours of graduate level (ME4XXX) level NPS courses in a program approved by the Department Chairman.

MASTER OF SCIENCE IN ENGINEERING SCIENCE (ASTRONAUTICAL ENGINEERING)

Candidates with acceptable academic background may enter a program leading to the degree of Master of Science in Engineering Science (with major in Astronautical Engineering). Candidates who have not majored in astronautical engineering or closely related subject areas, or who have experienced significant lapses in continuity with previous academic work, will initially take undergraduate courses in astronautical engineering and mathematics to prepare for their graduate program.

The Master of Science in Engineering Science (with major in Astronautical Engineering) degree requires a minimum of 48 quarter hours of graduate level work. The candidate must take all courses in an approved study program, which must satisfy the following requirements: there must be a minimum of 32 quarter hours of credits in 3000 and 4000 level courses, including a minimum of 12 quarter hours at the 4000 level. Of the 32 quarter hours at least 24 quarter hours must be in courses offered by the MAE Department.

A student seeking the Master of Science degree in Astronautical Engineering must demonstrate knowledge of orbital mechanics, space environment, attitude determination, guidance and control, telecommunications, space structures, spacecraft/rocket propulsion, and spacecraft design. The student must also demonstrate competence at the advanced level in one of the above disciplines of Astronautical Engineering. This may be accomplished by completing at least eight quarter hours of the 4000 level credits by courses in this department and a thesis in one of these discipline areas.

An acceptable thesis for a minimum of 16 credits is also required for the Master of Science in Engineering Science (with major in Astronautical Engineering) degree. The student's thesis advisor, the Academic Associate, the Program Officer and the Department Chairman must approve the study program and the thesis topic.

MASTER OF SCIENCE IN ENGINEERING SCIENCE (MATERIALS SCIENCE AND ENGINEERING)

Students with acceptable backgrounds in science or engineering may enter a program leading to the degree Master of Science in Engineering Science (with major in Materials Science and Engineering). The candidate must take all courses in a curriculum approved by the Chairman of the MAE Department and the faculty member designated to represent the Materials program. At a minimum, the approved curriculum must satisfy the requirements listed below.

The program must include at least 48 quarter hours of graduate work in Materials Science, consisting of 32 credit hours in graduate level courses and 16 credit hours of thesis work. Of the 32 course credit hours, at least 16 must be at the 4000 level and at least 8 quarter hours of graduate credit must be earned outside of Materials Science and Engineering.

An acceptable thesis is required for the Master of Science in Materials Science and Engineering degree. Approval of the thesis advisor and topic must be obtained from the Chairman of the MAE Department.

MECHANICAL ENGINEER

A graduate student with a superior academic record (as may be demonstrated by a graduate QPR of 3.70 or better) may apply to enter a program leading to the degree Mechanical Engineer. A candidate must prepare his or her application and route it through the Program Officer to the Department Chairman for decision. Typically, the selection process occurs after completion of the candidate’s first year of residence.

A candidate must take all courses in a curriculum approved by the Chairman of the MAE Department. At a minimum, the approved curriculum must satisfy the requirements stated in the following paragraphs.

The Mechanical Engineer degree requires at least 64 quarter-hours of graduate level credits in Mechanical Engineering and Materials Science, at least 32 of which must be at the 4000 level. At least 12 quarter-hours of graduate level credits must be earned outside of the MAE Department. At least one advanced Mathematics course should normally be included in these 12 quarter-hours.

An acceptable thesis of 28 credit hours is required for the Mechanical Engineer degree. Approval of the thesis advisor and program must be obtained from the Chairman of the MAE Department.

ASTRONAUTICAL ENGINEER

A graduate student with a superior academic record (as may be demonstrated by a graduate QPR of 3.70 or better) may apply to enter a program leading to the degree Astronautical Engineer. A candidate must prepare his or her application and route it through the Program Officer to the Department Chairman for decision. Typically, the selection process occurs after completion of the candidate’s first year of residence.

A candidate must take all courses in a curriculum approved by the Chairman of the MAE Department. At a minimum, the approved curriculum must satisfy the requirements stated in the following paragraphs.

The Astronautical Engineer degree requires at least 64 quarter-hours of graduate level credits in Astronautical Engineering or Mechanical Engineering and Materials Science, at least 32 of which must be at the 4000 level. At least 12 quarter-hours of graduate level credits must be earned outside of the MAE Department. At least one advanced Mathematics course should normally be included in these 12 quarter-hours.

An acceptable thesis of 28 credit hours is required for the Astronautical Engineer degree. Approval of the thesis advisor and program must be obtained from the Chairman of the MAE Department.

TOTAL SHIP SYSTEMS ENGINEERING PROGRAM

The Total Ship Systems Engineering Program is an interdisciplinary, systems engineering and design oriented program available to students enrolled in Mechanical and Astronautical Engineering, Electrical and Computer Engineering or Combat Systems programs. The program objective is to provide a broad-based, design-oriented education focusing on the warship as a total engineering system. The eight-course sequence of electives introduces the student to the integration procedures and tools used to develop highly complex systems such as Navy ships. The program culminates in a team-performed design of a Navy ship, with students from all three curricula as team members. Students enrolled in programs leading to the Engineer Degree are also eligible for participation. Entry requirements are a baccalaureate degree in an engineering discipline with a demonstrated capability to perform satisfactorily at the graduate level. The appropriate degree thesis requirements must be met, but theses that may address system design issues are welcome.

DOCTOR OF PHILOSOPHY AND DOCTOR OF ENGINEERING

Students who have a superior academic record may request entrance into the doctoral program. All applicants will be screened by the departmental doctoral committee for admission into the program. The department also accepts officer students selected in the Navy-wide doctoral study program, qualified international officers, and civilian students selected from the employees of the United States Federal Government.

An applicant to the doctoral program who is not already at NPS should submit transcripts of previous academic and professional work, plus results of a current Graduate Record Examination (GRE) general test (if available), to the Director of Admissions, Code 01C3, Naval Postgraduate School, Monterey, California 93943-5100.

Every applicant who is accepted for the doctoral program will initially be enrolled in the Mechanical and Astronautical Engineering Program under a special option which satisfies the broad departmental requirements for the Engineer's degree, which includes research work. As soon as feasible, the student must identify a faculty advisor to supervise research and to help formulate a plan for advanced study. As early as practicable thereafter, a doctoral committee shall be appointed to oversee that student's individual doctoral program as provided in the school-wide requirements for the doctor's degree. Joint programs with other departments are possible.

A noteworthy feature of the program leading to the Doctor of Engineering degree is that the student's research may be conducted away from the Naval Postgraduate School in a cooperating laboratory or other installations of the Federal Government. The degree requirements are as outlined in the general school requirements for the doctor's degree (see Academic Policy manual, Section 5.4)

LABORATORIES

MAE Laboratories are designed as complements to the educational mission and research interests of the department. In addition to extensive facilities for the support of student and faculty research, a variety of general use equipment is available. This includes equipment and facilities for the investigation of problems in engineering mechanics; a completely equipped materials science laboratory, including advanced scanning electron microscopes, an Auger microprobe, a transmission electron microscope and X-ray diffractometers; an oscillating water tunnel, a unique underwater towing tank and a low turbulence water channel; a vibration analysis laboratory; a fluid power controls laboratory; a robotics and real-time control laboratory; facilities for experimentation with low velocity air flows; equipment for instruction in thermal transport phenomena; a laser Doppler velocimeter; nuclear radiation detection equipment and an interactive CAD/CAE computer graphics laboratory. Experimentation is further enhanced by a broad selection of analog and digital data acquisition and processing equipment and instrumentation. The Mechanical Engineering Department also houses the largest of several machine shops on campus. The ME Dept. shop includes a state-of-the-art 3-axis CNC milling machine, a CNC lathe, and a variety of other high-precision machine tools and fabrication equipment which allow the manufacture of parts and systems in support of teaching and research.

The following laboratories are available for teaching and research:

UNMANNED SYSTEMS LAB/CTR: Unmanned Systems are a critical element in Navy planning for future littoral operations. They include fixed bottom mounted data gathering nodes, unmanned submarines, surface vessels, and aerial vehicles. Interconnectivity with acoustic and radio communications links are key to the development of modern naval systems. These assets may be used for mine clearing and other shallow water reconnaissance and intelligence gathering operations. The Laboratory houses 2 autonomous Submarines (ARIES and REMUS) as well as the UAV FROG and subsurface Acoustic Doppler Current Profilers (ADCP), equipped with Acoustic Modems and supports coursework in Control and Autonomous Systems.

CAD / CAE COMPUTER LABORATORY: This lab consists of Windows PC's and is used heavily by students from several departments for both class and thesis related work.

NANO/MEMSLABORATORY: This laboratory provides a facility for teaching the emerging technologies of NANO/MEMS.

FLUID MECHANICS COMBINED LABORATORIES: These labs include a hydrodynamics facility with U-tunnel for the study of a wide range of phenomena, such as the interaction of vortices with free surfaces. This lab is unique for research in the detection of submarines. Also, this laboratory provides for instruction in fluid power and power transmission systems. This laboratory also supports instruction in basic courses in fluid mechanics. This laboratory is equipped with a wind tunnel for specific instruction in hydro/aero-dynamic phenomena.

TECHNICAL SUPPORT FACILITY: This facility provides broad support, to both students and faculty, in electronics, data acquisition and computation; in machining and fabrication, and in instrumentation calibration.

MATERIALS LABORATORY: Laboratory supports teaching and research in processing, characterization and testing of advanced structural, functional and nanotechnology materials for defense applications

Auger Surface Analysis Laboratory: It consists of an ultrahigh vacuum system and an electron beam source to probe the surface and interface structure of composites and microelectronic devices.

Transmission Electron Microscopy Lab: Contains a TOPCON 002B TEM used for materials science and engineering teaching and research.

Scanning Electron Microscopy Lab: Contains a a TOPCON 540 SEM used for materials science and engineering teaching and research.

X-Ray Diffraction Laboratory: Two Philips X-ray Systems for materials research are used for materials science and engineering teaching and research.

Optical Microscopes Laboratory: This lab includes several optical microscopes as well as electronic imaging and image analysis systems that are used for materials science and engineering teaching and research.

Metallurgical Polishing Laboratory: This laboratory supports all teaching and research in materials by provision of facilities for the polishing of samples for metallo-graphic examination.

Metallurgical Sectioning Laboratory: This laboratory supports all teaching and research in materials by provision of facilities for the cutting/sectioning of samples for metallo-graphic examination.

Wet Sample Preparation Facility: This facility is mainly in support of the Transmission and Scanning Microscopy labs. It is used for chemical preparation of samples for microscopic examination.

Dark Room Facility: This facility is used in support of photographic work in the materials and other Departmental laboratories.

Transmission Electron Microscopy Ii Lab: This laboratory is equipped with a JEOL-100CX microscope and is used primarily for instruction of students in the techniques of electron microscopy.

Scanning Electron Microscopy Laboratory: This laboratory is equipped with an older model Cambridge Instruments SEM.

Physical Testing (Dilatometer) Laboratory: This laboratory is dedicated to dilatometry and is primarily used for research applications.

Heat Treatment Laboratory: This laboratory supports courses and research mainly in the materials area and consists mainly of a selection of conventional furnaces.

Corrosion Laboratory: This laboratory supports the instructional program in the area of corrosion science and engineering.

Metallurgical Etching Laboratory: This laboratory supports all teaching and research in materials by provision of facilities for the chemical treatment of samples for metallo-graphic examination.

Welding Laboratory: Welding is the primary method of fabrication for Naval vessels, and instruction and research on welding/ joining of both conventional and advanced alloys is carried out in this facility.

Materials Processing Laboratory: This laboratory supports both teaching and research involving deformation and thermal processing of materials. It is equipped with presses, a rolling mill and various heat treatment furnaces.

Creep Test Laboratory: This laboratory supports research in high-temperature structural metals and composites.

Mechanical Test Laboratory: This lab supports mechanical testing with impact, creep and fatigue instrument and electromechanical

Ceramics Laboratory: This laboratory is devoted primarily to research on high temperature materials based on various ceramic compositions.

Composites Laboratory: This laboratory supports research in composite materials, especially metal matrix composites.

Physical Testing (Shaker) Laboratory: This lab is dedicated to research in sound dampening materials. No activity is currently taking place in this area.

PROPULSION LAB: This lab includes the marine propulsion lab, the rocket propulsion lab, and the turbo-propulsion lab. The marine propulsion lab includes gas turbine and diesel engines. This forms the core of the instructional program in marine power and propulsion. The engines are utilized for both instruction and research. This lab includes a transonic compressor and turbine test rigs, a low-speed compressor test rig, a cascade wind tunnel and spin pit, Supersonic blow-down wind tunnels (2), free-jet facility, shock-tube and small-engine test cell with 8000 cubic feet air supply @ 300 psi.

STRUCTURAL DYNAMICS LABORATORY: This lab is devoted to structural dynamics and is especially designed to facilitate both teaching and research into vibration and shock effects associated with underwater explosions, as well as related shipboard vibration problems. The ability to validate simulation models with lab-scale tests is critical for student education.

THERMAL ENGINEERING LABS: These labs are used mainly for instruction in heat transfer by convection phenomena of single and multi-phase flows and includes facilities for measurement of temperature change and fluid motion in a range of systems. The lab also includes equipment/instrumentation for measurements in microelectronics and microheat exchanger systems.

Convection Heat Transfer Laboratory: Used mainly for instruction in heat transfer by convection phenomena and includes facilities for measurement of temperature change and fluid motion in a range of systems.

ME04 Electronic Cooling Laboratory: The operation of microelectronic devices results in intense but very localized heating of electronic devices. The phenomena involved are unique because of the small scale and are examined in courses and lab.

Two-Phase Heat Transfer Laboratory: This is an instructional and research laboratory for the study of heat transfer involving more than one phase, e.g. heat transfer involving liquid and vapor phases during boiling or condensation.

SHIP SYSTEMS ENGINEERING (TSSE) LAB: This is an integrated design center in which student teams perform their capstone design project of a Navy ship. Ship design encompasses hull, mechanical, and electrical systems as well as combat systems and is done in cooperation with the Meyer Institute of Systems Engineering.

ASTRO-ENGINEERING LAB

Spacecraft Design Laboratory: This laboratory houses computer–aided design tools for spacecraft design and a spacecraft design library. It is used heavily by students for three spacecraft design courses, AA 3870, AA 4870, and AA 4871. Students can do collaborative spacecraft design using the unique design tools on Windows or Unix PCs that are not available in other education institution.

Smart Structure and Attitude Control Laboratory: This lab consists of five major experiment setups to facilitate the instruction and research by students in the area of both smart structures, sensors, and actuators for active vibration control, vibration isolation, and shape control in space applications and attitude control of flexible spacecraft and space robotic manipulators. In addition to students' thesis research, it also supports courses, AE4816 Dynamics and Control of Smart Structures and AE3811 Space System Laboratory, and AA 3818, Spacecraft Attitude Dynamics and Control.

Optical Relay Spacecraft Laboratory: This joint laboratory of NPS and AFRL is used for both instruction and research on acquisition, tracking, and pointing of flexible military spacecraft. The main facilities include a bifocal relay mirror spacecraft attitude simulator, actuated by variable speed control moment gyros, a single focal spacecraft attitude simulators, actuated by reaction wheels, and an optical beam and jitter control test bed. This laboratory is used for courses AA 3811, AA 3818, and AA 4818.

Satellite Servicing Laboratory: The Satellite Servicing Laboratory, funded by NPS and AFRL, hosts the Autonomous Docking and Spacecraft Servicing Simulator (AUDASS). This test bed, consisting of two independent robotic vehicles (a chaser and a target), aims to carry out on-the-ground testing of satellite servicing and proximity formation flight technologies. The vehicles float, via air pads, on a polished granite table, providing a frictionless support for the simulation in 2-D of the zero-g dynamics. This is used for course AA 3811.

FLTSATCOM Laboratory: This laboratory consists of a qualification model of the Navy communications satellite, FLTSATCOM, the associated ground support equipment for testing the satellite. This is an instructional laboratory and is used by students in laboratory course AA 3811. Students send the command to the satellite for spin-up of reaction wheel, rotation of solar array drive and firing sequence of thrusters and get telemetry on status of the command and battery temperature and current etc.

RESEARCH CENTERS

The following Research Centers are organized in the MAE Department:

Center for Materials Sciences and Engineering

The Center for Materials Sciences and Engineering provides a focus for research and education in Materials Science and Engineering at NPS. Research projects span the range from basic research sponsored by the NSF to applied work on microelectronics reliability sponsor by Intel Corp. through the Semiconductor Research Corporation (SRC), the Army Research Office (ARO). Also, projects include advanced processing of Naval materials sponsored by DARPA.

Center for Autonomous Underwater Vehicle Research

The primary goal of the NPS Center for AUV Research is to educate Navy and USMC officer students in the development and use of technologies needed for unmanned underwater vehicles through coursework, thesis and dissertation research. The secondary goal of the Center is to advance Naval UUV operations by providing: Support to the Fleet, Navy Labs and Program Offices, Testing and Experimentation of Advanced Technologies, Independent Verification and Validation of UUV Concepts, and Innovative Concept Development. Research is conducted into topics falling in the following broad areas: Underwater Navigation, Control and Communication; Tactical Decision Aids; Collaborative Multi-Vehicle Operations; Obstacle Avoidance (OA) using Forward Look Sonar; and Common UUV Mission Description Language.

Turbo Propulsion Laboratory

The Turbo Propulsion Laboratory houses a unique collection of experimental facilities for research and development related to compressors, turbines and advanced air-breathing propulsion engine concepts. In a complex of specially designed concrete structures, one building, powered by a 750 HP compressor, contains 10 by 60 inch rectilinear and 4 to 8 foot diameter radial cascade wind tunnels, and a large 3-stage axial research compressor for low speed studies. A two-component, automated traverse, LDV system is available for CFD code verification experiments. A second building, powered by a 1250 HP compressed air plant, contains fully instrumented transonic turbine and compressor rigs in explosion proof test cells. A spin-pit for structural testing of rotors to 50,000 RPM and 1,800 degrees Fahrenheit is provided. Model experiments and equipment for instrumentation development are located in a separate laboratory. Data acquisition from 400 channels of steady state and 32 channels of non-steady measurements, at up to 200kHz, is controlled by the laboratory's Pentium workstations. A third building houses a 600 HP radial and 150 HP boost compressor capable of delivering 2000 scfm of air at 10 and 20 atmospheres respectively. These charge four tanks for blow-down to a supersonic wind tunnel (4 x 4 inches), a transonic cascade wind tunnel (2 x 3 inches), and two free jets (one 6 inch and one 1 inch in diameter). The large free jet is equipped with an instrumented thrust stand for the testing of small gas turbine engines. The building also houses a 3-inch diameter shock tube. Pressure measurements are made with a 96-channel Scanivalve ZOC system and pressure sensitive paint, and schlieren and shadowgraph techniques are used routinely.

Spacecraft Research & Design Center

The Spacecraft Research and Design Center at the Naval Postgraduate School consists of six state-of-the art laboratories: Fltsatcom Laboratory, Spacecraft Attitude Dynamics and Control Laboratory, Smart Structures laboratory, Spacecraft Design Center, NPS-AFRL Optical Relay Mirror Spacecraft Laboratory, and Satellite Servicing Laboratory. These laboratories are used for instruction and research in space system engineering and space operations curricula. The emphasis has been on providing students with hands-on experience in the design, analysis, and testing of space systems and systems and to provide students facilities for experimental research. The emphasis in the research h areas is on acquisition, tracking and pointing of flexible spacecraft with optical payloads; active vibration control, Isolation, and suppression using smart structures; space robotics, satellite servicing, space system design, and computer aided design tools. These laboratories has been used in joint projects with Naval Satellite Operational Center, NRL, AFRL, Columbia University, and Boeing.

MECHANICAL AND ASTRONAUTICAL ENGINEERING COURSE DESCRIPTIONS

AE0810 THESIS RESEARCH (0 - 8).
Every student conducting thesis research will enroll in this course.

AE2440 INTRODUCTION TO DIGITAL COMPUTATION (3 - 2).
Introduction to system operations and program development on the department UNIX workstations and the NPS computer facilities. High-level programming languages, including C, MATLAB, and FORTRAN. Development of computer programs, subroutine organization, input and output. Applications of programming techniques to the solution of selected problems in engineering. PREREQUISITE: MA1115.

AE2820 INTRODUCTION TO SPACECRAFT STRUCTURES (3 - 2).
Review of statics and strength of materials. Beam theory: axial, bending, shear and torsional loading, stress analysis and deflection of beams. Design of spacecraft structures for launch loads and a survey of typical launch vehicles. Beam buckling and vibration, critical buckling loads, natural frequencies, and mode shapes. Truss structures and introduction to the finite element method. PREREQUISITES: None.

AE3804 THERMAL CONTROL OF SPACECRAFT (3 - 0).
Conduction, radiation, thermal analysis, isothermal space radiator, lumped parameter analytical model, spacecraft passive and active thermal control design, heat pipes, and louvers. PREREQUISITES: None.

AE3811 SPACE SYSTEMS LABORATORY (2 - 2).
Principles of spacecraft test programs; component, subsystem, and system level tests; military standard test requirements for space vehicles, laboratory experiments in Fltsatcom Laboratory on satellite performance, in Spacecraft Test Laboratory for vibration, modal and thermal tests; and in Spacecraft Attitude Control Laboratory for spacecraft control performance. Graded Pass/Fail. PREREQUISITE: Consent of Instructor.

AE3815 INTRODUCTION TO SPACECRAFT DYNAMICS (3 - 2).
Coordinate system transformations (GCI, LVLH, etc.), time differentiation operator, velocity and acceleration in 3D-frames of reference, Poisson’s equations, spacecraft application examples (strapdown INS, etc.), angular momentum, inertia tensor transformations, Newton-Euler equations of motion, spin stability, single-spin spacecraft, nutation and precession, energy-sink analysis, passive nutation control, dynamics and stability of dual spin spacecraft, gravity-gradient stabilization. PREREQUISITES: PH1121, PH2511, MA2121.

AE3818 SPACECRAFT ATTITUDE, DYNAMICS AND CONTROL (3 - 2).
Stability of dual-spin stabilized spacecraft, active nutation control, disturbance torques: solar, magnetic, gravity gradient, and aerodynamic, attitude sensors, antenna beam pointing accuracy, three-axis-stabilized spacecraft, fixed momentum wheel with thrusters, three reaction wheel system, attitude control pointing requirements for military spacecraft. PREREQUISITES: EC2300 or equivalent, AE3815.

AE3820 DYNAMICS OF SPACE SYSTEMS (3 - 2).
This course is an intermediate level analysis of the dynamics of space systems, including: ascent and descent of rockets, tethers, yo-yo despin, spinning hubs with flexible appendages, single stage to orbit, and various problems in spacecraft attitude dynamics such as nutation dampers. The analysis will include developing the equation of motion, equilibrium and stability analysis, solutions of nonlinear systems using perturbation methods and numerical techniques. Computational and symbolic manipulator packages will be used extensively. PREREQUISITE: MA2121.

AE3830 SPACECRAFT GUIDANCE AND CONTROL (3 - 2).
Overview of the Spacecraft Guidance, Navigation and Control System. Sources and effects of navigation and modeling errors on guidance and control systems. Error propagation techniques: linearization of spacecraft dynamical equations, covariance propagation and Monte Carlo simulations. Applications to spacecraft rendezvous and attitude control. Introduction to optimal control theory. Optimal bang-bang control for spacecraft thrusters. Linear-quadratic control problems and feedback control. Selection of weights and performance analysis. Perturbation guidance. Application of the matrix Riccati equation to spacecraft stability, control and guidance. PREREQUISITES: MA2121, SS2500, EC2300 or equivalent, AE3815

AE3851 SPACECRAFT PROPULSION (3 - 2).
Introduces concepts and devices in spacecraft propulsion. It reviews fundamental fluid mechanics, electricity and

magnetism, and thermodynamics with molecular structure. Conventional chemical means such as H_2/O_2 and monopropellants are discussed. Electric propulsion schemes (resistojets, arc-jets, ion, magneto-plasma-dynamic, etc.) are introduced and their performances contrasted with chemical schemes. Characteristics of more advanced concepts (laser, solar, nuclear, etc.) are also considered. PREREQUSITE: None.

AE3852 PROPULSION FOR LAUNCH VEHICLES (4 - 0).
Introduction to propulsion for launch vehicles, beginning with mission energy requirements and an overview of current and proposed launch propulsion devices. Performance analysis, operating characteristics and propellant selection criteria are considered for air breathing and solid, liquid and nuclear rocket motor propulsion systems. Advanced cycles and concepts are presented. Design of components and subsystems. PREREQUISITE: ME3201.

AE3870 COMPUTATIONAL TOOLS FOR SPACECRAFT DESIGN (2 - 4).
In this course, the students become familiar with the use of computer aided design tools for spacecraft subsystems and system design. The tools are for conceptual spacecraft design trade-offs and detailed subsystem design, such as for structures, thermal, attitude control, and communications. PREREQUISITE: Consent of instructor.

AE4362 ASTRODYNAMICS (3 - 0).
Review of the two-body problem. The effects of a third point mass and a distributed mass. Expansion of the disturbing potential in series of Legendre functions. Variation of parameter equations for osculating orbital elements. Perturbation and numerical solution techniques. Statistical orbit determination. Codes used by the military to maintain the catalog of artificial satellites and space debris. PREREQUISITE: SS2500 or equivalent.

AE4452 ADVANCED MISSILE PROPULSION (4-1).
Analysis and design of solid propellant rockets, ramjets, dual-combustion ramjets, scramjets and ducted rockets. Propellant selection criteria and characteristics, combustion models and behavior, performance analysis, combustor design, combustion instabilities and damping, mission and flight envelope effects on design requirements and technology requirements. Use of performance and grain design codes (SPP, PEP, and NASA SP233) and laboratory test firings for comparison with measured performance. PREREQUISITE: AE3852 or consent of instructor.

AE4502 SUPERSONIC AND HYPERSONIC FLOWS (4-0).
One-dimensional, compressible flow is reviewed. Two-dimensional and axis-symmetric supersonic of ideal gases. Oblique shocks and expansion waves. General compressible flow equations. Potential supersonic and conical flows. Compressible scaling and transonic area ruling. Effects of very high velocity and low density. Hypersonic flow. Mach number independence and equivalence principles. Newtonian method. Blunt and slender body solutions. Real gas behavior and effect on shock and boundary layers. Applications are presented to satellite parasitic drag and re-entry flows. PREREQUISITE: ME3201 or consent of instructor.

AE 4506 RAREFIED GAS DYNAMICS (4-0).
Topics include advanced thermodynamics with molecular structure, kinetic theory, distribution functions, Boltzmann equation and transport phenomena from a kinetic theory point of view. Types of flow range from free-molecule to transition, to high temperature continuum. Numerical approaches are discussed. Applications to space problems and hypersonics are treated. PREREQUISITES: ME3201 or equivalent.

AE4816 DYNAMICS AND CONTROL OF SPACE STRUCTURES (4 - 0).
Review of dynamics, finite element method, structural natural frequencies, mode shapes, and control of flexible structures. Smart sensors and actuators and applications to active vibration control, shape control, vibration isolation and fine beam pointing. Equation of motion of spacecraft with flexible structures, and control of spacecraft and flexible structures. The interaction of flexibility and control. Impact of flexibility of on the performance of military spacecraft and future trends. PREREQUISITES: Graduate AE3830, ME3521, EC2300 or equivalent.

AE4818 ACQUISITION, TRACKING, AND POINTING OF MILITARY SPACECRAFT (3-2).
Acquisition, tracking, and pointing (ATP) requirements for military spacecraft, effects of jitter on ATP performance, jitter control, acquisition system, tracking algorithms, laser beam control, spacecraft attitude control using control moment gyros, example of ATP designs for military spacecraft, laboratory experiments on spacecraft attitude control and laser beam control. PREREQUISITES: AE 3818.

AE4830 SPACECRAFT SYSTEMS I (Intended for curriculum 366.) (3 - 2).
This course emphasizes the systems analysis of geosynchronous spacecraft and covers the analysis of GNC (orbit and attitude control), structures, propulsion, thermal and electrical power subsystems. Basic mathematical equations will be used in the preliminary design of the subsystems and the tradeoff studies involved. The differences and similarities between dual-spin and three-axis stabilized spacecraft will be covered in detail. Systems aspect of a

typical mission profile will be illustrated. Throughout, emphasis will be on the spacecraft bus. Students will be engaged in problem solving during most of the laboratory period. PREREQUISITES: Completion of Space Operations core-curriculum.

AE4831 SPACECRAFT SYSTEMS II (Intended for curriculum 366.) (3 - 2).
In this course, students will be involved in a group project to design a spacecraft to meet mission requirements. Material presented in AE4830 as well as AE4831 will be utilized. In parallel, this course covers some or all of the following aspects of spacecraft systems: spacecraft testing, TT&C subsystem, and design of observation payloads. Differences and similarities between geosynchronous spacecraft and LEO/HEO spacecraft will be discussed. Topics include gravitational perturbation (J2 effects), gravity-gradient stabilization and atmospheric drag effects. PREREQUISITE: AE4830.

AE4850 ASTRODYNAMIC OPTIMIZATION (3 - 2).
This course develops basic measures of performance of a space vehicle (including launch vehicles) with methods to target a set of conditions and optimize the performance. Topics include an overview of the Guidance, Navigation and Control System, fundamentals of nonlinear programming, state-space formulation, vehicle and environmental models, performance measures, problem of Bolza, the Maximum Principle, and transversality conditions. A significant focus of the course will be in practical methods and numerical techniques, particularly pseudospectral methods. Computational methods will be used to solve a wide range of problems in astrodynamic optimization arising in military space such as rapid spacecraft reorientation and targeting problems, launch-on-demand, strategic low-thrust orbital maneuvers and optimal formation-keeping strategies. Where appropriate, the course will illustrate systems aspects of mission design. PREREQUISITES: MA2121, SS2500, AE3815.

AE4860 MILITARY SPACE MANEUVERS (2 - 2).
This course develops the fundamentals of tactical and strategic space maneuvers and addresses the issues pertaining to space warfare. The course covers a wide range of specific military maneuvers that include their mathematical modeling, mission definitions, mission design and optimization. Special attention will be paid to the class of following maneuvers: pursuit-evasion problems, orbital intercept, destructive and nondestructive asset denial problems, rapid retargeting and minimum-time space maneuvers. These maneuvers and certain elements of high-speed velocity guidance will be modeled, simulated, optimized and analyzed as part of the laboratory sessions. Students will also gain practical experience in a state-of-the-art software t analyze the implementation of future military space maneuvers. Additional details pertaining to the course are classified. PREREQUISITES: MA2121, SS2500, AE3815. CLASSIFICATION: SECRET/NOFORN.

AE4870 SPACECRAFT DESIGN AND INTEGRATION I (4 - 0).
Principles of spacecraft design considerations, spacecraft configurations, design of spacecraft subsystems, interdependency of designs of spacecraft subsystems, launch vehicles, mass power estimation, and trade-offs between performance, cost, and reliability. The emphasis is on military geosynchronous communications satellites. The course includes an individual design project. PREREQUISITES: AE2820, AE3804, AE3851, AE3818, EC3230, PH2511.

AE4871 SPACECRAFT DESIGN AND INTEGRATION II (2 - 4).
A team project oriented course on design of non-geosynchronous spacecraft systems. Provides understanding of the principles of space system design, integration, and systems engineering, and their application to an overall spacecraft mission. Considerations are given to cost, performance, and test plan. Several DOD/NASA organizations, such as Naval Research Laboratory and Jet Propulsion Laboratory, provide support in the definition of the mission requirements for the project, spacecraft design, and design reviews. PREREQUISITE: AE4870.

AE4902 ADVANCED STUDY IN ASTRONAUTICAL ENGINEERING (Variable hours 1-0 to 5-0.) (V - 0).
Directed advanced study in Astronautical Engineering on a subject of mutual interest to student and staff member after most of a student’s electives have already been taken. May be repeated for credit with a different topic. PREREQUISITE: Permission of Department Chairman. Graded on Pass/Fail basis only.

ME0810 THESIS RESEARCH (0 - 8).
Every student conducting thesis research will enroll in this course.

ME0951 SEMINARS (NO CREDIT) (0 - 1).
Lectures on subjects of current interest are presented by NPS faculty and invited experts from other universities and government or industrial activities.

ME0952 SPECIAL TOPICS IN MECHANICAL ENGINEERING (1 - 0).
This course provides students with essential computer knowledge and topics of current research interest in mechanical engineering and materials science. PREREQUISITES: None. This is a Pass/Fail course required to all students in the curriculum.

ME1000 PREPARATION FOR PROFESSIONAL ENGINEERS REGISTRATION (3 - 0).
The course will cover the topics from the 8-hour Professional Examination given by the State of California for Professional Engineer. Discussion will involve applicable engineering techniques, including design and analysis of mechanical systems and components. PREREQUISITES: Prior passage of EIT Exam or consent of instructor. Graded on Pass/Fail basis only.

ME2101 ENGINEERING THERMODYNAMICS (4 - 2).
A comprehensive coverage of the fundamental concepts of classical thermodynamics, with insight toward microscopic phenomena. The laws of thermodynamics. Equations of state. Thermodynamic properties of substances. Entropy, irreversibility and availability. Cycle analysis, gas-vapor mixtures, combustion. PREREQUISITE: MA1115.

ME2201 INTRODUCTION TO FLUID MECHANICS (3 - 2).
Properties of fluids, hydrostatics and stability of floating and submerged bodies. Fluid flow concepts and basic equations in steady flows: mass, momentum, and energy considerations. Dimensional analysis and dynamic similitude. Viscous effects and fluid resistance. Drag and separated flow over simple bluff bodies. PREREQUISITE: ME2503.

ME2503 ENGINEERING STATICS AND DYNAMICS (5 - 0).
Forces and moments, equilibrium equations, statically indeterminate objects, trusses, methods of joints and sections, centroids, composites, rectilinear and plane curvilinear motion, absolute and relative motion, work and energy, virtual work, impulse and momentum, impact, system of particles, rigid body motion, moving frame, plane motion, fixed-axis rotation. PREREQUISITE: MA1115 (may be concurrent).

ME2601 MECHANICS OF SOLIDS I (4 - 1).
Stress-strain. Plane stress and plane strain, principal stresses, maximum shear stress, thermal stress, Mohr's circle, axial loading, indeterminate members, pressure vessels, elastic torsion, indeterminate torsion, shear moment diagram, elastic bending, beam deflection, combined loading, theory of failure. Supporting laboratory work. PREREQUISITES: ME2503 and MA1115 or equivalent.

ME2801 INTRODUCTION TO ENGINEERING SYSTEM DYNAMICS (3 - 2).
Generalized system modeling principles and reduction to mathematical forms. Analogies between electrical, mechanical, fluid, and thermal systems. Response of first and second order systems, characteristics, transient response. Introduction to feedback. PREREQUISITES: ME2503 and MA2121.

ME3150 HEAT TRANSFER (4 - 1).
Introduction to the various modes of heat transfer and their engineering applications. Steady and unsteady conduction involving the use of thermal circuit analogs, analytical, and numerical techniques. Introduction to conservation of mass, momentum and energy. External and internal forced convection fundamentals and correlation. External natural convection. Boiling. Condensation. Heat exchanger analysis and design including a design project. Thermal radiation. PREREQUISITES: ME2101, ME2201, MA3132 (may be taken concurrently).

ME3201 APPLIED FLUID MECHANICS (4 - 1).
Steady one-dimensional compressible flow. Fundamentals of ideal-fluid flow, potential function, stream function. Analysis of viscous flows, velocity distribution in laminar and turbulent flows, introduction to the elements of the Navier-Stokes equations, solution of classical viscious laminar flow problems. Applications to Naval Engineering. PREREQUISITES: ME2101, ME2201, MA3132 (may be taken concurrently).

ME3205 MISSILE AERODYNAMICS (4-1).
Potential flow, thin-airfoil and finite wing theories. Linearized equations, Ackeret theory, Prandtl-Glauert transformations for subsonic and supersonic wings. Planform effects. Flow about slender bodies of revolution, viscous crossflow theory. PREREQUISITE: ME3201.

ME3240 MARINE POWER AND PROPULSION (4 - 2).
This course provides an introduction to the basic principles of power and propulsion systems, with an emphasis on performance of platforms and weapons for naval applications. The laws of thermodynamics and fluid mechanics are applied to analyze and design of components and systems. The thermodynamics of simple gas and vapor cycles are

presented, including the Otto, Diesel, Brayton and Ranking cycles, and complex and combined cycles with intercooling, reheat, regeneration and combined cycles. The aerothermodynamics of compressors, combustors, turbines, heat exchangers, inlets and nozzles are presented along with preliminary design methods, such as meanline design of turbomachinery. Component matching and engine operation of simple gas generators is treated. Mechanical and structural design aspects of engine development are presented. Propeller characteristics and propulsion/vehicle integration are presented. This course includes laboratories on gas turbines, diesels and turbomachinery. PREREQUISITES: ME2101, ME3201, ME3521, (ME3201 and ME3521 may be taken concurrently).

ME3410 MECHANICAL ENGINEERING INSTRUMENTATION AND MEASUREMENT LAB (2 - 4).
Introduction to measurement systems, statistical analysis of data, error analysis, uncertainty analysis, manipulation of data including electrical readout and processing, data acquisition fundamentals and Fourier decomposition and dynamic signals. Measurements of temperature, pressure , velocity, flow rates. Energy balances, surface temperature visualization, flow visualization. Measurement of motion using accelerometers and encoders. Measurement of strain and force. Operational amplifiers, analog computers, filters. PREREQUISITES: ME2601, ME2801, ME3150, ME3521 (ME3150 and ME3521 may be taken concurrently).

ME3440 ENGINEERING ANALYSIS (4 - 0).
Rigorous formulation of engineering problems arising in a variety of disciplines. Approximate methods of solution. Finite difference methods. Introduction to finite element methods. PREREQUISITES: ME2201, ME2503, and ME2601.

ME3450 COMPUTATIONAL METHODS IN MECHANICAL ENGINEERING (3 - 2).
The course introduces students to the basic methods of numerical modeling for typical physical problems encountered in solid mechanics and the thermal/fluid sciences. Problems that can be solved analytically will be chosen initially and solutions will be obtained by appropriate discrete methods. Basic concepts in numerical methods, such as convergence, stability and accuracy, will be introduced. Various computational tools will then be applied to more complex problems, with emphasis on finite element and finite difference methods, finite volume techniques, boundary element methods and gridless Lagrangian methods. Methods of modeling convective non-linearities, such as upwind differencing and the Simpler method, will be introduced. Discussion and structural mechanics, internal and external fluid flows, and conduction and convection heat transfer. Steady state, transient and eigenvalue problems will be addressed. PREREQUISITES: ME3150, ME3201, ME3601.

ME3521 MECHANICAL VIBRATION (3 - 2).
Elements of analytical dynamics, free and forced response of single degree and multi-degree of freedom systems. Dynamic response using modal superposition method. Properties of stiffness and inertia matrices, orthogonality of modal vectors, eigenvalue problem, modal truncation, vibration isolation and suppression. Vibration of bars, shafts, and beams. Supporting laboratory work. PREREQUISITES: ME2503, ME2601; MA2121 or equivalent (may be taken concurrently)

ME3611 MECHANICS OF SOLIDS II (4 - 0).
Differential equations of bars, shafts and beams with Macauley functions. Unsymmetric bending. Curved beams. Shear flow in thin walled sections. Shear center. Torsion of thin walled open sections. Thick walled cylinders. Energy including Castigliano and unit dummy load methods for displacements. Statically indeterminate systems including beams, frames, trusses, arches and combined structures. PREREQUISITE: ME2601.

ME3711 DESIGN OF MACHINE ELEMENTS (4 - 1).
Design of representative machine elements with consideration given to materials selection, tolerances, stress concentrations, fatigue, factors of safety, reliability, and maintainability. Typical elements to be designed include fasteners, columns, shafts, journal bearings, spur and helical gears, and clutches and brakes. In addition to traditional design using factors of safety against failure, particular emphasis is placed on design for specified reliability using probabilistic design methods. PREREQUISITE: ME2601.

ME3712 CAPSTONE DESIGN (1 - 6).
Design teams apply integrated ad systematic design processes to real multifunctional and multidisciplinary problems in mechanical systems. Students develop process concepts, planning, design methodology, material selection, manufacturing and engineering analysis. Capstone design projects include projects provided by industry partners as well as DoD sponsors. The scope of design problems range across both engineering and non-engineering issues in the integrated design process. PREREQUISITES: ME2801, ME3150, ME3201, ME3450, ME3521, ME3711, MS3202, OS3104.

ME3750 PLATFORM SURVIVABILITY (4-0).
This course introduces the concepts and analytical tools used in designing and testing survivable combat platforms and weapon systems. The applications are to a broad range of platforms and weapons, including submarines, surface ships, fixed and rotary wing aircraft, cruise missiles, and satellites in a hostile (non-nuclear) environment. The technology for increasing survivability and the methodology for assessing the probability of survival hostile environments are presented. Topics covered include: current and future threat descriptions; the mission/threat analysis; combat analysis of SEA, vulnerability reduction technology for the major systems and subsystems; susceptibility reduction concepts, including stealth; vulnerability, susceptibility, and survivability assessment; and trade-off methodology. PREREQUISITES: None.

ME3780 INTRODUCTION TO MICRO ELECTRO MECHANICAL SYSTEMS DESIGN (3 - 3).
This is a class introducing students to Micro Electro Mechanical Systems (MEMS). Topics include material considerations for MEMS and microfabrication fundamentals; Surface, bulk and non-silicon micromachining; Forces and transduction; forces in micro- nano- domains and actuation techniques. Case studies of MEMS based microsensor, microactuator and microfluidic devices will be discussed. The laboratory work includes computer aided design (CAD) of MEMS devices and group design projects. PREREQUISITES: EC2200, or MS2201 or PH1322 or consent of instructor.

ME3801 CLASSICAL CONTROL OF NAVAL ENGINEERING SYSTEMS (3 - 2).
Classical control design for linear systems with single-input, single-output design requirements. Transient response analysis, steady state error analysis. Routh, root locus and frequency response stability methods. Phase lead/lag and multimode compensation techniques. The course includes a laboratory. PREREQUISITE: ME2801.

ME4101 ADVANCED THERMODYNAMICS (4-0).
This course reviews elementary definitions, concepts and laws of thermodynamics and then extends these to cover general thermodynamics and advanced topics. The concepts of availability, exergy, irreversibility, and general equilibrium conditions in single and multi-component systems are presented. Ideal and non-ideal solutions and chemical potential are treated along with an introduction to statistical thermodynamics and non-equilibrium concepts such as Osager's reciprocal relations. PREREQUISITE: ME2101.

ME4160 APPLICATIONS OF HEAT TRANSFER (4 - 0).
Applications of heat transfer principles to engineering systems. Design topics include heat exchangers (e.g., boilers, condensers, coolers), cooling electronic components, heat pipes, solar collectors, turbine blade cooling. PREREQUISITE: ME3150.

ME4161 CONDUCTION HEAT TRANSFER (4 - 0).
Steady-state heat conduction in multi-dimensions with and without heat sources. Transient conduction. Numerical methods for heat conduction. Mechanical Engineering applications. PREREQUISITE: ME3150.

ME4162 CONVECTION HEAT TRANSFER (4 - 0).
Fundamental principles of forced and free convection. Laminar and turbulent duct flows and external flows. Dimensionless correlations. Heat transfer during phase changes. Heat exchanger analysis with Mechanical Engineering applications. PREREQUISITES: ME3150, ME4220, or consent of instructor.

ME4163 RADIATION HEAT TRANSFER (4 - 0).
Basic laws and definitions. Radiation properties of surfaces. Radiant interchange among diffusely emitting and reflecting surfaces. Applications and solutions of the equations of radiant interchange. Radiant interchange through participating media. Combined conduction and radiation. PREREQUISITE: ME3150.

ME4202 COMPRESSIBLE AND HYPERSONIC FLOW (4 - 0).
One-dimensional, compressible flow is reviewed. Two-dimensional and axis-symmetric supersonic of ideal gases. Oblique shocks and expansion waves. General compressible flow equations. Potential supersonic and conical flows. Compressible scaling and transonic area ruling. Effects of very high velocity and low density. Hypersonic flow. Mach number independence and equivalence principles. Newtonian method. Blunt and slender body solutions. Real gas behavior and effect on shock and boundary layers. Applications are presented to satellite parasitic drag and re-entry flows. PREREQUISITE: ME3201 or consent of instructor.

ME4211 APPLIED HYDRODYNAMICS (4 - 0).
Fundamental principles of hydrodynamics. Brief review of the equations of motion and types of fluid motion. Standard potential flows: source, sink, doublet, and vortex motion. Flow about two-dimensional bodies. Flow about axisymmetric bodies. Added mass of various bodies and the added-mass moment of inertia. Complex variables

approach to flow about two-dimensional bodies. Conformal transformations. Flow about hydro and aerofoils. Special topics such as dynamic response of submerged bodies, hydroelastic oscillations, etc. Course emphasizes the use of various numerical techniques and the relationship between the predictions of hydrodynamics and viscous flow methods. PREREQUISITE: ME3201.

ME4220 VISCOUS FLOW (4 - 0).
Development of continuity and Navier-Stokes equations. Exact solutions of steady and unsteady viscous flow problems. Development of the boundary-layer equations. Similarity variables, numerical and integral techniques. Separation, boundary-layer control. Time-dependent boundary layers. Origin and nature of turbulence, phenomenological theories, calculation of turbulent flows with emphasis on naval engineering applications, and numerical models and CFD. PREREQUISITE: ME3201 and instructor’s permission.

ME4225 COMPUTATIONAL FLUID DYNAMICS AND HEAT TRANSFER (3-2).
This course presents numerical solution of sets, of partial differential equations, that describe fluid flow and heat transfer. The governing equations for fluid dynamics are reviewed and turbulence modeling is introduced. Discretization techniques are applied to selected model equations and numerical methods are developed for inviscid and viscous, compressible and incompressible flows. Individual term projects include application of CFD to thesis research and to current military problems. PREREQUISITES: ME3201 or ME3450.

ME4231 ADVANCED TURBOMACHINERY (3-2).
The underlying principles governing flow through and energy exchange in turbomachines are developed to provide a basis for understanding both design and advanced computational methods. Key considerations and procedures followed in the design of new aircraft engine fans, compressors and turbines are introduced. Lectures are coordinated with experimental test experience at the Turbopropulsion Laboratory. PREREQUISITE: ME3240.

ME4251 ENGINE DESIGN AND INTEGRATION (3-2).
The conceptual and preliminary component, subsystem, and systems design of military, or military related, airbreathing engines along with the integration of the engine in a platform is experienced within student design teams. The course is focused on a team response for a Request-for-Proposal (RFP) for an engine meeting specific requirements. Performance, cost, supportability, deployment, manufacturing, product quality and environmental considerations may be included in the design process. The project draws on all of the mechanical engineering disciplines. PREREQUISITE: ME3240.

ME4240 ADVANCED TOPICS IN FLUID DYNAMICS (4 - 0).
Topics selected in accordance with the current interests of the students and faculty. Examples include fluid-structure interactions, cable strumming, wave forces on structures, free-streamline analysis of jets, wakes, and cavities with emphasis on computational fluid dynamics. PREREQUISITES: ME4220 and ME4211.

ME4420 ADVANCED POWER AND PROPULSION (4 - 0).
This course presents an advanced treatment of power and propulsion topics, primarily for naval applications. Thermodynamic analysis of simple, advanced and complex cycles, such as combined and augmented cycles (e.g. RACER and STIG) are presented along with new and direct energy conversion concepts. Design integration of single and multi-type (CODAG, CODOG, etc.) power and propulsion systems with vehicles. Engine installation considerations, including the design of auxiliary equipment and inlet/exhaust systems, are presented. Design and current research topics in fluid mechanics and rotordynamics of turbomachinery are presented. Repair, condition based maintenance and machinery operation, including balancing techniques, are discussed. PREREQUISITE: ME3240.

ME4522 FINITE ELEMENT METHODS IN STRUCTURAL DYNAMICS (4 - 0).
This course provides an introduction to the principles and methods of computational structural dynamics and vibration analysis. Modern computational methods make use of the matrix structural models provided by finite element analysis. Therefore, this course provides an introduction to dynamic analysis using the finite element method, and introduces concepts and methods in the calculation of modal parameters, dynamic response via mode superposition, frequency response, model reduction, and structural synthesis techniques. Experimental modal identification techniques will be introduced. PREREQUISITES: ME3521.

ME4525 NAVAL SHIP SHOCK DESIGN AND ANALYSIS (4 - 0).
Characteristics of underwater explosion phenomena, including the shock wave, bubble behavior and bubble pulse loading, and bulk cavitation. Surface ship/submarine bodily response to shock loading. Application of shock spectra to component design. Dynamic Design Analysis Method (DDAM) and applications to shipboard equipment design. Fluid-Structure Interaction (FSI) analysis, including Doubly Asymptotic Approximation (DAA) and surface ship FSI. Current design requirements for shipboard equipment. PREREQUISITE: ME3521 or equivalent.

ME4550 RANDOM VIBRATIONS AND SPECTRAL ANALYSIS (3 - 2).
Engineering application of spectral analysis techniques to characterize system responses under a random vibration environment. Characteristics of physical random data and physical system responses. Application of probability concepts to random data and response analysis. Correlation and spectral density functions. Transmission of random vibration. System responses to single/multiple random excitations. Failure due to random vibration. Supporting laboratory work. PREREQUISITE: ME3521 or equivalent.

ME4612 ADVANCED MECHANICS OF SOLIDS (4 - 0).
Selected topics from advanced mechanics of materials and elasticity. Stress and strain tensors. Governing equations such as equations of equilibrium, constitutive equations, kinematic equations and compatibility equations. Two-dimensional elasticity problems in rectangular and polar coordinate systems. Airy stress function and semi-inverse technique. Energy methods with approximate solution techniques including Rayleigh-Ritz method. Buckling of imperfect columns. Introduction to plate and shell bending theory. PREREQUISITE: ME3611.

ME4613 FINITE ELEMENT METHODS (4 - 0).
Introduction to the fundamental concepts of the finite element method. Weighted residual methods and weak formulation. Element discretization concept and shape functions. Generation of element matrices and vectors, and their assembly into the matrix equation. Application of boundary and initial conditions. Isoparametric elements and numerical integration techniques. Computer programming and application to engineering problems such as boundary value, initial value and eigenvalue problems. PREREQUISITES: ME3611; ME3440 or equivalent or consent of the instructor.

ME4620 THEORY OF CONTINUOUS MEDIA (4 - 0).
Tensor analysis. Stress and strain tensors. Motion of continuum. Energy and entropy. Constitutive equations. Applications to elasticity and fluid dynamics. PREREQUISITES: ME3201 and ME3611.

ME4700 WEAPONEERING (3 - 2).
This course is meant to describe and quantify the methods commonly used to predict the probability of successfully attacking ground targets. The initial emphasis will be on air launched weapons. These weapons include guided and unguided bombs, air-to-ground missiles, LGB's, rockets and guns. The course will outline the various methodologies used in operational products used widely in the USN, USAF and Marine Corps. PREREQUISITES: ME2503 or MA2121 or equivalent, ME3410 or OS3104 or equivalent, or consent of the instructor.

ME4702 ENGINEERING SYSTEMS RISK BENEFIT ANALYSIS (3-2).
This course emphasizes three methodologies, Decision Analysis (DA), Reliability and Probabilistic Risk Assessment (RPRA) and Cost-Benefit Analysis (CBA). The course is designed to give students an understanding of how these diverse topics can be applied to decision making process of product design that must take into consideration significant risk. The course will present and interprets a framework for balancing risks and benefits to applicable situations. Typically these involve human safety, potential environmental effects, and large financial and technological uncertainties. Concepts from CBA and RPRA are applied for real world problems resulting in decision models that provide insight and understanding and consequently leading to improved decisions. Same course as OS4010. PREREQUISITES: Course in probability, EO4021 or equivalent, or consent of instructor.

ME4703 MISSILE FLIGHT AND CONTROL (4-1).
Static and dynamic stability and control; transient modes; configuration determinants; subsonic, transonic, supersonic force and moment data for performance calculations with short and long-range cruciform missiles and cruise missiles; acceleration, climb, ceiling, range and agility in maneuvering trajectories. Principles of missile guidance, including guidance control laws, and six degree-of-freedom motion simulations. Additional topics are selected from the following areas to address the general interests of the class: advanced guidance laws, passive sensors, INS guidance, fire control and tracking systems. PREREQUISITE: ME3205 and ME2801 or equivalent.

ME4704 MISSILE DESIGN (3-2).
Conceptual missile design methodology centered around a student team design project, focused on a military need defined by a Request-for-Proposal. It stresses the application aerodynamics, propulsion, flight mechanics, cost, supportability, stability and control and provides the student with their application to design. Consideration is given to trade-offs among propulsion requirements, air loads, quality sensors, guidance laws, quality, controls, and structural components. PREREQUISITE: ME4703 or equivalent.

ME4731 ENGINEERING DESIGN OPTIMIZATION (4 - 0).
Application of automated numerical optimization techniques to design of engineering systems. Algorithms for solution of nonlinear constrained design problems. Familiarization with available design optimization programs. State-of-the-

art applications. Solution of a variety of design problems in mechanical engineering, using numerical optimization techniques. PREREQUISITES: ME2440, ME3150, ME3201, ME3611.

ME4751 COMBAT SURVIVABILITY, RELIABILITY, & SYSTEMS SAFETY ENGINEERING (4/1).
This course provides the student with an understanding of the essential elements in the study of survivability, reliability and systems safety engineering for military platforms including submarines, surface ships, fixed-wing and rotary wing aircraft, as well as missiles, unmanned vehicles and satellites. Technologies for increasing survivability and methodologies for assessing the probability of survival in a hostile (non-nuclear) environment from conventional and directed energy weapons will be presented. Several in-depth studies of the survivability various vehicles will give the student practical knowledge in the design of battle-ready platforms and weapons. An introduction to reliability and system safety engineering examines system and subsystem failure in a non-hostile environment. Safety analyses (hazard analysis, fault-tree analysis, and component redundancy design), safety criteria and life cycle considerations are presented with applications to aircraft maintenance, repair and retirement strategies along with the mathematical foundations of statistical sampling, set theory, probability modeling and probability distribution functions. PREREQUISITES: Consent of Instructor.

ME4801 MARINE NAVIGATION (3 – 2).
Introduction to the general functional and system architecture of a typical marine navigation system. Examples of several inertial sensors are discussed. Introduction to inertial navigation and navigation using external navaids such as LORAN, TACAN and GPS. Brief discussion of GPS. Introduction to Kalman filtering in order to integrate inertial and external sensors. Time permitting more complex mechanizations of inertial systems are discussed. PREREQUISITE: ME 2801 or consent of instructor.

ME4811 MULTIVARIABLE CONTROL OF SHIP SYSTEMS (3 - 2).
Multivariable analysis and control concepts for MIMO systems. State Observers. Disturbances and tracking systems. Linear Optimal Control. The linear Quadratic Gaussian compensator. Introduction to non-linear system analysis. Limit cycle behavior. PREREQUISITE: ME3801.

ME4821 ADVANCED DYNAMICS (3 - 2).
Newtonian mechanics: kinematics and dynamics of three dimensional motion of complex systems using Newton-Euler’s method, analytical mechanics, generalized coordinates, virtual work, Lagrange’s equations, calculus of variations, Hamilton’s principle. PREREQUISITE: ME3521.

ME4822 GUIDANCE NAVIGATION AND CONTROL OF MARINE SYSTEMS (3 – 2).
This course TAKES students through each stage involved in the design, modeling and testing of a guidance, navigation and control (GNC) system. Students are asked to choose a marine system such as an AUV, model its dynamics on nonlinear simulation package such as SIMULINK and then design a GNC system for this system. The design is to be tested on SIMULINK or a similar platform. Course notes and labs cover all the relevant material. PREREQUISITE: ME4801 or consent of instructor.

ME4823 DYNAMICS OF MARINE VEHICLES (4 - 0).
Development of the nonlinear equations of motion in ship-fixed coordinates. Linear forms. Elements of pathkeeping and stability for ships and submersibles. Maneuverability. Motions in waves. Added mass and damping. Statistical description of the seaway. Seakeeping consideration in ship design. PREREQUISITE: ME3201.

ME4825 MARINE PROPULSION CONTROL (3 - 2).
Introduction to dynamic propulsion systems modeling and analysis methods. Control design specifications and design strategies. Introduction to modern control design theory and multivariable methods. Theory and applications of optimal control and discrete-time control systems. Case studies of current Naval propulsion control systems. PREREQUISITES: ME3801, ME3240 (may be taken concurrently), and MA3132.

ME4902 ADVANCED STUDY IN MECHANICAL ENGINEERING (Variable hours 1-0 to 6-0.) (V - 0).
Directed advanced study in Mechanical Engineering on a subject of mutual interest to student and staff member after most of a student’s electives have already been taken. May be repeated for credit with a different topic. PREREQUISITE: Permission of Department Chairman. Graded on Pass/Fail basis only.

MS2201 INTRODUCTION TO MATERIALS SCIENCE AND ENGINEERING (3 - 2).
This is a first course in Materials Science and Engineering and emphasizes the basic principles of microstructure-property relationships in materials of engineering and Naval relevance. Topics include crystalline structure and bonding, defects, thermodynamics and kinetics of reactions in solids, deformation, strengthening mechanisms and heat treatment. Students will acquire a working vocabulary and conceptual understanding necessary for advance

study and for communication with materials experts. PREREQUISITES: Undergraduate courses in calculus, physics and chemistry.

MS3202 PROPERTIES, PERFORMANCE & FAILURE OF ENGINEERING MATERIALS (3 – 2).
The purpose of this course is to advance the students' understanding of the fundamentals of materials science, while putting that understanding in the context of the behavior of materials in engineering applications. Contemporary developments in engineering materials such as composites, ceramics and polymers are considered, as well as traditional engineering alloys such as steels and aluminum alloys. Performance and failure histories of materials in service will be studied, as well as conventional textbook subjects. Examples pertinent to Naval, Aero and Combat Systems Science are emphasized. Topics include mechanical properties, fracture, fatigue, failure analysis and corrosion. PREREQUISITE: MS2201 or equivalent or consent of instructor.

MS3203 STRUCTURAL FAILURE, FRACTURE AND FATIGUE (3-2).
Theories of yield and fracture for aircraft design limit loads and ultimate loads; stress-life and strain-life fatigue theories of crack initiation in aircraft structures subjected to realistic flight load spectra, using Neuber's approximation and incorporating the Miner concept of cumulative damage. Fatigue crack propagation concepts and Navy methods of fleet structural fatigue tracking and monitoring. PREREQUISITE: MS3202.

MS3214 INTERMEDIATE MATERIALS SCIENCE AND ENGINEERING (4 - 0).
The purpose of this course is to provide a bridge between the introductory courses in materials science, MS2201 and MS3202, and the 4000-level elective courses in materials science. The emphasis is on a deepening of understanding of basic principles which govern the behavior of solid materials. Principles of physical metallurgy and the physics of materials will be considered in detail. Topics include thermodynamics of solids, electronic structure of alloys, lattice stability, phase equilibria, diffusion, dislocation theory, deformation mechanisms and an introduction to the kinetics of phase transformations. The course is intended to show how the application of basic principles leads to clearer understanding and control of the behavior and properties of contemporary materials. PREREQUISITES: MS2201 and MS3202 or equivalent or consent of instructor.

MS3304 CORROSION AND MARINE ENVIRONMENTAL DETERIORATION (3 - 2).
The fundamentals of corrosion science and the practice of corrosion engineering are discussed. The objectives include an appreciation of the varied causes, mechanisms and effects of corrosion. Fundamental topics such as basic electrochemistry, polarization and passivity are covered. A primary goal of the course is the development of skill in the recognition and prevention of a wide variety of types of corrosion. Standard methods of corrosion control are discussed, including cathodic protection, coatings, alloy selection and inhibitors. PREREQUISITE: MS2201 or equivalent or consent of instructor.

MS3606 INTRODUCTION TO WELDING AND JOINING METALLURGY (3 - 2).
Welding and joining are presented from the point of view of metallurgy. Topics include the nature and applications of welding and joining processes; the welding thermal cycle; metallurgical effects of the welding thermal cycle; welding and joining of steels, aluminum alloys, stainless steels and heat-resistant alloys. Also, weldment inspection and quality assurance are introduced. PREREQUISITE: MS2201 and MS3202 or consent of the instructor.

MS4215 PHASE TRANSFORMATIONS (3 - 2).
The mechanisms and kinetics of structural changes in solid materials are considered in detail. A wide variety of transformation mechanisms are studied, including solidification, recrystallization, precipitation and martensitic transformation. The basic principles which govern these reactions are developed, including principles of nucleation and growth, diffusion and lattice distortion. The relevance of various transformations to practical heat treatment, thermomechanical processing, and technological advances is discussed. Microstructural recognition and methods of monitoring phase transformations are included. Changes in properties which result from phase transformations are given limited attention. PREREQUISITE: MS3214 or equivalent or consent of instructor.

MS4312 CHARACTERIZATION OF ADVANCED MATERIALS (3 - 2).
This course is structured to provide an insight into the various tools available for advanced physical examination of engineering materials. Topics covered include X-ray diffraction and optical, scanning, transmission and scanning transmission electron microscopies. PREREQUISITE: MS3202 or consent of instructor.

MS4811 MECHANICAL BEHAVIOR OF ENGINEERING MATERIALS (4 - 0).
The response of structural materials to stress is discussed, including elastic and plastic deformation and fracture. Topics include elastic response and the modules of elasticity; plasticity; deformation mechanisms and dislocation theory; strengthening mechanisms; and fatigue and fracture. Application to materials development is also considered. PREREQUISITE: MS3202, and MS3214 or consent of the instructor.

MS4822 THE ENGINEERING AND SCIENCE OF COMPOSITE MATERIALS (4 - 0).
This course focuses on the structure-property correlation in composites utilizing a multi-disciplinary approach, covering the areas of materials science and engineering and solid mechanics. Emphasis is given to the theoretical constitutive behavior at the micro- and macro-levels, as well as on how such behavior can be altered by processing and service variables. The course is divided into three broad parts: (1) Theoretical predictions of composite properties; (2) Materials issues (including processing) complicating accurate performance prediction; and (3) Thermo-mechanical behavior in actual service conditions. PREREQUISITES: ME3611, MS3202 or equivalent.

MS4902 SPECIAL TOPICS IN MATERIALS SCIENCE (Variable 1-0 to 6-0.) (V - 0).
Directed advanced study in materials science on a subject of mutual interest to student and staff member after the student has taken most of his or her electives. May be repeated for credit with a different topic. PREREQUISITE: Permission of Department Chairman. Graded on Pass/Fail basis only.

TS3000 ELECTRICAL POWER ENGINEERING (3 - 2).
An overview of the principles, concepts and trade-offs which form the foundation for shipboard electric power systems. The composition of electrical power systems for present and future Navy vessels is presented. Theory necessary to understand interactions among shipboard electric power system components is discussed. The interactions between the electric power system and the various types of loads is introduced. PREREQUISITE: EC2270.

TS3001 FUNDAMENTAL PRINCIPLES OF NAVAL ARCHITECTURE (3 - 2).
The geometry, hydrostatics and hydrodynamics of monohull and other floating and submerged bodies; Froude similarity; wave and skin friction resistance; powering determination. Longitudinal and transverse stability of floating bodies. Hull girder strength. Introduction to seakeeping and passive survivability principles. PREREQUISITES: ME2201, ME2601 or consent of Instructor.

TS3002 PRINCIPLES OF SHIP DESIGN AND CASE STUDIES (3 - 2).
Systems engineering in the design of complex systems; systems architecture and interface engineering and the Navy design environment. The systems development process, including need identification, requirements, feasibility determination, risk reduction, contract and detailed design. The iterative, multilevel ship design process, with affordability as a fundamental feature; modern ship design and construction methods, systems engineering techniques and tools. Case studies, ship design trends, design exercises and illustrative. PREREQUISITE: TS3001.

TS3003 NAVAL COMBAT SYSTEM ELEMENTS (3 - 2).
This course will cover combat system detection and engagement elements. This includes radar, ESM, active and passive sonar, infrared, warheads, guns, missiles, torpedoes, fire control and countermeasures. The emphasis will be on what the elements contribute to a combat system, their basic principles of operation, their performance limitations, and their interfaces with the rest of the combat system. Details on specific elements and systems will be limited to those needed to illustrate basic principles and interactions affecting systems engineering. PREREQUISITES: ME2503, EC2170 or equivalent or consent of Instructor.

TS4000 NAVAL COMBAT SYSTEM ENGINEERING (3 - 2).
Covers the definition and integration of Naval combat systems. The emphasis will be on how the various detection, engagement, and control elements interact with each other and on how to combine them into an efficient and survivable combat system. Also addressed will be topside arrangements, signature reduction, readiness assessment, embedded training, and support system interfaces. PREREQUISITES: TS3000, TS3003.

TS4001 INTEGRATION OF NAVAL ENGINEERING SYSTEMS (3 - 2).
A system-oriented approach to integrating the principles of Naval Architecture and Marine Engineering in the design of ship subsystems. Lectures and projects exploring engineering design tools and analysis methods to meet specified systems requirements are used. Projects on hull, mechanical and electrical ship systems design are emphasized. The impact of systems design on other systems and subsystems and on the ship, including affordability, military effectiveness and survivability at the whole ship level are considered. PREREQUISITES: TS3000, TS3001, TS3002.

TS4002 SHIP DESIGN INTEGRATION (2 - 4).
The ship-impact of requirements/cost/performance tradeoffs within technical and acquisition constraints. Conversion of broad military requirements to mission-based ship requirements and specific tasks resulting from those requirements. Exploration of alternative methods of satisfying requirements, leading to combat systems (payload) definition. Conduct of feasibility studies to investigate whole-ship alternatives which meet requirements. Selection of a best design approach. Design considerations for unusual ship types and an assessment of future Navy ship and combat systems needs and trends. PREREQUISITES: TS4001 and TS4000.

TS4003 TOTAL SHIP SYSTEMS ENGINEERING (2 – 4).
The design of a Naval vessel as a single engineering system satisfying mission requirements, with emphasis on affordability and survivability. The interaction and interfacing of various subsystems such as hull, propulsion, and combat systems will be explored through a joint ship “preliminary design” project to produce a balanced ship design based on the alternative chosen from feasibility studies conducted in TS4002. Concepts of design optimization within constraints. PREREQUISITE: TS4002