ABET
Self-Study Report

for the

Master of Science in Astronautical Engineering

at

Naval Postgraduate School

Monterey, CA 93940

June 2019

CONFIDENTIAL

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Acronyms

AC	Assessment Criteria
AE	Astronautical Engineering
AFOSR	Air Force Office of Scientific Research
APC	Academic Profile Code
DARPA	Defense Advanced Research Projects Agency
EAC	Engineering Accreditation Commission
EDO	Engineering Duty Officer
EMS	Education Management System
ESR	Educational Skill Requirements
FLTSCOM	Fleet Satellite Communication
GSEAS	Graduate School of Engineering and Applied Sciences
MAE	Mechanical and Aerospace Engineering
ME	Mechanical Engineering
MSAE	Master of Science in Astronautical Engineering
MSME	Master of Science in Mechanical Engineering
MSES	Master of Science in Engineering Science
NAVSEA	Naval Sea Systems Command
NNPS	Naval Nuclear Power School
NPS	Naval Postgraduate School
NSAM	Naval Support Activity Monterey
OPN	Other Procurement, Navy
OPTAR	Operating Funds
PEO	Program Educational Objectives
PO	Program Officer
QPR	Quality Point Rating
SPAWAR	Space and Naval Warfare Systems Command
SSAG	Space Systems Academic Group
SOF	Student Opinion Forms
SME	Subject Matter Expert
TC	Technical Committee
TSSE	Total Ship Systems Engineering
UAV	Unmanned Aerial Vehicle

A. Contact Information

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B. Program History

September 2013 was the last ABET review and successful evaluation of this program.

Significant changes have been made in the way the Department has been structured. Six Technical Committees (TC) were constituted, each headed by a senior faculty member.

The six Technical Committees are;

- Astronautical Engineering; Chair, Professor Marcello Romano
- Thermo/Fluids; Chair, Professor Garth Hobson
- Solids/Structures; Chair, Distinguished Professor Young Kwon
- Controls; Chair, Professor Isaac Kaminer
- Materials; Chair, Professor Claudia Luhrs
- Design/Survivability/Weaponeering; Chairs, Emeritus Professor Morris Driels, Senior Lecturer, Christopher Adams

(While this accreditation is primarily concerned with the Astronautical Engineering TC, courses within this program were assigned to the Thermo/Fluid and Solids/Structures TCs and one Controls course is cross-listed as a ME/AE course.)

Chairs of these TCs constitute the Departmental ABET Committee with assistance from Mr Jarema Didoszak, who compiled the ME Self Study Report for the 2013 review. Mr Alan Scott (Capt, USN retired), now the Director of International Student Programs compiled the 2013 AE Self Study Report. Faculty members within the TCs met regularly to review the courses under their purview to update and confirm their accuracy in description, prerequisites, ABET criteria. From 2014 till 2017 the old a-k ABET outcomes were assessed and then in 2018 the new ABET outcomes 1 thru 7 were mapped for 2000 and 3000 level courses. These were also discussed within the Technical Committees for accuracy and course outlines were added to the overall course assessment. The ongoing assessment of these courses resulted in significant course catalogue changes. These had to be submitted to the Academic Council of the Naval Postgraduate School for their approval via the Dean of the Graduate School for Engineering and Applied Sciences.

Figure 1 below shows the time period over which these reviews were performed and what actions were taken during each quarter. This was accomplished over three years from the beginning of FY16 until the end of FY18 during which all the programs were reviewed twice.

Current Status of Technical Commi3 ee Assessments

Technical Committee	QTR 1	QTR 2	QTR 3	QTR 4	QTR 5	QTR 6
	FY16 Q1	FY16 Q2	FY16 Q3	FY16 Q4	FY17 Q1	FY17 Q2
	FY17 Q3	FY17 Q4	FY18 Q1	FY18 Q2	FY18 Q3	FY18 Q4
Structures / Solids	Dec-15					
	Jun-18					
Fluids / Thermodynamics		Mar-16				
		Jun-18				
Controls / Unmanned Vehicles			Jul-16			
			Sep-18			
Material Science				Mar-17		
				Oct-18		
Weaponeering / Survivability / TSSE					Dec-16	
					Sep-18	
Astronautical Engineering						Oct-17
						Oct-18

	Completed
	In progress
	Overdue
	Scheduled

Last updated: 12/6/2018

Technical Commi3 ee Ac?ons Tracker

Technical Committee	Actions Required	Current Level	Status
Structures / Solids	Course updates	Completed	
Fluids / Thermodynamics	Course updates	Completed	
Controls / Unmanned Vehicles	Course updates	Completed	
Material Science	Course updates	Completed	
Weaponeering / Survivability / TSSE	Course updates	Completed	
Astronautical Engineering	Course Updates	Submitted to AC	

	Completed
	In progress
	Overdue
	Scheduled

Fig. 1, Status of Technical Committee Assessments and Action Tracker

C. Options

The MSAE degree is one of several degree options within the NPS Space Systems Engineering (SSE) curriculum. The SSE (or 591) curriculum requirements encompass not only the requirements for the specified degree of choice, but also additional content necessary to meet Educational Skill Requirements (ESRs) established by Department of the Navy sponsors. The course requirements necessary to meet the 591 curriculum ESRs are in excess of the credit hours required for the MS-AE degree program. Completion of the full 591 curriculum typically takes at least 24 months. Details of the course requirements for the Space Systems Engineering (SSE) curriculum and the MSAE degree program are provided in the Student Program of Study and Educational Goals section of this report.

While there are no specific tracks within the MSAE degree option of the SSE program, each student must demonstrate competence at the advanced level in one of the disciplines of Astronautical Engineering. These disciplines include orbital and attitude mechanics, attitude determination and control, guidance and control, space structures and materials, rocket propulsion, space environment and spacecraft design. Demonstration of competence at the advanced level is typically accomplished by completing at least eight-quarter hours of 4000 level credits by courses in the MAE department in the particular discipline area and a thesis in the same area.

D. Program Delivery Modes

The primary delivery method used is mostly the traditional resident style of lectures and laboratories led by the course instructor. These instructional sessions are primarily held on site at the Naval Postgraduate School in Monterey, CA, which includes the “Annex Labs” situated on the golf course adjacent to the main campus of the school. Typical course offerings include, 50-minute lectures and/or laboratory sessions. When appropriate, two or more periods may be scheduled as in the case for laboratories. All instruction is conducted during normal business hours, which is generally considered to be from 8 am to 5 pm Monday through Friday. The school follows a quarter system, wherein roughly 10 weeks of scheduled classes are allocated, plus a formal period for finals at the end of each quarter. The actual schedule follows the University of California System that by occasional switching class days, ensures that the same number of lectures days of each day of the week fall in each academic quarter, regardless of the holidays that fall in a given quarter, such as having two Monday holidays in the Winter Quarter for Martin Luther King and Presidents Day.

All courses considered in this accreditation request are delivered in synchronous mode to resident students. Some courses AE3830, AE4850 and AE4881 are delivered in hybrid mode to resident and distance-learning students, currently at Naval Air Warfare Center-China Lake, who have signed up a certificate in Applied Trajectory Optimization.

E. Program Locations

The NPS Astronautical Engineering Program is offered in-residence at the Naval Postgraduate School campus in Monterey, CA.

F. Public Disclosure

https://www.nps.edu/web/mae/msae

G. Deficiencies, Weaknesses or Concerns from Previous Evaluation(s) and the Actions Taken to Address Them

The ABET Program Evaluator in 2013 provided their statements and MSAE did very well with;

- no Deficiencies
- no Weaknesses

Two concerns were however noted;

1. Criterion 4 – Continuous Improvement. While the Evaluator was impressed with our way of assessment and our Annual ABET Reports, he noted that we were not as explicit as we could be on how our eight (8) assessment tools are related to a-k Student Outcomes as required by ABET. This has been addressed by modifications of the Student Outcomes and explicit links to 1-7 in our assessment tool for all the 2000 and 3000 level courses (this was initially done for a-k for all MAE courses). We diligently corrected our course descriptions, syllabi and prerequisites, all of which underwent Academic Council approval as shown in Table 1.

Table 1. List of courses requiring Academic Council Approval

Technical Committee	Course #	Course Name	Change Pre-requisites	Change of Course Descriptions
Astronautical Engineering	AE3811	Space Systems Laboratory	Yes	Substantive
	AE3815	Spacecraft Rotational Mechanics	Yes	Substantive
	AE3818	Spacecraft Attitude, Determination and Control	Yes	Substantive
	AE3830	Spacecraft Guidance and Control	Yes	Substantive
	AE3851	Spacecraft Propulsion	Yes	Minor
	AE4818	Acquisition, Tracking, and Pointing of Military Spacecraft	Yes	Substantive
	AE4820	Robotic Multibody System	Yes	Substantive
	AE4830	Spacecraft Systems I	Yes	No
	AE4850	Astrodynamic Optimization	Yes	Substantive
	AE4860	Space Control (Security Clearance)	Yes	Substantive
Solids/ Structures	ME2601	Mechanics of Solids I	Yes	Minor
	AE2828	Introduction to Spacecraft Structures	Yes	Substantive
	ME2501	Statics	Yes	Substantive
	ME3611	Mechanics of Solids II	No	Substantive
	ME3450	Computational Methods in Mechanical Engineering	Yes	No
	ME3711	Design Of Machine Elements	Yes	No
	ME3712	Capstone Design Project	Yes	No
	ME4550	Random Vibrations and Spectral Analysis	No	Substantive
	ME4613	Finite Element Methods	Yes	No
	ME4731	Engineering Design Optimization	Yes	No
Fluids/ Thermo	AE3804	Thermal Control of Spacecraft	No	Substantive
	AE4452	Advanced Missile Propulsion	Yes	Substantive
	ME2101	Engineering Thermodynamics	No	Substantive
	ME2201	Introduction to Fluid Mechanics	No	Substantive
	ME3150	Heat Transfer	No	Substantive
	ME3240	Marine Power and Propulsion	No	Minor
	ME4101	Advanced Thermodynamics	No	Substantive

Technical Committee	Course #	Course Name	Change Pre-requisites	Change of Course Descriptions
Controls/ Unmanned Systems	AE2440	Introduction to Scientific Programming	No	Minor
	ME3801	Dynamics and Control of Marine and Autonomous Vehicles I	Yes	Minor
	ME4703	Missile Flight and Control	No	Minor
	ME4811	Multivariable Control of Ship Systems	No	Substantive
	ME4823	Cooperative Control of Multiple Marine Autonomous Vehicles	No	Substantive
Materials	MS2201	Introduction to Materials Science and Engineering	Yes	Minor
	MS4312	Characterization of Advanced Materials	No	Minor
	MS4410	Advanced Energy Materials	Yes	Substantive
	MS4811	Mechanical Behavior of Engineering Materials	Yes	No

The list of courses shown in table 1 is the result of all the courses that were reviewed within the department during the FY16/17 cycle based on the old a-k Student Outcomes.

1. Criterion 8. Institutional Support. There was a problem identified with lack of administrative (ASA) and technical support (two technician positions) in the Department as well as issues with contracting and financial reporting. The department has had an ASA continuously throughout the current assessment period. We did loose our Office Assistant (OA) for a period of approximately a year during our year of record 2018. Fortunately our ASA was willing to work overtime on primary OA tasks such as travel during this time and the Dean's office helped when needed. We were able to hire an OA in September 2018.

   During this assessment period we have been able to hire a Supervisory Technician and Electronics Technician, both of which have had a most positive effect on the teaching and research needs within the department.

Internal concerns that were evident at the time of last review that were also corrected are;

Not the whole Department was involved in the most recent ABET review, which was addressed by the establishment of the TC's. Within each of these committees each professor in charge of a course performed the initial assessment of his or her course. This was then brought before the TC for discussion and final adjustment before presenting these quarterly to the whole department at one of our monthly meetings.

Faculty and staff numbers continue to be low – addressed through recent hiring actions, particularly in the Materials Track with the hiring of two tenure track faculty, one non-tenure track faculty member and two National Academies of Sciences, Engineering, Medicine, (NRC) post-doctoral associate.

Upkeep of Department instrumentation was questionable. This has now been corrected by support via a maintenance budget controlled by the Dean of the Graduate School of Engineering and Applies Sciences (GSEAS) office.

GENERAL CRITERIA FOR MASTER'S LEVEL PROGRAMS

STUDENTS AND CURRICULUM

I. Verification of Post-Secondary Education and Professional Experiences

Student Outcomes

1. Graduating students will meet the ABET 1 through 7 outcomes either by previous attainment of an ABET BSAE Degree, or by having the knowledge and skills equivalent to an ABET-accredited BSAE.
2. Graduating students will have a minimum of one (1) year of advanced study beyond the bachelor's level and have advanced level knowledge in Astronautical Engineering as demonstrated by the ability to apply master's level knowledge in one of the available specialized disciplines of Astronautical Engineering.
3. Graduating students will have the ability to apply technical knowledge in a leadership role related to national security.

The Student Outcome requirements set by ABET in (1) – (7), shown below, are inherent in Student Outcome 1, presented above.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

The contents of the 2XXX and 3XXX courses, which are offered in part to meet BSAE equivalency for students that do not already have a BSME from an ABET accredited program, were reviewed and evaluated as to what degree each meets the Student Outcome #1, which incorporates the ABET (1)-(7) criteria. Table 2 summaries by degree the contribution

(strong, moderate, weak or none) how each course helps satisfy this requirement.

Table 2. Relationship of Courses to Student Outcomes

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Outcome 6	Outcome 7
AE2440	S	W	N	W	M	S	M
AE2820	S	S	W	M	N	M	S
AE3804	S	M	S	M	S	S	S
AE3811	M	M	S	S	S	S	S
AE3815	S	N	M	N	M	S	M
AE3818	S	N	S	N	M	S	M
AE3830	M	W	M	W	W	W	S
AE3851	M	W	W	M	N	S	M
ME1000	S	M	W	M	N	N	S
ME2101	S	M	M	W	M	S	S
ME2201	M	W	W	W	W	M	M
ME2501	S	W	M	W	W	S	S
ME2502	S	W	M	W	M	S	S
ME2601	S	M	W	M	N	N	S
ME2801	S	W	N	W	M	S	M
ME3150	S	M	M	M	M	S	S
ME3201	S	S	M	M	M	S	M
ME3205	S	M	M	M	S	M	M
ME3240	S	M	M	S	M	S	M
ME3450	S	W	M	W	W	M	M
ME3521	S	W	W	M	S	S	M
ME3611	S	W	M	W	M	N	S
ME3711	S	W	M	M	W	M	M
ME3712	S	M	S	M	S	M	S
ME3801	S	W	W	M	S	S	M
MS2201	S	M	S	M	S	S	S
MS3202	S	S	S	S	S	S	S
MS3304	S	S	M	M	S	M	S
MS3606	M	S	W	W	M	M	S

Appendix E contains the results of the fillable pdf forms that each of the above courses were assessed with during the review process. These forms show the criteria used to make the above assessment and the order of their priority.

The BSAE equivalency form, which every student is required to complete prior to graduation, documents the courses taken which comprise the equivalent of an ABET accredited BSAE degree. No courses used to populate the BSAE equivalency form may be used towards the MSAE Degree Requirements. The latest revision of the BSAE checklist issued by the program is from Aug 2016. The BSAE checklist had only minor updates and no substantive changes.

An example of the BSAE Checklist is appended in Appendix F

II. Student Program of Study and Educational Goals

Overview

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

Degree Requirements

The Master of Science degree in Astronautical Engineering requires a minimum of 48-quarter hours of graduate level work. The candidate must take courses in an approved study program which address the Program Educational Objectives and 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.

Astronautical Engineering Disciplines

A student seeking the Master of Science degree in Astronautical Engineering must demonstrate knowledge in the following disciplines:

- Orbital and Attitude Mechanics
- Space Environment
- Attitude Determination
- Guidance and Control
- Telecommunications
- Space Structures and Materials
- Spacecraft/Rocket Propulsion
- Spacecraft Systems 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 in a particular area and a thesis in the same discipline area.

More than fifty percent of Astronautical Engineering students are either US Navy Aerospace Engineering Duty Officers (AEDO's) or Engineering Duty Officers (EDO's) who have to satisfy their engineering skill requirements (ESR's) to obtain the necessary P-code. To satisfy this requirement means that all the courses on the matrix below either have to be taken or validated from previous degrees.

(591) Space Systems Engineering Matrix - MS-AE Track URL Matrix w/ Integrated JPME and Refresher (updated Jul 2017)

Qtr	Course	Course	Course	Course	Seminar	Course
1 F	**MA2121** (4-0) Differential Equations	**AE2820** (3-2) Introduction to Spacecraft Structures	**ME2801** (3-2) Control Systems	**JPME - NW3230** (4-0) Strategy & War	**SS4000** (0-1) Seminar	
2 W	**SS3500** (4-2) Orbital Mechanics & Launch Systems	**PH2514** (4-0) Space Environment	**MA3046** (4-1) Matrix Analysis	**JPME - NW3285** (4-0) Theater Security Decision Making	**SS4000** (0-1) Seminar	
3 Sp	**AE3815** (3-2) Spacecraft Rotational Mechanics	**EO2525** (4-1) Analysis of Signals & Comm Systems	**PH3052** (4-0) Remote Sensing	**AE3830** (3-2) Spacecraft Guidance & Control	**SS4000** (0-1) Seminar	
4 Su	**AE3818** (3-2) Spacecraft Attitude Determination & Control	**EO3525** (4-1) Communications Engineering	**SS3051** (4-0) Mil. DoD & Comm Space (S)	**ME3521** (3-2) Mechanical Vibrations	**SS4000** (0-1) Seminar	
5 F	**SS3861** (2-4) Spacecraft Payload Design I	**EC3230** (3-1) Space Power	**AE3804** (3-0) Thermal Control of Spacecraft	**AE4850** (3-2) Astrodynamic Optimization	**SS4000** (0-1) Seminar	
6 W	**SS4861**(2-4) Spacecraft Payload Design II	**SS3001 (4-1)** Military Applications of Nat. Space TS/SCI	**AE3851** (3-2) Spacecraft Propulsion	**AE4818** (3-2) Acquisition, Tracking and Pointing	**SS4000** (0-1) Seminar	
7 Sp	**AE4870** (4-0) Spacecraft Design & Integration I	**AE0810** (0-8) Thesis Research	**SS3101** (3-2) Space Ground Systems	**AE4820** Robotic Multibody Systems	**SS4000** (0-1) Seminar	**AE3811** (2-2) Space Systems Laboratory
8 Su	**AE4871** (2-4) Spacecraft Design & Integration II	**AE0810** (0-8) Thesis Research	**E02701** Cyber Fundamentals (or other)	**JPME - NW3275** (4-0) Joint Maritime Operations - Part 1	**SS4000** (0-1) Seminar	
9 F	**MN3331** (5-1) Principles of Acquisition & Pgm Management	**AE0810** (0-8) Thesis Research	**AE0810** (0-8) Thesis Research	**JPME - NW3276** (2-2) Joint Maritime Operations - Part 2	**SS4000** (0-1) Seminar	

Legend
Preparatory Courses
591 Core
Track/Electives
JPME

Fig. 2, MSAE Generic 9-Quarter matrix

To satisfy all these requirements entails; 8.5 credits of Mathematics at the 1XXX, 2XXX and 3XXX level, 17.5 credits in Electrical Engineering at the 2XXX and 3XXX level, 8 credits in Physics at the 2XXX and 3XXX level, 8 credits at the AE/ME2XXX level, 23 credits at the AE/ME3XXX level, 19 credits at the AE4XXX level as well as the 16 credits for the thesis. This does not include additional non-engineering courses such as Joint Professional Military Education (JPME) courses as well as a Management course MN3331. Hence to satisfy the P-code requirement students have to have taken 56 course credits as shown by the generic course matrix in figure 2. The P-code requirement satisfies the ABET breadth requirement for all AEDO students. In addition all students have to take a full load of four courses per quarter, which is a Secretary of the Navy directive, that means that non-AEDO or unrestricted line officers (URLs) who do not have to satisfy the P-code also get to take additional courses beyond the degree requirement. Some take courses out of Department however, a large percentage take courses within MAE. This too satisfies the ABET breadth requirement.

Navy AEDO's and EDO's, also benefit from a structured mentoring program. Senior engineering duty officers who are routinely invited to present at departmental seminars make themselves available for individual career development counseling sessions with the students.

Thesis Requirements

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, co-advisor or second reader, the Academic Associate, the Program Officer and the Department Chairman must approve the study program and the thesis topic and final dissertation.

III. Evaluating Student Performance

Students enrolled in the NPS MSAE Degree Program are fully funded participants. Thus they are required to attend all class sessions and laboratories unless they have been excused with good cause by the instructor or Program Officer, or in the case of an emergency. Class sizes in the program are small. Generally 6-12 students are enrolled in each graduate course; though some lower level course may have upwards of 24 students. This facilitates the instructor and student interaction and quickly leads to professional relationships in class, which enable the instructor to have a good working knowledge of the individual students' participation and performance through in-class participation, along other direct measures such as homework and quizzes.

The Program Officer is typically a senior military officer who is responsible as the first point of contact in the chain of command for the student, both academically and militarily. Each student's academic progress is closely monitored by the Curriculum Program Officer. The goal is to ensure that the student does not fall behind in class work, research and other aspects of their graduate studies. Faculty members are encouraged to contact the Program Officer directly if a student is not meeting expectation in their class.

Student course matrices as established in coordination with the Academic Associate and Program Officer and are entered and managed in the NPS Python Education Management System (EMS). The student reviews and updates his or her program matrix each quarter in Python with the consent of the above-mentioned advisors. Addition or deletion of any courses in a matrix requires approval of the course instructors as well as those of the Program Officer and Academic Associate. The PO and AA review any changes to ensure that prerequisite and other degree requirements are met. Successful completion of the courses outlined in the course matrix assures that the student meets the Master's Degree requirements in Astronautical Engineering as well as Educational Skill Requirements (ESRs) as defined by program sponsors.

Student performance is evaluated for each course via letter grades, or in some instances, via pass/fail criteria. Additional evaluation opportunities are provided via review of capstone projects and the thesis approval and assessment process. The Academic Associate and Program Officer monitor grades and course completion via the Python EMS. In addition, each student completes checklists to verify completion of course requirements for BSAE degree equivalency and MSAE degree satisfaction. The Academic Associate conducts a review of these checklists to ensure student programs meet all requirements.

Additionally student research progress is tracked by their supervising professor once a thesis topic has been selected and formally approved via the student Thesis Proposal Approval Form. An example of this form is provided in Appendix H. The advisor(s) assess the student's progress through formal thesis review meetings, written updates and/or informal reports as individually set by the faculty advisor.

Each student's mastery of an advanced field in Astronautical Engineering is demonstrated by the successful completion of their thesis, which involves the approval of the Advisor and co-Advisor, if so chosen, a Second Reader and finally the Chair of Department. Additionally all students have to present their research findings during a seminar session which usually is open to faculty and their peers. Occasionally thesis topics that are restricted, such as "no foreign", or classified are presented in restricted environments including the Sensitive Compartmented Information Facility (SCIF). Finally each thesis is evaluated by the student's Advisor and sometimes the Co-Advisor the results of which are given in summary form in figure 3 and in detail in Appendix I for the year of record and the first quarter of the following year. Because of the small class size and single cohort of students who graduate in the Fall (Quarter 1) it was deemed illustrative to include at least two cohorts so as show a variance in the presented data. Included in Appendix I are excerpts from a few faculty comments on their thesis students.

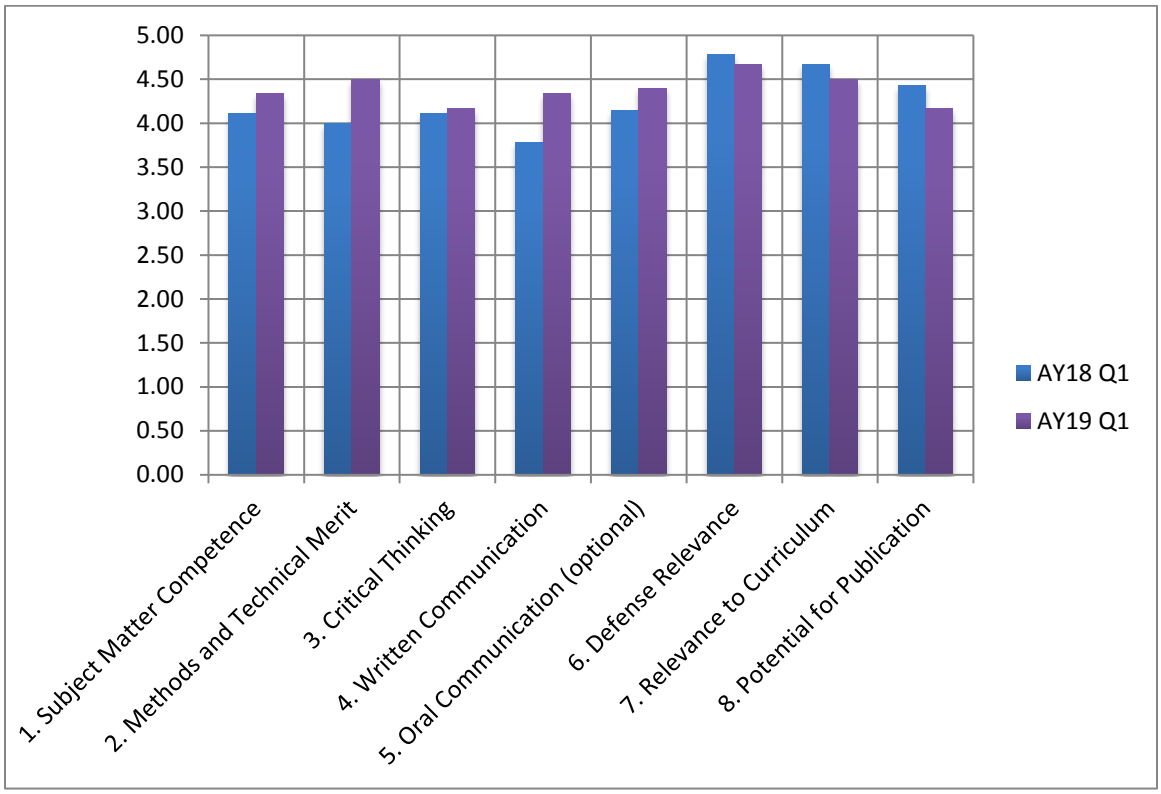

Fig. 3, Summary of thesis evaluations AY 2018 and AY 2019 (both Quarter 1).

In the event that a student fails to maintain a 3.0 QPR after any quarter, he is put on academic probation and given a program plan designed to return the student to acceptable standing. This process is monitored closely by the Program Officer and Academic Associate to ensure course hour management and extra academic and professional activities are tailored to provide the maximum opportunity for recovery. The faculty thesis advisor is also advised of the student's probationary status and included in this corrective process. In cases where the student is not able to recover to a 3.0 QPR, the student may be transferred to program that is less demanding than Astronautical Engineering.

With regard to prerequisite courses, students are required to adhere to the prerequisites or co-requisite courses listed in the NPS course catalog, generally without exception. Initially the Program Officer and Academic Associate review each student's course matrix for program course ordering. Instructors are also able to verify the courses that students have completed and are scheduled to take at NPS via the Python Educational Management System (EMS).

For a limited number of upper level courses, course instructors may have the option to grant acceptance into the course based on the "with permission of the instructor" determination as outlined in the academic catalog description. In these cases the instructor may request additional information from the student concerning their past academic coursework, and assess whether or not the individual has the appropriate educational background acquired in other related coursework to ensure an opportunity for successful attainment of the course objectives. In the rare occasion that the student cannot meet the prerequisite requirements prior to taking the follow-on course, and when necessitated by schedule demands (required for thesis, change in detachment date, etc.) the instructor may permit the student to take the course with exception and concurrence with the Program Officer and Academic Associate and work with the student individually to provide the necessary supplemental reading, exercises and verification of prerequisite knowledge.

In the past where a pattern regarding the inability to successfully meet prerequisite courses was identified by the course instructor, academic associate or program officer, the concern has been raised to the MAE Department Chairman, and then to the faculty at the monthly faculty meetings for discussion and appropriate action as necessary.

IV. Graduation Requirements

As stated in the NPS Academic Catalog, graduation requirements for the Master of Science Degree in Astronautical Engineering are:

> "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 must demonstrate knowledge of space environment, orbital mechanics, attitude determination, guidance and control, telecommunications, space structures, spacecraft/rocket propulsion, space power, spacecraft thermal control, and spacecraft design and testing.
>
> 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 in a particular area and a thesis in the same discipline area. The typical specialization track is in Structures, Dynamics, and Control, and requires two (2) non-design AE48XX courses.
>
> An acceptable thesis for a minimum of 16 credits is also required. The student's thesis advisor, the Academic Associate, the Program Officer, and the Department Chairman must approve the study program and the Thesis Proposal."

The MSAE checklist is used to verify and document that each student has completed all graduation requirements for the program. The Program Officer and Academic Associate review and submit qualified candidate students' packages to the Department Chairman for final approval. The MSAE checklist verifies completion of BSE equivalency, thesis requirement, specialization track requirements, and MSAE Degree Program course credit requirements. A copy of the MSAE checklist is included as Appendix J.

Additionally in order to be eligible for earning the Master's degree, the student must attain a minimum average quality point rating of 3.00 in all of the 3000 and 4000 level courses in his/her curriculum and a 2.75 in all courses of the curriculum.

The following degree options also lead to the attainment of a MSAE degree:

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 MAE Department Chairman. At a minimum, the

approved curriculum must satisfy the requirements stated in the following paragraph.

The Astronautical Engineer degree requires at least 64 quarter-hours of graduate level credits in Mechanical and Aerospace Engineering, 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.

V. Transcripts of Recent Graduates

Transcripts provided for one graduate of the academic year of record (Fall 2018) are shown in figure 4.

The student completed a thesis on the Enhancement of the Science Collection Capability of the Lunar Reconnaissance Orbiter (LRO). By applying optimal control theory to the rapid slew solution of target selection he was able to demonstrate significant time saving at no added cost to scientific data collection of the LRO.

He took six 4000 level courses all before his last two quarters, which were his thesis slots and all of which were applicable to his thesis;

AE/ME4881 Aerospace Trajectory Planning And Guidance (Q3/AY17),
Prerequisites, AE4850 Astrodynamic Optimization (Q1/AY17) or Consent of Instructor
ME4823 Cooperative Control Of Multiple Marine Autonomous Vehicles (Q3/AY17)
Prerequisites, ME3801 Dynamics and Control of Marine and Autonomous Vehicles I,
ME3201 Applied Fluid Mechanics, neither of which he took.
ME4751 Combat Survivability, Reliability and Systems Safety Engineering (Q2/AY17)
Prerequisites, Consent of Instructor
AE4818 Acquisition, Tracking and Pointing of Military Spacecraft (Q2/AY17)
Prerequisites, AE3818 Spacecraft Attitude, Determination and Control (Q1/AY17),
ME3521 Mechanical Vibration (Q4/AY16)
AE4850 Astrodynamic Optimization (Q1/AY17)
Prerequisites, AE3815 Space craft Rotational Mechanics (Q3/AY16)
SS3500 Orbital Mechanics and Launch Systems (Q2/AY16)
ME2121 Differential Equations (Q1/AY16)
AE4820 Robotic Multibody Systems (Q1/AY17)
Prerequisites, AE3818 Spacecraft Attitude Determination and Control (Q1/AY17)

In addition to these 4000 level courses he also took the mandatory design sequence of;

AE4870 Spacecraft Design and Integration I (Q3/AY17)
Prerequisites, AE3851 Spacecraft Propulsion (Q4/AY16)
AE3804 Thermal Control of Spacecraft (Q1/AY17)
AE2820 Intro to Spacecraft Structures (Q1/AY16)
AE4871 Spacecraft Design and Integration II (Q4/AY17)
Prerequisites, AE870 Spacecraft Design and Integration I (Q3/AY17)

[redacted]

Fig. 4, Student A Transcripts

PROGRAM EDUCATIONAL OBJECTIVES AND STUDENT OUTCOMES

I. Program Educational Objectives

https://www.nps.edu/web/mae/msae

Master of Science in Astronautical Engineering Program Educational Objectives

The overall Program Educational Objective of the NPS Astronautical Engineering Program is to support the NPS Mission by producing graduates who have knowledge and technical competence in astronautical engineering at the advanced level and who can apply that knowledge and competence to fill technical leadership roles in support of national security. In order to achieve this goal, the specific objectives are to produce graduates who achieve the following within a few years of graduation:

1. Are established as a valued source of technical expertise in research, design, development, acquisition, integration and testing of national security space (NSS) systems including formulation of operational requirements, plans, policies, architectures, and operational concepts for the development of space systems.
2. Have assumed positions of leadership involving program management, systems engineering, and/or operational employment of space systems within the national security space (NSS) enterprise.
3. Have effectively managed the operation, tasking, and employment of national security space (NSS) systems to increase the combat effectiveness of the Naval Services, other Armed Forces of the U.S. and our partners, to enhance national security.

II. Student Outcomes

https://www.nps.edu/web/mae/msae

1. Graduating students will meet the ABET 1 through 7 outcomes either by previous attainment of an ABET BSAE Degree, or by having the knowledge and skills equivalent to an ABET-accredited BSAE.
2. Graduating students will have a minimum of one (1) year of advanced study beyond the bachelor's level and have advanced level knowledge in Astronautical Engineering as demonstrated by the ability to apply master's level knowledge in one of the available specialized disciplines of Astronautical Engineering.
3. Graduating students will have the ability to apply technical knowledge in a leadership role related to national security.

A student must demonstrate knowledge of space environment, orbital mechanics, attitude determination, guidance and control, telecommunications, space structures, spacecraft/rocket propulsion, space power, spacecraft thermal control, and spacecraft design and testing.

Specific courses included in the NPS MSAE Program, which can be applied to address each of these topics are:

1. Orbital and Attitude Mechanics:
SS3500 Orbital Mechanics and Launch Systems (4-2)
AE3815 Spacecraft Rotational Mechanics (3-2)

2. Space Environment (complete at least one of the following courses):
PH2514 Introduction to the Space Environment (4-0)
EC3230 Space Power and Radiation Effects (3-1)

3. Attitude Determination (complete at least one of the following courses):
AE3818 Spacecraft Attitude, Determination and Control (3-2)

4. Guidance and Control
AE3818 Spacecraft Attitude, Determination and Control (3-2)
AE3830 Spacecraft Guidance and Control (3-2)

5. Telecommunications (complete at least one of the following courses):
EO2525 Probabilistic Analysis of Signals and Communications Systems (4-1)
EO3525 Communications Engineering (4-1)
SS3101 Ground Systems and Mission Operations (3-2)

6. Space Structures and Materials:
AE2820 Introduction to Spacecraft Structures (3-2)

6. Rocket Propulsion:
AE3851 Spacecraft Propulsion (3-2)

In addition, all of these topics are addressed in the capstone design project sequence of courses;

AE4870 Spacecraft Design and Integration I (4-0)
AE4871 Spacecraft Design and Integration II (2-4)

The program ensures that graduates have knowledge in these areas via completion of the BSAE Degree Equivalency Checklist and the MSAE Checklist respectively. Student knowledge is assessed using a combination of homework, exams, laboratory reports and oral and written project reports. In addition students are required to provide a comprehensive oral presentation on their spacecraft capstone design project to external reviewers, including the project sponsor and various Aerospace Corporation, DoD, and space industry representatives. This project presentation along with the accompanying written report provides additional verification that students have acquired knowledge in the specified topic areas.

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 in a particular area and a thesis in the same discipline area. The typical specialization track is in Structures, Dynamics, and Control, and requires two (2) non-design AE48XX courses.

PROGRAM QUALITY

I. Assessment Processes

CONTINUOUS IMPROVEMENT (CRITERION 4)

A variety of specific assessment processes have been established by the MAE Department and SSAG Chairs, the AE Academic Associate, the Space Systems Program Officer and the AE faculty to regularly assess the extent to which the program educational objectives and student outcomes are being attained. Each assessment process is established to measure specific PEOs and Student Outcomes. The results of the various assessment processes are subsequently evaluated individually and in total via the curriculum / program review process.
The specific processes used to assess and evaluate the Program Educational Objectives and Student Outcomes are listed below. The frequency with which these processes are carried out and the expected level of attainment for each of the Program Educational Objectives and Student Outcomes are provided in Table 3.

Assessment and Evaluation Processes

1. **BSAE Degree Equivalency Checklist**: All students will complete the BSAE degree equivalency checklist and the completed checklist must be evaluated and approved by the Academic Associate and MAE Department Chairman prior to graduation.

2. **MSAE Degree Checklist**: All students will complete the MSAE degree checklist and the completed checklist must be evaluated and approved by the Academic Associate and MAE Department Chairman prior to graduation.

3. **Thesis Assessment and Evaluation**: All MSAE degree recipients will complete a thesis and associated thesis presentation. Theses and associated presentations will be assessed and evaluated using the thesis evaluation. In addition, the MAE Department Chairman will review each thesis to ensure demonstration of applicable Program Educational Objectives and Student Outcomes. Final approval of the thesis will be reflected on the thesis signature page and thesis distribution form.

4. **Student Design Project Reviews**: External and internal reviews of the student design project completed in AE4871 (Spacecraft Design and Integration II) have been conducted and feedback has been obtained from review participants. The feedback has been evaluated by the Program Officer, Academic Associate and Department Chair.

5. **Student Opinion Forms (SOFs) and Exit Survey**: Students have completed Student Opinion Forms (SOFs) for each course as well as a graduating student exit survey. Data collected by these tools have been evaluated by the Program Officer, Academic Associate and Department Chair.

6. **ESR Assessment and Evaluation**: Faculty and sponsor / SME representatives will evaluate applicability of Educational Skill Requirements and program content to meet those ESRs. This assessment and evaluation will determine / verify the level of expertise required by AE program graduates to perform job responsibilities. In addition, this process will assess and evaluate the level of expertise provided by the NPS MSAE Program.

7. **Program Sponsor / SME Assessment and Evaluation**: The program sponsor and SMEs will conduct an independent evaluation of the program based on the previously listed assessment processes as well as any other assessment processes they elect to perform. This evaluation will be completed as part of the biennial curriculum review process.

Table 3. AE Program Educational Objectives and Student Outcomes - Assessment and Evaluation Processes

Assessment / Evaluation Process Attribute **Assessment and Evaluation Process**	**Method of Assessment / Evaluation**	**Frequency of Assessment / Evaluation**	**Expected Level of Attainment**	**Date of Last Assessment / Evaluation**	**Level Attained**
1. BSAE Degree Equivalency Checklist	**Checklist**	**All Students**	**100%**	**Continual**	**100%**
2. MSAE Degree Checklist	**Checklist**	**All Students**	**100%**	**Continual**	**100%**
3. Thesis Assessment and Evaluation	**Form**	**All Students**	**4.0 Average (Each category)**	**Continual**	**100%**
4. Student Design Project Reviews	**Form**	**All Students**	**TBD**	**Sep 2018**	**TBD**
5. SOFs and Exit Surveys	**Survey**	**All Students**	**TBD**	**Continual**	**TBD**
6. ESR / POE Assessment and Evaluation	**Survey**	**Biennial**	**100%**	**June 2018**	**100%**
7. Program Sponsor Assessment and Evaluation	**Review**	**Biennial**	**Program Approval**	**June 2018**	**Program Approval**

The various assessment and evaluation processes are executed on a recurring basis to support the biennial curriculum review process. As a result of this review process the sponsor may identify specific revisions to Program Educational Objectives, Student Outcomes, ESRs and specific curriculum content as well as other action items along with deadlines for completion of the mandated actions. The final outcome of each review is approval of the objectives, outcomes, ESRs and other detailed requirements / actions by the Program Sponsors and SMEs. The most recent example of this is the June 2018 Curriculum review as summarized in Appendix O. This was one of the most extensive reviews in recent memory as attested by the list of participants that included Rear Admiral Fritzemeier, Vice Admiral Gilday, six US Navy Captains, four US Navy Commanders, and one each a US Army Lieutenant Colonel and US Marine Corp Major as well as five subject matter experts from the Program Executive Office Space.

As a note, there are several assessment and evaluation processes for which the expected and actual levels of attainment are qualitative. In preparation for this accreditation review, it was determined that quantitative measures need to be established for these processes. In addition, several of the processes need to be better aligned with student outcomes. Details regarding planned modifications to these processes are provided in the following sections.

A. Program Educational Objectives

The Astronautical Engineering Student Outcomes are designed to prepare graduates to attain the Program Educational Objectives. Accordingly, attainment of the PEOs is primarily ensured by verifying attainment of the Student Outcomes. Detailed analysis of the assessment, evaluation and attainment of Student Outcomes, which thereby substantiates attainment of the PEOs is provided in the following section of this report.

In addition to providing verification of student outcome attainment, Assessment and Evaluation by the Curriculum Sponsor and Subject Matter Experts (SMEs) specifically addresses the Program Educational Objectives. Consequently, details regarding Assessment and Evaluation Process are provided in the following paragraphs.

Assessment and Evaluation Process by Sponsors and SMEs was established to ensure attainment of all Program Educational Objectives as well as a number of Student Outcomes. This assessment criterion employs direct feedback from the Program Sponsor/Subject Matter Expert (SME), Commander, SPAWAR Space Field Activity (SSFA). The Commander, SSFA is a Navy Admiral who manages all Navy space system research, development and acquisition programs. Consequently, he or she oversees most graduating officers from the NPS Astronautical Engineering Program who are engaged in engineering, technical management and operational support positions within National Security Space programs. In this role, he or she along with other senior officers and civilian personnel in his/her leadership team are able to directly observe how well graduates from the NPS MSAE Program have been prepared to assume the positions of technical expertise and leadership in the National Security Space (NSS) enterprise they have held since graduating from the Program. In addition, the sponsor/SME and his/her leadership team are able to observe how effectively the graduates manage the operation, tasking and employment of NSS Systems when those skills are applicable to the graduate’s subsequent assignment.

The Commander, SSFA participates directly in the biennial Astronautical Engineering Program Reviews. Throughout the preparation process for the formal review, the Sponsor/SME is able to provide feedback on any concerns developed since the preceding review. In addition, the actual review itself provides a formal venue to discuss any concerns the Sponsor/SME might have regarding preparation of MSAE Program graduates to meet the demands of the highly technical positions to which they are assigned in space systems program offices (SPOs) and operational support offices within the national security space environment. The review addresses the Program Educational Objectives, student outcomes/ESRs, course matrix, the breadth and depth of the course material and how well the material meets needs for knowledge in advanced topics and specialized disciplines. Other issues addressed include the need/desirability of covering additional topics or replacing some courses by others to stay within the students' time constraints and workloads, the nature and quality of the faculty/student research projects, the nature and extent of faculty/student interactions with sponsoring organizations and other Navy/DoD laboratories and contractors, the nature and extent of the Department's seminar program and other interactions between the sponsors, SMEs and the Department. During the review process, the sponsors also meet with the students to obtain their input on current curriculum quality and suggestions for improvements.

The program review process provides the Sponsor/SME with a significant opportunity to provide feedback on his/her assessment of how well graduates from the NPS MSAE Program have been prepared to assume positions of technical expertise and leadership in the National Security Space (NSS) Enterprise. As a result of the review process the sponsor may identify specific action items and deadlines for completion of the mandated actions. The final outcome of the review is approval of the Program Educational Objectives, Student Outcomes and detailed requirements by the Program Sponsor/SME and verification that desired objectives and outcomes are being met. The last review of the Astronautical Engineering Program was conducted in June, 2018 with results as documented in Appendix O.

In addition to the formal review process, the program receives informal feedback on the performance of our graduates on a regular basis from the Sponsor/SME and other mid to senior level NSS officials. Many graduates of the NPS Astronautical Engineering Program receive follow-on assignments to technical and leadership positions in Space Systems Program Offices within the national security space environment. NPS Astronautical Engineering graduates are always highly sought after to fill assignments in the NSS arena and a number have been selected for senior level positions as Major Program Managers for DoD space programs such as the Mobile User Objective System (MUOS) and classified programs at the National Reconnaissance Office (NRO). These officers regularly visit the program to present seminar lectures and participate in capstone project design reviews. During these visits, the senior-level officers are provided the opportunity to provide feedback regarding the performance of NPS MSAE graduates in their Program Offices.

B. Student Outcomes

The specific processes used to address each Student Outcome are identified in Table 3. Details regarding the assessment and evaluation processes employed for each student outcome are provided in the following paragraphs.

1. Student Outcome 1: ABET - Accredited BSAE Equivalency

As indicated in Table 3, Student Outcome 1: *Graduating students will have knowledge and skills equivalent to an ABET-accredited BSAE*, is assessed and evaluated via Assessment and Evaluation Process 1. In order to assess the outcome, a form called the BSAE Degree Equivalency Checklist was devised and has been used to guide each student's educational progress. This form, shown in Appendix F, is prepared by each student with assistance from the Academic Associate (a faculty member who guides students to meet the degree requirements). It is then reviewed and approved by the Academic Associate and MAE Department Chair and completion is verified by the Program Officer.

The form first identifies whether a new student has an ABET-accredited BSAE degree from his or her undergraduate degree. The student is required to identify the BS degree major, the institution, and whether or not the program was ABET accredited. If the student has not earned an ABET-accredited BSAE degree, the form then requires the student to list courses taken under the various categories required for ABET BSAE certification.

The BSAE Degree Equivalency form contains three sections. The first section verifies the Mathematics and Basic Sciences requirements. This section requires a minimum of 32 semester credit hours (or 48 quarter credit hours) of college level mathematics and basic sciences in accordance with ABET accreditation criteria. In addition to verifying the total mathematics credit hours completed, the form also verifies completion of individual topic courses like Multivariable Calculus, Differential Equations, Linear Algebra, and Statistics as stated in the ABET Curriculum Description. Per ABET accreditation criteria, basic sciences include biological, chemical, and physical sciences.

The second section verifies completion of engineering topics, consisting of engineering sciences and engineering design. In accordance with ABET accreditation criteria, a minimum of 48 semester credit hours (or 72 quarter credit hours) is required in engineering sciences and engineering design. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. Engineering design is the process of devising a system, component, or process to meet desired needs.

The third section of the BSAE Degree Equivalency form verifies completion of the general education component of the curriculum. General education includes humanity and other non-engineering courses, which complement the technical content of the curriculum. A minimum of 32 semester credit hours (or 48 quarter credit hours) of general education courses are required.

Approved BSAE Degree Equivalency forms for past graduates have been archived by the department on a SharePoint site. As all students are required to verify BSAE degree equivalency by completing the BSAE Degree Equivalency form, the expected level of attainment for this student outcome is 100%. The Academic Associate tracks completion of these forms to ensure the actual level of attainment is 100%.

2. Student Outcome 2 - Advanced Level Knowledge in Astronautical Engineering

As shown in Table 3, Student Outcome 2: *Graduating students will have advanced level knowledge in Astronautical Engineering as demonstrated by the ability to apply masters level knowledge in one of the available specialized disciplines of Astronautical Engineering*, is assessed and evaluated via Assessment and Evaluation Processes 2 and 3.

A. Assessment and Evaluation Process 2 was created to verify MAE Department requirements have been met for the MSAE degree, including the requirement for advanced level knowledge in Astronautical Engineering. To accomplish this process, the MSAE Degree Checklist form is completed by each student and reviewed by the student and Academic Associate. The form, shown in Appendix J, is then approved by the Academic Associate and MAE Department Chair and completion is verified by the Program Officer.

The MSAE Degree Checklist form verifies completion of the overall credit requirements for the MSAE degree, which have been established by NPS. To earn the MSAE Degree, the student must complete at least 32-quarter hours of graduate level credits. At least 12-quarter hours must be at the 4000 level and at least 24 quarter hours must be in courses offered by the Mechanical and Aerospace Engineering Department. It is also verified that no dual counting of any 3000 or 4000 level courses occurs between the MSAE requirement and the BSAE equivalency requirement.

Verification of the requirement for students to demonstrate competence at the advanced level in one of the disciplines of Astronautical Engineering is also provided by ensuring the student has completed at least eight quarter-hours of the 4000 level credits by courses in that discipline area. Completion of an acceptable thesis for a minimum of 16 credits in the specific discipline area is also verified.

Approved MSAE Degree Checklist forms for past graduates have been archived by the department on a SharePoint site. As all students are required to verify satisfaction of MSAE degree requirements by completing the MSAE Degree Checklist form, the expected level of attainment for this student outcome is 100%. The Academic Associate tracks completion of these forms to ensure the actual level of attainment is 100%.

B. Assessment and Evaluation Process 3 was established to assess and evaluate Student Outcome 2, as well as other outcomes as shown in Table 3. This process is a direct assessment technique which employs the Thesis Evaluation and Rating Form shown in. Each student selects his or her thesis topic after discussion with various faculty members. Once the thesis topic is selected, a thesis proposal form is filled out by the student, and the form is approved by the Thesis Advisor, Academic Associate and MAE Department Chair and completion is verified by the Program Officer.

After completion of their research work, the student writes his or her thesis and presents the findings to students, faculty, and other guests. The final thesis is approved by the Thesis Advisor, Co-Advisor and/or Second Reader and Department Chairman.

Finally, the Thesis Advisor evaluates the student thesis and associated presentation in terms of (1) Subject Matter Competence, (2) Scientific, Technical or Engineering Merit of the Thesis, (3) Critical Thinking (4) Written communication (5) Oral Communication (6) Defense Relevance, (7) Relevance to Curriculum, (8) Publication Type (Academic and/or Practitioner Publication) and (9) Potential for Publication. This evaluation is confidential to the students. At the end of each quarter, the Thesis Evaluation and Rating Forms are collected from all thesis advisors. In order to make sure the form is completed, the faculty approved that the Department Chairman will not sign off each student thesis unless the form is filled out and submitted with the thesis.

Some of the comments by thesis advisors from their evaluations of their students work;

“This thesis satisfies the depth requirement as the work takes the development of an advanced control system concept from theory, through hardware instantiation, and then to practical implementation. This thesis satisfies the breadth requirement in that concepts from space-systems, multi-body dynamics, control and optimization as well as practical laboratory experimentation are used as part of the thesis work.”

“The thesis research included techniques from various subjects including structures, finite element, optics, and controls. Several different software was utilized in the thesis such as Nastran, Sigfit, and Matlab to provide analysis and simulation. This provided students to expose an real-world engineering problem that is relevant to DoD space.”

“We plan to publish his thesis next year.”

3. Student Outcome 3 - Ability To Apply Technical Knowledge In A Leadership Role Related To National Security

As noted earlier Assessment and Evaluation Process by Sponsors and SME’s during biennial curricula reviews was established to ensure attainment of all Program Educational Objectives as well as a number of Student Outcomes. This assessment criterion employs direct feedback from the Program Sponsor/Subject Matter Expert (SME), Commander, SPAWAR Space Field Activity (SSFA). The Commander, SSFA is a Navy Admiral who manages all Navy space system research, development and acquisition programs. Consequently, he or she oversees most graduating officers from the NPS Astronautical Engineering Program who are engaged in engineering, technical management and operational support positions within National Security Space programs. In this role, he or she along with other senior officers and civilian personnel in his/her leadership team are able to directly observe how well graduates from the NPS MSAE Program have been prepared to assume the positions of technical expertise and leadership in the National Security Space (NSS) enterprise they have held since graduating from the Program. In addition, the sponsor/SME and his/her leadership team are able to observe how effectively the graduates manage the operation, tasking and employment of NSS Systems when those skills are applicable to the graduate’s subsequent assignment.

II. Maintenance and Enhancement of the Program

The MAE Department uses detailed "Annual Reports," included as Appendices K-N, as a primary means to assist in the evaluation of assessment data collected throughout the year from various sources. As part of the continuous improvement process, these reports, prepared by the Mechanical Engineering Chair assisted by the "ABET Standing Committee", are used as a key assessment tool in the identification of how well the program is meeting its stated Program Educational Objectives and student outcomes. This report contains direct and indirect measures of program objectives and student outcomes, process reviews and other assessments to aid in continually improving the program leading to the awarding of a MSAE degree at NPS.

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III. Additional Information

The first ever departmental retreat was held on Monday, May 16th 2016, at the Monterey Peninsula Yacht Club. The agenda for the retreat is included as Appendix P. During this event it was enlightening to new and old faculty as to the state of the Department under severe hiring restrictions and fiscal and safety compliance regulations that had been imposed on faculty and staff since the recent Inspector General (IG) inspection report of 2012.

"The NPS of 2016 is no longer the NPS of 2012. It is a highly dedicated, professional team, executing a complex educational mission to provide relevant and unique advanced education and research programs to teach graduate level education with advanced research, increase the combat effectiveness of the naval service, and enhance the security of the United States. It serves an important role as a hub of naval innovation, coordinating with NRL and other graduate level educational institutes, and staying at the forefront of technology."

VADM Herman A. Shelanski, NAVINSGEN 10 May 2016

The morning sessions were devoted to state of the department addresses including curricula statistics as well as the description to faculty how these curricula are presented to and attended by students. The afternoon session was devoted to presentations by professors who have accomplished themselves in various aspects of research funding, execution and reporting. While consensus was not reached on a Mission Statement for the Department, research thrust areas such as energy (renewable), materials, autonomous systems and additive manufacturing were identified as areas that are crucial to the US Navy and hence important to the MAE.

In AY2019 the MAE Department Chair constituted a Strategic Planning committee chaired by Professor Claudia Luhrs (Materials) with members from each Technical committee. The members of this committee being; Distinguished Professor Young Kwon (Solids/Structures), Distinguished Professor Michael Ross (Astronautical Engineering), Associate Professor Brian Bingham (Controls/AUVs), Associate Professor Anthony Gannon (Thermo/Fluids) and Senior Lecturer Christopher Adams (Design, Survivability and TSSE). The charter is to develop a Strategic Plan for the Department for the next five to ten years. The draft plan will be presented to the faculty of the Department at a retreat either late in 2019 or early 2020 for final modification and acceptance. The hope is that this plan will keep the MAE Department relevant to US Navy needs for the next decade.

FACULTY

I. Faculty Qualifications

The qualifications of the faculty, with their educational and experience to teach Master's level courses are show in Table M-1 (page 37). The Department has 30 PhD's out of a total of 37 faculty, the rest having at least a Master of Science in Engineering. Faculty resumes are included in Appendix B.

II. Faculty Workload (*)

Table M-2, Faculty Workload Summary describes this information in terms of workload expectations or requirements and is available on page 40.

III. Faculty Size

The department has 13 tenure track professors out of a total of 37 faculty, 5 technical staff and two administrative staff. During the year of record; 83 sections were taught by the department, 34.5 sections were taught by tenure-track faculty and the rest were taught either by non-tenure track faculty, faculty from other departments or contract teaching. The breakdown of faculty is felt to be adequate, however the one area were the department has not been successful in hiring a faculty member is that of Total Ship Systems Engineering. The breakdown of staff is adequate, however there are times when technical staff are in short supply particularly during crucial theses research activities. Hence it is felt that one more electronics technician which computer and data acquisition skills would alleviate this shortage.

The quality of faculty involvement in interactions with students is excellent as class sizes are small 9.3, with a standard deviation of 4.76. Since MAE does not have any teaching assistants faculty have to grade all the homework assignments, quizzes, tests, laboratory reports and exams of all the students in every course. Hence feedback comes directly from faculty who are intimately involved with all student progress during individual courses.

IV. Professional Development

In the event a faculty member has problems with their teaching based on student feedback the chair instructs that faculty member to attend instructional workshops hosted by the Director of Faculty Development, Ms. Ali Rogers. In the present chairs time three faculty members have benefited enormously from these workshops and have gone on to be of the top instructors within MAE.

Faculty are encouraged and do attend as many technical conferences and symposia as possible. This to present the research work accomplished with students and also to keep current with the latest technological developments with their field of teaching and research.

V. Authority and Responsibility of Faculty

Within each technical committee (TC) as described above, faculty were assigned as members. Each course was assigned a Professor in Charge (PiC), who was responsible for the initial evaluation of the course, its contents as well its contributions to the ABET criteria. Each course was then discussed within the TC wherein a consensus was reached as to these criteria. Once these changes were agreed upon they were then assembled by the chair of the TC and passed on the Chair of the department for his concurrence. On a regular basis course description changes and prerequisites were forwarded to the Dean of GSEAS for his approval before routing to the Academic Council for their final approval. Once approved these changes were effected in the course catalogue.

Table M-1. Faculty Qualifications (*)

Department of Mechanical and Aerospace Engineering

Faculty Name	Highest Degree Earned-Field and Year	Rank	Type of Academic Appointment T, TT, NTT	FT or PT	Years of Experience			Professional Registration/ Certification	Level of Activity H, M, or L		
					Govt./Ind. Practice	Teaching	This Institution		Professional Organizations	Professional Development	Consulting/summer work in industry
Adams, Christopher A.	MS, Aerospace Engineering, 1997	I	NTT	FT	0.0	0.0	10.2	0	1	5	0
Agrawal, Brij N.	PhD, Mechanical Engineering, 1970	P	T	FT	15.0	30.0	30	1	3	21	7
Alley, Erick S.	PhD, Mechanical Engineering, 2009	AST	NTT	PT	13.2	4.5	4.5	1	3	3	0
Biblarz, Oscar	PhD, Mechanical Engineering, 1968	P	T	PT	0.0	45	45	0	0	0	0
Bingham, Brian S.	PhD, Mechanical Engineering, 2003	ASC	T	FT	0.0	14.7	3.0	0	6	10	4
Brophy, Christopher M.	PhD, Mechanical Engineering, 1997	ASC	T	FT	0.0	20	20	0	8	18	2
Chandrasekhara, Muguru M.	PhD, Mechanical Engineering, 1983	P	NTT	FT	6.0	31	31	0	3	10	0
Chaves, Andrew D.	MS, Mechanical Engineering, 2017	O	NTT	PT	0.0	1	1	0	1	2	0
Dausen, David F.	MS, Aeronautical	O	NTT	FT	0.0	5	5	0	0	0	0

	Engineering, 2006										
Didoszak, Jarema M.	MS, Mechanical Engineering, 2003	I	NTT	FT	23.7	8	8	0	6	21	0
Dobrokhodov, Vladimir N.	PhD, Aerospace Engineering Sciences, 1999	ASC	NTT	FT	9.0	17	17	0	2	18	0
Driels, Morris R.	PhD, Mechanical Engineering, 1979	P	T	FT	0.0	31	31	0	3	3	0
Gannon, Anthony J.	PhD, Mechanical Engineering, 2002	AST	TT	FT	0.0	13	13	1	1	14	0
Gordis, Joshua H.	PhD, Mechanical Engineering, 1990	ASC	T	FT	2.5	27	27	0	2	1	0
Greene, Todd R.	MS, Mechanical Engineering, 2007	I		FT	0.0	2	2	0	0	0	0
Hobson, Garth V.	PhD, Aerospace Engineering, 1989	P	T	FT	10.0	30	30	0	2	13	0
Horner, Douglas P.	PhD, Computer Science, 2013	AST	NTT	FT	14.8	10	14	0	2	10	0
Jones, Kevin D.	PhD, Aerospace Engineering, 1993	ASC	NTT	FT	0.6	12	12	0	3	17	0
Kaminer, Isaac I.	PhD, Electrical Engineering, 1992	P	T	FT	8.0	27	27	0	2	24	0
Karpenko, Mark	PhD, Mechanical Engineering, 2004	ASC	NTT	FT	0.0	6	6	0	27	51	0
Kim, Jae-Jun	PhD, Mechanical Engineering, 2004	ASC	NTT	FT	0.0	6	6	0	1	10	0
Kragelund, Sean P.	PhD, Mechanical Engineering, 2016	AST	NTT	FT	7.0	2	2	0	0	14	0
Kwon, Young W.	PhD, Mechanical Engineering, 1985	P	T	FT	3.1	29	29	0	33	78	0
Luhrs, Claudia C.	PhD, Materials Science, 1997	P	T	FT	3.0	13.0	8	0	8	31	0
Marsh, Harleigh	PhD, Applied Mathematics & Statistics, 2017	O	NTT	PT	0.0	1	1	0	0	0	0

Menon, Sarath K.	PhD, Material Science, 1985	P	NTT	FT	22.0	21	21	0	0	17	0
Park, Chanman	PhD, Material Science,	I	NTT	PT	0.0	6	6	0	0	0	0
Rhatigan, Jennifer L.	PhD, Mechanical and Aerospace Engineering, 2001	P		PT	23	7	7	0	0	1	0
Romano, Marcello	PhD, Aerospace Engineering, 2001	P	T	FT	0.0	15	15	0	4	19	0
Ross, Isaac M.	PhD, Aerospace Engineering, 1990	P	T	FT	0.0	29	29	0	5	38	0
Seivwright, Douglas L.	MS, Aeronautical Engineering, 1994	I	NTT	FT	10	6	6	1	0	2	0
Sharma, Ramesh C.	PhD, Physical Metallurgy, 1973	I	NTT	PT	32	6	6	0	0	0	0
Tran, Kimgnoc	PhD, Material Science and Engineering, 2012	A	NTT	PT	20	3	3	0	0	0	0
Wright, Robert G.	MS, Astronautical Engineering, 2018	O	NTT	FT	0.0	1	1	0	0	1	0
Wu, Chun-Hsien	PhD, Material Science and Engineering, 2013	AST	NTT	FT	3.2	2	2	0	0	7	0
Platzer, Maximilian	PhD, Mechanical Engineering, 1964	P	T	PT	6	39	39	0	0	1	0
McNelley, Terry	PhD, Materials Science and Engineering, 1973	P	T	PT	0.0	36	33	0	0	0	0

Table M-2. Faculty Workload Summary (*)

Department of Mechanical and Aerospace Engineering

Faculty Member (name)	PT or FT 1	Classes Taught (Course No./Credit Hrs.) Term and Year2	Program Activity Distribution3			% of Time Devoted to the Program 5
			Teaching	Research or Scholarship	Other[4]	
Adams, Christopher A.	FT	ME 2502, Q4 - SUMMER - AY 2018, "Dynamics", (5) ME 4751, Q4 - SUMMER - AY 2018, "Combat Survivability, Reliability and Systems Safety Engineering", (5) ME 2501, Q3 - SPRING - AY 2018, "Statics", (3) ME 2502, Q2 - WINTER - AY 2018, "Dynamics", (5) ME 4751, Q2 - WINTER - AY 2018, "Combat Survivability, Reliability and Systems Safety Engineering", (5) ME 2501, Q1 - FALL - AY 2018, "Statics", (3)	60%	30%	10%	100%
Agrawal, Brij N.	FT	AE 3811, Q3 - SPRING - AY 2018, "Space Systems Laboratory", (4) AE 3804, Q2 - WINTER - AY 2018, "Thermal Control of Spacecraft", (5) AE 4818, Q2 - WINTER - AY 2018, "Acquisition, Tracking, and Pointing of Military Spacecraft", (5)	40%	50%	10%	100%
Alley, Erick S.	PT	MS 4811, Q4 - SUMMER - AY 2018, "Mechanical Behavior of Engineering Materials", (4) ME 3611, Q3 - SPRING - AY 2018, "Mechanics of Solids II", (4)	30%	70%	0%	100%
Biblarz, Oscar	PT	AE 3851, Q4 - SUMMER - AY 2018, "Spacecraft Propulsion", (5)	10%	0%	0%	10%

Bingham, Brian S.	FT	ME 2801, Q3 - SPRING - AY 2018, "Introduction to Control Systems", (5) ME 4823, Q3 - SPRING - AY 2018, "Cooperative Control of Multiple Marine Autonomous Vehicles", (4) ME 2801, Q1 - FALL - AY 2018, "Introduction to Control Systems", (5)	50%	40%	10%	100%
Brophy, Christopher M.	FT	ME 4704, Q4 - SUMMER - AY 2018, "Missile Design", (5) ME 2101, Q3 - SPRING - AY 2018, "Engineering Thermodynamics", (6) AE 4452, Q1 - FALL - AY 2018, "Advanced Missile Propulsion", (5)	50%	40%	10%	100%
Chandrasekhara, Muguru S.	FT	ME 3201, Q4 - SUMMER - AY 2018, "Applied Fluid Mechanics", (5) ME 4220, Q4 - SUMMER - AY 2018, "Viscous Flow", (4) ME 4162, Q3 - SPRING - AY 2018, "Convection Heat Transfer", (4) ME 4220, Q3 - SPRING - AY 2018, "Viscous Flow", (4) ME 4220, Q2 - WINTER - AY 2018, "Viscous Flow", (4) ME 3201, Q1 - FALL - AY 2018, "Applied Fluid Mechanics", (5) ME 4162, Q1 - FALL - AY 2018, "Convection Heat Transfer", (4) ME 4220, Q1 - FALL - AY 2018, "Viscous Flow", (4)	50%	50%	0%	100%
Chaves, Andrew D.	PT		0%	100%	0%	100%
Crane, William M.	PT		0%	0%	100%	100%
Dausen, David F.	FT	AE 3851, Q4 - SUMMER - AY 2018, "Spacecraft Propulsion", (5) ME 2201, Q4 - SUMMER - AY 2018, "Introduction to Fluid Mechanics", (5)	40%	50%	10%	100%

		ME 2201, Q2 - WINTER - AY 2018, "Introduction to Fluid Mechanics", (5) ME 2101, Q1 - FALL - AY 2018, "Engineering Thermodynamics", (6)				
Didoszak, Jarema M.	FT	TS 3001, Q4 - SUMMER - AY 2018, "Fundamental Principles of Naval Architecture", (5) TS 4002, Q4 - SUMMER - AY 2018, "Ship Design Integration", (6) TS 4003, Q1 - FALL - AY 2018, "Total Ship Systems Engineering", (6)	30%	60%	10%	100%
Dobrokhodov, Vladimir N.	FT	ME 3801, Q4 - SUMMER - AY 2018, "Dynamics and Control of Marine and Autonomous Vehicles I", (5) PC 4015, Q4 - SUMMER - AY 2018, "Advanced Applied Physics Laboratory", (7) ME 4703, Q2 - WINTER - AY 2018, "Missile Flight and Control", (5) PC 4015, Q2 - WINTER - AY 2018, "Advanced Applied Physics Laboratory", (7)	40%	60%	0%	100%
Driels, Morris R.	PT	AE 2440, Q3 - SPRING - AY 2018, "Introduction to Scientific Programming", (5) ME 4700, Q3 - SPRING - AY 2018, "Weaponeering", (5)	20%	0%	0%	20%
Fernandez, Bautista R.	FT		0%	0%	100%	100%
Gannon, Anthony J.	FT	ME 3150, Q4 - SUMMER - AY 2018, "Heat Transfer", (5) ME 4101, Q4 - SUMMER - AY 2018, "Advanced Thermodynamics", (4) ME 3150, Q2 - WINTER - AY 2018, "Heat Transfer", (5) ME 3711, Q2 - WINTER - AY 2018, "Design Of Machine Elements", (5)	50%	40%	10%	100%
Gordis, Joshua H.	FT	ME 4522, Q3 - SPRING - AY 2018, "Finite Element Methods in Structural Dynamics", (4)	60%	20%	20%	100%

		ME 3521, Q2 - WINTER - AY 2018, "Mechanical Vibration", (5) ME 3712, Q1 - FALL - AY 2018, "Capstone Design Project", (7)				
Greene, Todd R.	FT	TS 4000, Q3 - SPRING - AY 2018, "Naval Combat System Engineering", (5)	20%	0%	80%	100%
Hobson, Garth V.	FT	ME 3240, Q4 - SUMMER - AY 2018, "Marine Power and Propulsion", (6) ME 4225, Q4 - SUMMER - AY 2018, "Computational Fluid Dynamics and Heat Transfer", (5) ME 4420, Q4 - SUMMER - AY 2018, "Advanced Power and Propulsion", (4) ME 3450, Q3 - SPRING - AY 2018, "Computational Methods in Mechanical Engineering", (5) ME 0951, Q2 - WINTER - AY 2018, "MAE Seminar (No Credit)", (1) ME 3240, Q2 - WINTER - AY 2018, "Marine Power and Propulsion", (6) ME 4225, Q2 - WINTER - AY 2018, "Computational Fluid Dynamics and Heat Transfer", (5) ME 4225, Q1 - FALL - AY 2018, "Computational Fluid Dynamics and Heat Transfer", (5)	30%	30%	40%	100%
Holmes, Andrea D.	FT		0%	100%	0%	100%
Horner, Douglas P.	FT	ME 3720, Q2 - WINTER - AY 2018, "Introduction to Unmanned Systems", (5)	20%	80%	0%	100%
Jones, Kevin D.	FT	ME 3201, Q3 - SPRING - AY 2018, "Applied Fluid Mechanics", (5) ME 3450, Q1 - FALL - AY 2018, "Computational Methods in Mechanical Engineering", (5)	30%	70%	0%	100%
Kaminer, Isaac I.	FT	ME 4821, Q4 - SUMMER - AY 2018, "Marine Navigation", (5) ME 3801, Q2 - WINTER - AY 2018, "Dynamics and Control of Marine and Autonomous Vehicles I", (5)	40%	50%	10%	100%

		ME 4811, Q2 - WINTER - AY 2018, "Multivariable Control of Ship Systems", (5)				
Karpenko, Mark	FT	AE 3820, Q4 - SUMMER - AY 2018, "Advanced Mechanics and Orbital Robotics", (5) AE 3830, Q3 - SPRING - AY 2018, "Spacecraft Guidance and Control", (5) ME 4881, Q2 - WINTER - AY 2018, "Aerospace Trajectory Planning and Guidance", (6) AE 4850, Q1 - FALL - AY 2018, "Astrodynamic Optimization", (5)	0%	100%	0%	100%
Kim, Jae-Jun	FT	ME 3521, Q4 - SUMMER - AY 2018, "Mechanical Vibration", (5) AE 4818, Q2 - WINTER - AY 2018, "Acquisition, Tracking, and Pointing of Military Spacecraft", (5)	10%	90%	0%	100%
Kragelund, Sean	FT		0%	100%	0%	100%
Kwon, Young W.	FT	ME 2601, Q2 - WINTER - AY 2018, "Mechanics of Solids I", (5) ME 4612, Q2 - WINTER - AY 2018, "Advanced Mechanics of Solids", (4) ME 4613, Q1 - FALL - AY 2018, "Finite Element Methods", (4)	40%	50%	10%	100%
Luhrs, Claudia C.	FT	ME 4901, Q3 - SPRING - AY 2018, "Advanced Topics in Mechanical (Aerospace) Engineering", (5) MS 3202, Q3 - SPRING - AY 2018, "Properties, Performance & Failure of Engineering Materials", (5) MS 3606, Q3 - SPRING - AY 2018, "Introduction to Welding and Joining Metallurgy", (5) MS 2201, Q2 - WINTER - AY 2018, "Introduction to Materials Science and Engineering", (5) MS 3202, Q1 - FALL - AY 2018, "Properties, Performance & Failure of Engineering Materials", (5)	50%	40%	10%	100%
Marsh, Harleigh	PT	AE 3820, Q4 - SUMMER - AY 2018, "Advanced Mechanics and Orbital Robotics", (5)	0%	100%	0%	100%

Menon, Sarath K.	PT	(Retired in 2017)	0%	0%	0%	
Park, Chanman	FT		0%	0%	100%	100%
Rhatigan, Jennifer L.	PT	AE 4871, Q4 - SUMMER - AY 2018, "Spacecraft Design and Integration II", (6) ME 3150, Q4 - SUMMER - AY 2018, "Heat Transfer", (5) AE 4870, Q3 - SPRING - AY 2018, "Spacecraft Design and Integration I", (4)	40%	30%	0%	70%
Romano, Marcello	FT	AE 3818, Q1 - FALL - AY 2018, "Spacecraft Attitude, Determination, and Control", (5) AE 4820, Q1 - FALL - AY 2018, "Robotic Multibody Systems", (5)	20%	80%	0%	100%
Ross, Isaac M.	FT	AE 3830, Q3 - SPRING - AY 2018, "Spacecraft Guidance and Control", (5) ME 4881, Q2 - WINTER - AY 2018, "Aerospace Trajectory Planning and Guidance", (6) AE 4850, Q1 - FALL - AY 2018, "Astrodynamic Optimization", (5)	40%	40%	20%	100%
Seivwright, Douglas L.	FT	ME 2601, Q4 - SUMMER - AY 2018, "Mechanics of Solids I", (5) ME 1000, Q2 - WINTER - AY 2018, "Preparation for Professional Engineers Registration", (3) ME 3611, Q1 - FALL - AY 2018, "Mechanics of Solids II", (4)	30%	60%	10%	100%
Sharma, Ramesh C.	PT		15%	0%	0%	15%
Tran, Kimngoc	PT	MS 3606, Q3 - SPRING - AY 2018, "Introduction to Welding and Joining Metallurgy", (5)	15%	0%	0%	15%
Wright, Robert G.	FT		0%	100%	0%	100%
Wu, Chun-Hsien	FT	MS 4312, Q1 - FALL - AY 2018, "Characterization of Advanced Materials", (5)	25%	10%	20%	55%

FACILITIES

I. Student Communication and Learning

The Department is geographically located on the main campus in Watkins Hall and in the adjacent Halligan Hall, with additional instruction and research labs located at the NPS annex off campus. The consolidation of main campus facilities largely in one area (Watkins/Halligan) greatly improves interactions and collaborations among the faculty and between faculty and students. A large portion of the Department's instructional facilities are located in Watkins Hall and are fully equipped with a computer laboratory and dedicated laboratories for both instruction and research. The classrooms have been upgraded on a three-yearly basis with the installation of computers and projectors to use existing NPS network connections.

NPS has a space management policy and plan, and the MAE Department, which delivers the MSAE degree complies with that plan. The Dean of GSEAS allocates space within the engineering school. At present the MAE department occupies most of Watkins Hall, excluding the west side addition. The MAE Department also maintains a hydrodynamics laboratory, an extensive machine shop, other specialized laboratories and office spaces in Halligan Hall, the former engineering building. The NPS "golf course" Annex, located adjacent to the main campus also houses significant laboratories and shops related to the air breathing propulsion and power area of study.

Advanced level MSAE Degree Program courses are typically scheduled in Watkins Hall classrooms, though other general courses may be distributed throughout the campus. Often courses are taught adjacent to laboratory spaces supporting course instruction. Generally the classrooms have seating for 25-30 students and are equipped with several white boards and laptop and network computer connections. Hybrid courses taught as distance learning segments, with resident and remote students, are delivered from special VTE equipped classrooms in Root Hall. These classrooms provide the instructor and students with many interactive options and two-way audio-visual communications. White boards, document cameras, access to computer displays, video players and other teaching aids are provided in each of these classrooms. Additionally the course content is recorded for online streaming to students enrolled in the course.

As it is a multi-disciplinary program, the MSAE Program utilizes classroom and laboratory space across the NPS campus. For example, classes and research activities are conducted in the Space Systems Academic Group Smallsat Lab, Physics Department Remote Sensing Lab and various ECE Department labs and classified courses and research are conducted in the Sensitive Compartmented Information Facility (SCIF).

II. Laboratories

The Mechanical and Aerospace Engineering 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 to enhance instruction and research. The Mechanical and Aerospace Engineering Department also houses the largest of several

machine shops on campus and it includes a state-of-the-art 5- axis and 3-axis CNC milling machines, 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 Department participates in an NPS Laboratory Recapitalization Program and other equipment/facilities funding mechanisms that upgrade both instructional and research laboratories in the Department. Over the past five years the Department received an average of $375,000 of equipment as part of the Laboratory Recapitalization Program, End of Year funds, and Research Direct funded equipment.

The Department's more than nine laboratory facilities are organized into six major areas aligned with our academic program, which spans the disciplines of the thermal-fluid sciences, structural mechanics, dynamic systems and control, materials science and engineering and total ship systems engineering. These disciplines are blended together with a strong emphasis on naval engineering applications such as may be experienced on surface vessels and in submarines. These facilities are listed below:

SPACECRAFT RESEARCH AND DESIGN CENTER and ADAPTIVE OPTICS CENTER OF EXCELLENCE FOR NATIONAL SECURITY
Director: Distinguished Professor Brij Agrawal

Instructional Laboratory for a sequence of Astronautics design project courses, supports Space Systems Laboratory Classes as well as student theses, Bifocal Relay Mirror Laboratory supports AE3811, AE4818, AE4816 classes as well as student theses research. FltSatCom laboratory houses a flight certified FltSatCom Satellite and ground telemetry and command system. Adaptive Optics Beam Control Laboratory is a class 10,000 clean room that houses NPS High Energy Laser Beam control test bed, Maritime Adaptive Optics Test bed, and other optical testing equipment Spacecraft Design Laboratory: This laboratory houses computer–aided design tools for spacecraft design and a spacecraft design library. It has GENSAT, a general-purpose software application for satellite design, and Conceptual Design Center (CDC) software from Aerospace. In addition, it has several subsystem design software packages, such as STK, NASTRAN, IDEAS, Solidworks and Matlab/Simulink. It is used heavily by students for three spacecraft design courses, AE4870, and AE4871. Students can do collaborative spacecraft design using the unique design tools 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.

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

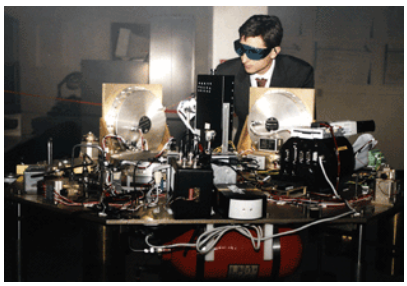
simulator, actuated by variable speed control moment gyros, single focal spacecraft attitude simulators, actuated by reaction wheels, and an optical beam and jitter control test bed. This laboratory is used for courses AE3811, AE3818, and AE4818.

FLTSATCOM Laboratory: This laboratory consists of a qualification model of the Navy FLTSATCOM communications satellite, the associated ground support equipment for testing the satellite, and the FLTSATCOM Attitude Control Simulator, which provides a graphical display of the spacecraft's attitude and rotational motion in response to commands similar to the commands required for flight model FLTSATCOM spacecraft. This is an instructional laboratory and is used by students in laboratory course AE3811. 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.

Optical Relay Mirror Laboratory

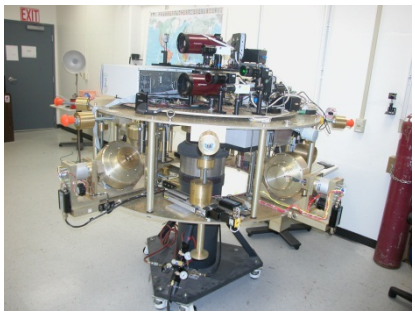
The NPS-AFRL Optical Relay Spacecraft Laboratory is used for both instruction and research on acquisition, tracking, pointing and beam control of spacecraft. It houses two generations of three-axis spacecraft testbeds: Three-Axis Spacecraft Simulator 1 (TAS1) and Three-Axis Spacecraft Simulator 2 (TAS2). It also houses the Jitter Control Testbed and the Adaptive Optics Testbed.

Three-Axis Simulator 1



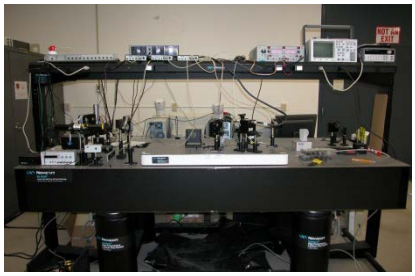
Three-axis simulator 1 can simulate spacecraft three-axis motion as well as the optical system of a space telescope. The spacecraft simulator has three reaction wheels and thrusters as actuators; rate gyros and sun sensors as sensors; an on-board processor and batteries; and is supported on a spherical air bearing.

Three-Axis Simulator 2



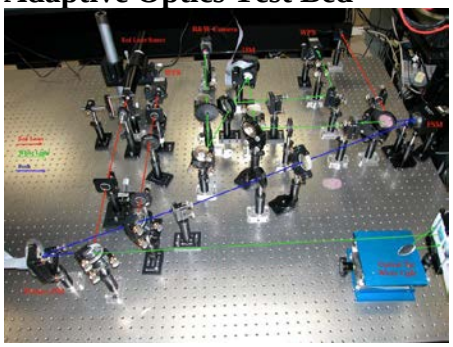
Three-axis simulator 2 can be divided into three modules: spherical air bearing, spacecraft bus module and optical payload module. The spacecraft bus has three variable speed control moment gyros (CMGs), a Northrop Grumman - Litton LN-200 IMU consisting of three fiber optics rate gyroscopes, sun sensors, magnetometers, inclinometer, a fine sensor, batteries, power switching and control electronics, and an automatic balancing system.

Laser Jitter Control Testbed



The purpose of the Laser Jitter Control testbed is to investigate control methods to reduce optical jitter and mitigate disturbances to optical beams and structures.

Adaptive Optics Test Bed

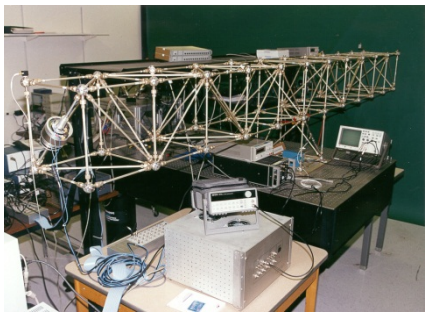


The purpose of this test bed is to develop improved control techniques for adaptive optics. The current application is controlling the surface of large flexible mirrors in space. The test bed has two adaptive optics systems (two deformable mirrors and two wave front sensors). One system corrects the surface of the flexible mirror and the other system corrects aberrations in the imaging object beam. The test bed also has a fast steering mirror for correcting jitter.

Smart Structures Laboratory

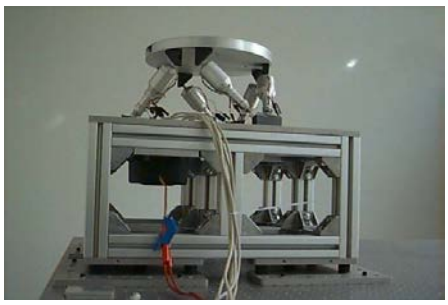
The Smart Structures Laboratory was developed under a five-year research grant to develop smart structures, sensors, actuators and controls for active vibration control, vibration isolation, and shape control in space applications. Active shape control of antennae is studied using piezo-electric and shape memory alloy actuators. The laboratory has three experimental platforms: the NPS space truss, the Ultra Quite Platform and the Positioning Hexapod.

NPS Space Truss



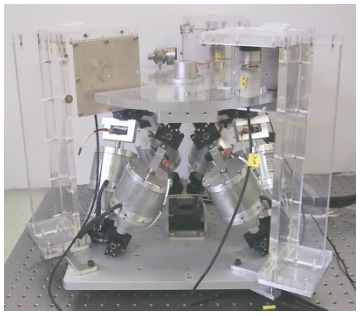
The overall dimension of the NPS space truss is 3.76 m long, 0.35 m wide and 0.7 m tall. Two piezo-ceramic struts are installed as actuators near the base of the truss. The output force for the actuator is 0-100 N and the displacement range is 0-90mm. A linear Proof Mass Actuator, located at the left end of the truss, generates the disturbance.

Ultra Quiet Platform



The Ultra Quiet Platform (UQP) is used for testing imaging payload vibration isolation control algorithms. The UQP is configured similar to a six degree of freedom cubic Stewart Platform.

Precision Pointing Hexapod



The Positioning Hexapod is used for testing control algorithms for both vibration isolation of an imaging payload and fine steering. It is based on an arrangement of six self-supporting electromagnetic voice coil actuators with in-line accelerometers that could enable control of high vibration. Lower frequency steering and vibration isolation is provided by the use of a laser-photo-diode based on a 2-axis position detecting system and eddy current position sensors.

Spacecraft Attitude Dynamics and Control Laboratory

Flexible Spacecraft Simulator (FSS)

The FSS, as shown in the figure, simulates attitude motion in the pitch axis of a flexible spacecraft. It consists of a central rigid body representing the spacecraft central body and a flexible appendage representing a reflector with a flexible support structure. This system is floated on air pads over a granite table to simulate a micro-gravity environment.

FLTSATCOM Laboratory

This laboratory, as shown in the figure, consists of a qualification model of the Navy FLTSATCOM communications satellite, the associated ground support equipment for testing the satellite, and the FLTSATCOM Attitude Control Simulator, which provides a graphical display of the spacecraft's attitude and rotational motion in response to commands similar to the commands required for flight model FLTSATCOM spacecraft.

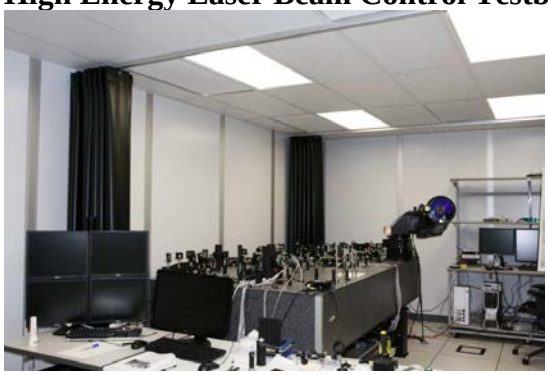
Spacecraft Design Laboratory

This laboratory houses computer–aided design tools for spacecraft design and a spacecraft design library. It has GENSAT, a general-purpose software application for satellite design, and Conceptual Design Center (CDC) software from Aerospace. In addition, it has several subsystem design software packages, such as STK, NASTRAN, IDEAS, Solidworks and Matlab/Simulink. Using these unique design tools, students can perform collaborative spacecraft design.

Adaptive Optics Beam Control Laboratory

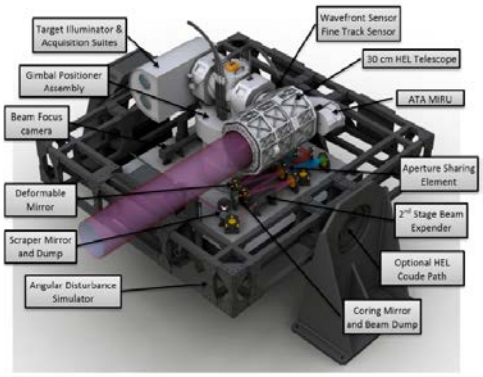
The Adaptive Optics Beam Control Laboratory is housed in a Class 10,000 clean room environment for ideal operation of testbed optical components. Within the laboratory are the High Energy Laser (HEL) Beam Control Testbed 1, the HEL Beam Control Testbed 2 (HBCT), and the HEL Adaptive Optics Testbed.

High Energy Laser Beam Control Testbed 1



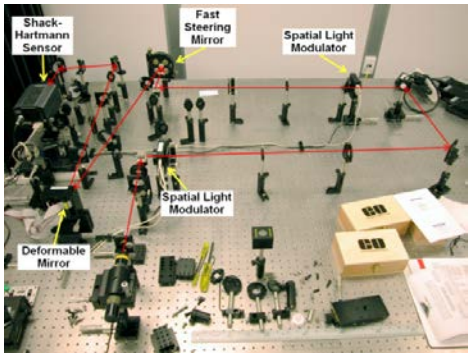
The HEL Beam Control Testbed is used to develop capabilities for end-to-end directed energy beam control applications. Necessary technologies for end-to-end beam control include adaptive optics, jitter control, structural design, optical design, and acquisition, tracking, and pointing.

High Energy Laser Beam Control Testbed 2



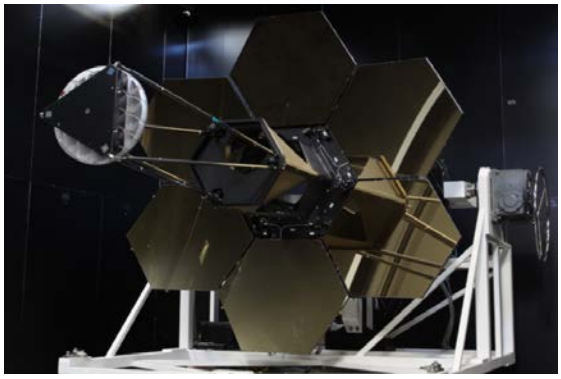
The contract to integrate and assemble the 10 kW capable HEL Beam Control Testbed 2 (HBCT) was awarded and the testbed was made operational in 2014. HBCT is an end-to-end beam control system installed on an Angular Disturbance Simulator with two rotational degrees of freedom. Control algorithms will be studied on HBCT before installation of a high-power laser and implementation in the field.

High Energy Laser Adaptive Optics Testbed



The HEL Adaptive Optics Testbed is used to develop advanced adaptive optics control techniques to overcome the challenges of maritime environment atmospheric disturbances and to demonstrate wavefront correction using a wavefront sensor and a deformable mirror. Spatial Light Modulators (SLMs) are used to accurately reproduce atmospheric disturbances on the optical beam.

Segmented Mirror Telescope Laboratory

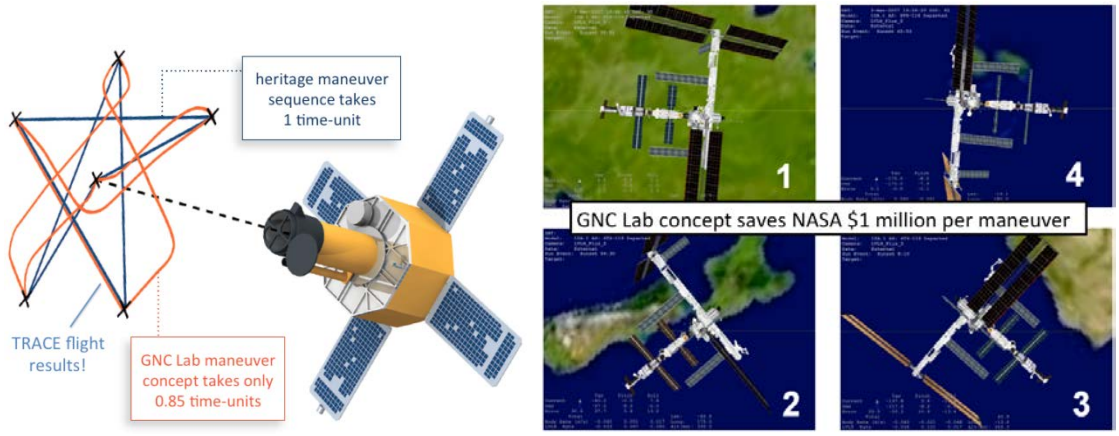


SMT is a 3m diameter space telescope consisting of six hexagonal one meter mirror segments. The segments are constructed using a nano-laminate foil mirror surface bonded to a silicon carbide substrate. Built into the substrate of each segment are 156 Face Sheet Actuators (FSAs). The FSAs are used to actively change the surface of each mirror segment. SMT uses a Shack-Hartmann wavefront sensor. The mirror segments are mounted at three points to Fine Control Actuators (FCAs). Each FCA is mounted to two Coarse Control Actuators (CCAs) in a hexapod arrangement. The FCAs and CCAs provide six degree of freedom (DOF) motion for alignment and phasing. Segment alignment also involves a phase diversity sensor. A fast steering mirror is used for jitter control.

SPACE AND AUTONOMOUS SYSTEMS LABS
Director: Distinguished Professor Mike Ross

The space and autonomous systems laboratories are a collection of laboratories that support courses and student theses in Mechanical, Astronautical and Space Operations curricula. The Guidance, Navigation and Controls Laboratory focuses on high-fidelity modeling, simulation and optimization of nonlinear dynamical systems, the Space Systems Identification Laboratory houses a flight-qualified model of NPSAT-1, a spacecraft conceived, designed and built at NPS, the DARK MIRROR Laboratory houses R-SAT, a reconfigurable space autonomy testbed, and the Embedded and Autonomous Systems Laboratory provides a workshop-like environment for embedded systems development and hardware-in-the-loop testing of next-generation algorithms for autonomous operations of mobile ground robots, robotic manipulator systems, unmanned air systems (fixed and rotary wings) and small autonomous space systems.

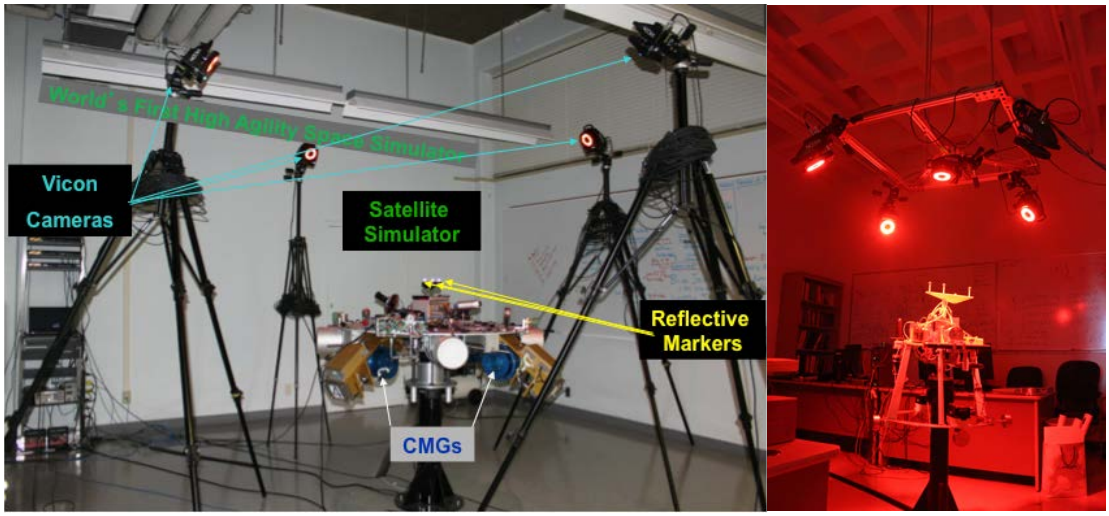
Guidance, Navigation and Control Laboratory: This laboratory houses a workshop and computer–aided tools for advancing seedling GNC algorithms and analyzing their impact on the design and operation of space and other autonomous systems. This laboratory serves as the "back of the envelope idea generator" for concepts that will eventually be ground tested in our other laboratories or flight proven in field or upon already operational systems. Concepts originating from this laboratory have been successfully flown onboard TRACE, a NASA space telescope and the International Space Station, a $100B space asset. This laboratory also has developed advanced tools for control and optimization that have been used by over 100 thesis students. This lab also supports AE3830 Spacecraft Guidance and Control, AE4362 Astrodynamics, and AE4850 Astrodynamic Optimization.



Space Systems Identification Laboratory: The Space Systems Identification Laboratory consists of a flight-qualified model of NPSAT-1 floating on an airbearing assembly. Vicon motion capture cameras are used to estimate the motion of the spacecraft to sub-millimeter-level accuracy and provide a truth model for attitude estimates. Optimized control inputs are designed and sent to the NPSAT-1 actuators, as

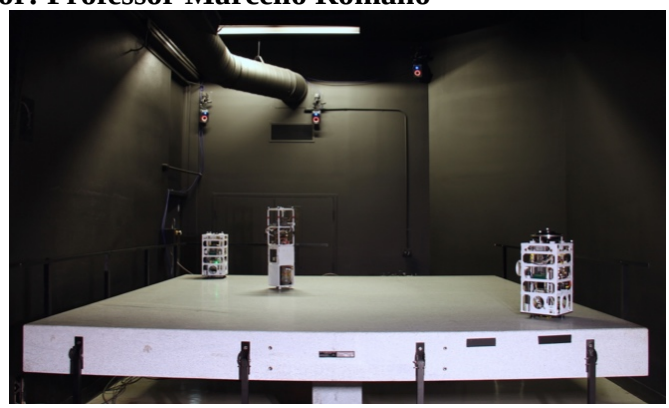
enablers to new nonlinear system identification algorithms that can converge orders of magnitude faster than legacy Kalman filtering techniques. The laboratory also supports AE3820, Spacecraft System Dynamics and AE3815 Spacecraft Dynamics.

DARK MIRROR Laboratory: This laboratory was funded as a joint-services laboratory (by the Secretary of the Air Force) to support the emerging needs of advanced space systems designed by the USAF. The facility houses a reconfigurable space autonomy testbed (R-SAT). This agile spacecraft simulator is actuated using control moment gyros and thrusters. In addition to a Vicon motion capture system, in situ sensing is also used to generate and execute optimal slew maneuvers for targeting and retargeting of spacecraft imaging sensors and performing various other operations common to USAF spacecraft. The laboratory is currently being upgraded to support research on subsystem pointing, and to serve as a open-architecture environment for the development of advanced CMG control algorithms. The lab is used for courses AE3830 Spacecraft Guidance and Control, AE4850 Astrodynamic Optimization and Astronautical Engineering thesis students.



Embedded and Autonomous Systems Laboratory: This laboratory hosts a workshop for development of embedded systems and associated hardware-in-the-loop testing for deployment of advanced algorithms previously incubated at the GNC laboratory. Some of these algorithms include cooperative and non-cooperative targeting as well as motion control and planning concepts. Various platforms including a collection of mobile ground robots, multi-link robotic manipulator systems, unmanned air systems (fixed and rotary wings) and small satellite systems are available upon which to test advanced GNC concepts in the laboratory setting. This laboratory is both an instructional and research laboratory and is funded by DARPA and AFOSR.

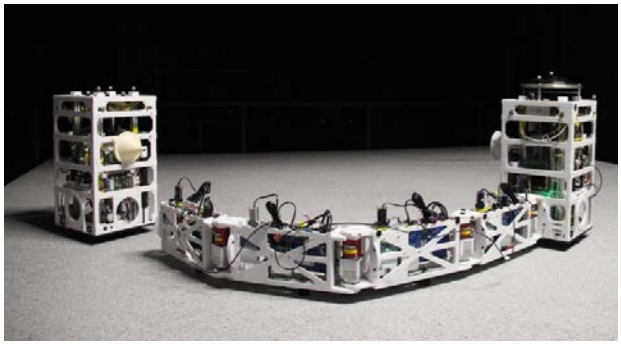
SPACECRAFT ROBOTICS LABORATORY
Director: Professor Marcello Romano



The Spacecraft Robotics Laboratory supports Master level courses and Master and PhD student theses in Mechanical, Astronautical and Space Operations curricula, in addition to reimbursable research. The Spacecraft Robotics Laboratory focuses on high-fidelity modeling, numerical simulations, experimental testing of dynamic modeling, guidance and control of nonlinear dynamical systems. The Spacecraft Robotics Laboratory supports the courses AE3815 Spacecraft Rotational Mechanics, AE3818 Spacecraft Attitude Determination and Control and AE4820, Robotic Multibody Systems.

The laboratory is used to support research sponsored by DoD Agencies.

Floating Spacecraft-Simulator Testbed

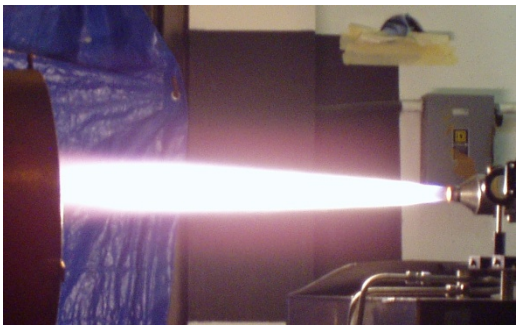


The POSEYDIN Testbed at the NPS Spacecraft Robotics Lab consists of custom developed Floating Spacecraft Simulators capable of floatation, via air-pads, on a high accuracy flat table in order to recreate in 2D the weightlessness and frictionless conditions of orbital space flight. The test-bed is used to validate Guidance, Navigation and Control (GNC) algorithms and their hardware-in-the-loop validation for multiple spacecraft maneuvering, in particular rendezvous and proximity operations. Particular recent emphasis has been on the problem of approaching and docking with a tumbling Resident Space Object.

ROCKET PROPULSION LABORATORY
Director: Associate Professor Christopher Brophy

This lab conducts research on advanced concepts in solid, liquid, and combined mode propellants. Experimental and computational research is conducted in the areas of propellant mixing, combustion, pulse detonation, thrust control, and plume mixing. The lab is able to store up to 11 lbs. of class 1.1 or 1.3 propellant. A full range of mechanical and optical diagnostic techniques are used on small and subscale experiments.

The Rocket Propulsion Laboratory consists of an instrumented control room, a propellant evaluation laboratory, a high-pressure air facility and four test cells equipped with diagnostic apparatus and motor hardware for investigating solid and liquid rockets, solid fuel ramjet, pulse detonation engine, and gas turbine propulsion systems. Vitiated air heaters are used to simulate combustor inlet conditions representative of supersonic flight and generate temperatures up to 1400°F. Several continuous wave and pulsed laser systems are available along with high-speed/high frame rate CCD cameras, light scattering and transmission measurement systems, schlieren systems, sampling probes, infrared imaging systems, and both visible and infrared spectrometers. Two internal test areas are available for spray characterization and other non-reacting flow testing. Multiple National Instruments data acquisition systems monitor high and low frequency pressure transducers, thermocouples, and other diagnostic devices.



MATERIALS CHARACTERIZATION LABORATORIES:
Director: Distinguished Professor Young Kwon

These laboratories are used for the measurement of mechanical behavior of materials, for teaching, for master's thesis projects, and for reimbursable research. Laboratory supports teaching and research in characterization 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.

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

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

Transmission Electron Microscopy 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.

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

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.

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.

CENTER FOR AUTONOMOUS VEHICLE RESEARCH (CAVR):
Director: Associate Professor Vladimir Dobrokhodov

The center supports teaching and research in the area of autonomous systems. In particular, extensive work is done on autonomous underwater, surface and air vehicles. The center provides teaching labs for ME3720, ME3801, ME4811 and ME4823 as well as experimental facilities for numerous theses in the ME and Under Sea Warfare (USW) curricula.

The primary goal of the NPS Center for Autonomous Vehicle Research (CAVR) is to educate students in the development and use of technologies needed for unmanned vehicles through coursework, thesis and dissertation research. The secondary goal of the CAVR is to advance Naval autonomous vehicle operations by providing support to the fleet, Navy labs and Program Offices, testing and experimentation of advanced technologies, independent verification and validation of a variety of novel autonomous vehicles concepts, and by innovative concept development.

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 vital 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.

III. Computing Resources

Institutional funds have been used on a two-yearly basis to upgrade the computer laboratory with new workstations and selected peripherals. This computer laboratory is available at all times to the students and is consistently the most heavily used facility in the building. In view of diminishing funds for the hiring and use of supporting staff, the degree program as a whole has recently lessened reliance on formal physical laboratory work. In response to our Navy sponsor, we continue to offer a course in finite element analysis of structures and fluids. Also, computer simulation is widely used in our Dynamics and Control classes with Matlab, and Simulink projects being given.

The laboratory currently houses 36 Dell windows XP 64-bit workstations and has over 50 major software applications and licenses installed. Included, for example, are Matlab, SolidWorks, NX, STK, NASTRAN, DYTRAN, PATRAN, AutoCad, ANSYS. NPS also has access to mainframe computers and a developing cluster for large-scale processing is available.

The School also has a cluster of Linux CPU's described in more detail in the Institutional Summary, Appendix D.

IV. Guidance

During yearly in-briefs, students are made aware of resources that are available for their use and the correct and safe operation of such equipment.

During each course students in the AE program are provided guidance regarding the use of the tools, equipment, computing resources, and laboratories from the faculty, research assistants, and laboratory staff. Laboratories that require safety oversight have standard operating procedures and user training.

V. Maintenance and Upgrading of Facilities

Funds for the ongoing maintenance and upgrading of the Department's laboratory facilities have been provided through both laboratory and research recapitalization and maintenance budgets. Also, substantial support for maintaining and improving these laboratories has come from reimbursable research funding raised by the faculty. The ongoing maintenance and further upgrading of these has been hindered more by lack of support staff and absence of institutional support for faculty labor for these purposes than by lack of funds for the equipment itself.

VI. Library Services

The Knox Library located at NPS is an incredible resource for students, faculty and other government institutions alike. The library catalog is entirely electronic and accessible via

secure login online. The library has vast holding onsite specific to engineering and military technology and with its participation in the national interlibrary loan collaborations, there is rarely a reference that cannot be found and delivered within a short period of time. The library is proactive in accepting requests for new journal titles and maintaining those that are accessed frequently. They provide a full service reference desk, staffed with librarians knowledgeable in both general and discipline specific sources of information. These services are available to students as well as faculty.

In particular, an engineering and technology focused research (subject specialist) librarian is assigned to the MAE Department. As part of the MAE Department seminar series, which is mandatory for all MSAE degree students, this librarian regularly, at least annually, conducts a formal presentation to alert thesis students to the specific services available to them in a technical curriculum. Examples of their training include an onsite orientation; help with the electronic databases searches such as LexisNexis Academic, IEEE Explore, Engineering Village and others; and guidance on obtaining and using controlled access materials.

The library has group study and meeting spaces, individual student study desks, several computer terminals available for searching its holdings and access to the local network.

VII. Overall Comments on Facilities

The MAE Department has a vested interest in ensuring that the facilities used in the instruction of students are safe and that tools and equipment are utilized in a proper manner.
As such, safety is the responsibility of all program members, but there are a few key individuals assigned by the department to supervise these actions.

All the Astronautical Engineering Laboratories situated in Halligan Hall as well as the Astronautical Engineering Design Laboratory are under the auspices of Dr Fernandez Bautista. He takes care of all the maintenance within these labs; Spacecraft Research And Design Center, Adaptive Optics Center Of Excellence For National Security, Space And Autonomous Systems Laboratory and Spacecraft Robotics Laboratory, including assisting in the teaching of various labs during scheduled classes. He also is the Contract Oversite Representative (COR) for large contracts, purchasing or maintenance, that need to be carried out to maintain the excellence within the labs.

A Building Manager, currently Doug Seivwright, sees to all building upgrades, oversees the Naval Facilities instituted card key policy for all the spaces within Watkins Hall. He also oversees the gas handling system within Watkins Hall that monitors hazardous gasses within both the MEMS Lab as well as the Marine Propulsion Laboratory exhaust gas analyzing system.

Supervisory Technician, Stefan Kohlgrueber the head departmental technical staff member, is assigned within the MAE Department and acts as the primary liaison for

materials, maintenance and safety issues associated with the departmental offices, laboratories, student study and research areas. He also oversees all safety aspects within the department including laser and radiation safety.

There is also a Departmental HAZMAT coordinator assigned. This staff member, currently Dr. Chanman Park, is responsible for ensuring that student and faculty work is conducted in a safe and proper manner when using hazardous materials. In addition, trained laboratory technicians are responsible for the operation of equipment in their designated spaces.

All of these individuals work with the Command Safety Program Officer, Command HAZMAT Coordinator, Industrial Hygienist, Research Safety Officer, Radiological Officer, Laser Safety Officer, Curriculum Officer and others to ensure safety guidelines and best practices are in place. The Departmental staff works with faculty and students to ensure the availability and adherence to safety instructions, placard, and personnel protection equipment, proper storage facilities for chemicals, Material Safety Data Sheets and individual equipment training. For operation of inherently dangerous items such as overhead cranes and other heavy equipment the Navy requires students, staff and faculty to complete formal training via the ESAMS (Enterprise Safety Applications Management System) program. This web-based system enables Navy personnel to demonstrate full compliance with all current OSHA and SOH standards. Other equipment safety programs follow similar training and adherence programs. Facilities are inspected regularly as part of the command wide inspection schedules maintained by Naval Support Activity Monterey.

INSTITUTIONAL SUPPORT

I. Leadership

The Department Chairman, Dr. Garth Hobson, is a tenured full professor in the MAE Department and has been the Chairman since 2014, and from 2008 until 2014 he was the MAE Associate Chairman. He also severed as the Director of the Turbopropulsion Laboratory from 2004 until 2016, administering a research budget of at least $1.0M a year. He has more than 60 journal and refereed conference publications in the field of experimental and computational turbomachinery problems including airbreathing propulsion. He has taught most of the Thermo Fluids courses within the department including computational methods that includes finite element analysis of structural elements. He introduced the elective ME4225 Computational Fluid Dynamics and Heat Transfer, which he has taught since it inception sometime multiple times per year because of student demand. He has advised more than 70 Masters thesis students and has had two PhD students. As one of the three external invited professionals by the Academic Dean he served on the Visiting Committee for the US Naval Academy's Aerospace Engineering Department mid term ABET review in March 2015. He is therefore very knowledgeable about engineering education.

II. Program Budget and Financial Support

The Naval Postgraduate School is on a "9-month" model where tenure track faculty are paid for three of the four quarters to perform a standard workload of teaching four courses, conducting research, advising Master's, Engineer's and Doctoral students, and to perform service for their department, school, NPS, the Navy/DoD, and the broader professional community in which they identify. Since the number of tenure track faculty in MAE is not adequate to teach all our sections, additional funding is provided to support hiring adjunct faculty to teach the remaining sections. There is a general lack of understanding at the central budgeting function that engineering education costs more per student than other programs.

Separate funds are made available for administrative and technical staff. There is no standard model to allocate staff funding and every year is a new challenge to secure sufficient funding to support engineers and technicians required for course labs and thesis/dissertation work. Prior to 2014 the NPS supported about half the salaries for technical staff in MAE, and the rest was covered by reimbursable research projects. More recently the funding for staff has decreased significantly and is a concern.

NPS also has several sources of funds for laboratory equipment, some of these are recurring and some are one-time occurrences. For example, last end-of-year funds from central administration allowed the purchase of a $0.25M 3D Metal Printer.

III. Staffing

The Department has approximately 13 staff members in both administrative and technical roles, as either employees or contractors. More than half of these staff members are totally supported by reimbursable projects. Only seven technical and administrative staff are supported wholly by the Department.

The Department currently has one request to hire for an Aerospace Technician. However due to the current fiscal situation in NPS this will likely not be approved in the near future.

If and when this position is filled, the Department will barely have adequate staffing to fulfill its mission.

IV. Faculty Hiring and Retention

NPS follows national standards and processes for faculty hiring. Specifically we form a hiring committee, advertise nationally, receive from 30 to 50 applications for a single position, narrow down the applicants to 10 or so top candidates, make inquiries with references, invite 3 or 4 prospects to Monterey for 2 days interviews, and then based on the information available make a selection.

For the last three (3) tenure track hires, the Dean of Research, has barely been able to support these new faculty for their intersessionals and approximately $50k of equipment.

Neither the MAE Department nor NPS at large have much in the way of strategies to retain current faculty. The MAE Department has had some difficulty in retaining some of our top faculty members over the years. MAE faculty members have left for positions at Purdue University, and University of Alabama and to take industry positions at Apple, Toyota and SpaceX.

V. Support of Faculty Professional Development

Describe the adequacy of support for faculty professional development, how such activities such as sabbaticals, travel, workshops, seminars, etc., are planned and supported.

There is adequate support for professional development activities.

Faculty members are encouraged to take the instructional design course offered by the campus Center for Educational Design, Development, and Delivery. Additionally there are other new faculty courses offered through the Office of Academic Affairs.
The department has a weekly seminar series for its faculty and graduate students. NPS has a campus wide guest speaker program that brings distinguished members of government to campus about five times per quarter to lecture students and faculty. In

order to share professional knowledge throughout the school, Departments often notify each other of their invited seminar speakers.

NPS runs a sabbatical program, for which tenured department members are eligible to apply.

The majority of faculty in the MAE Department conducts at least a minimum level of research. In doing so, it is common for research programs to provide funds to support travel to professional meetings.

Faculty without a doctoral degree can enroll in NPS doctoral programs at no cost; while all faculty members are free to take courses on campus at no cost to gain further enlightenment and foster cooperative research in new and emerging fields.

Appendix A-1 – Course Syllabi for Master's Level Courses

AE2440 – Introduction to Scientific Programming (3-2)

Contact Hours - Meets three times per week for 50-minutes lectures and two 50-minute labs per week.

Course Coordinator/Instructor - Oleg A. Yakimenko

Textbook(s) and/or other Required Material
Engineering Computations and Modeling in MATLAB®/Simulink®, Yakimenko, O. A., ISBN: 978-1-60086-781-1, AIAA Education Series, 2011.

Course (Catalog) Description
This course offers an introduction to computer system operations and program development using NPS computer facilities. The main goal of the course is to provide an overview of different structured programming techniques, along with introduction to MATLAB/Simulink/GUIDE and to use modeling as a tool for scientific and engineering applications. The course discusses the accuracy of digital computations, ways to incorporate symbolic computations, and presents numerical methods in MATLAB functions.

Prerequisites and Co-Requisites - Knowledge of single variable calculus and matrix algebra.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
The course teaches students how to
1. Use the MATLAB and Simulink development environment effectively for writing professional-level scripts, solving applied engineering problems, developing and running models of Naval engineering systems
2. Choose wisely and apply correctly different numerical methods
3. Analyze limitations, advantages, and disadvantages of the chosen numerical method
4. Use interactive and graphical capabilities of MATLAB and Simulink to make your models universal and easy-to-understand (analyze)

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Perform matrix analysis
2. Formulate algorithms to solve problems numerically
3. Recognize engineering applications of the various numerical methods;
4. Solve numerical problems in
    - identifying roots of equations
    - finding solutions of linear simultaneous equations
    - interpolating values of a dependent variable given a set of discrete measurements

- approximating the differential or integral of an unknown function given a set of discrete measurements from the function
- finding solutions to differential equations
- describing data graphically and computing important characteristics of sample measurements
- making basic statistical computations, and
- fitting a curve or a model to data

5. Understand the limitations of each numerical method, especially the conditions under which they may fail to converge to a solution
6. Model simple systems by differential equations, block diagrams, and transfer functions
7. Develop and run continuous and discrete Simulink models
8. Use MATLAB proficiently for scientific and engineering applications including writing script and function files, 2-D and 3-D plotting, programming (flow control), and producing meaningful and readable solutions (reports)

Topics Covered

1. Introduction to MATLAB/Simulink - Technical Computing Language
2. MATLAB's Development Environment and Basic Operations
3. Arrays and Array Operations
4. Data Structures, Types of Files, Managing Input/Output Data
5. Programming with MATLAB and Debugging Tools
6. Two- and Three-Dimensional Plotting and Animation
7. MATLAB's Symbolic Math Toolbox
8. Accuracy of Digital Computations
9. Matrix Algebra and Eigenvalue Problems
10. Root Finding and Optimization
11. Curve Fitting to Measured Data
12. Numerical Differentiation
13. Numerical Integration
14. Initial-Value Problem
15. Simulink Basics

AE2820 Introduction to Spacecraft Structures (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor –Marcello Romano

Textbook(s) and/or other Required Material
Text: Instructor Notes.

Course (Catalog) Description
Students will be introduced to solid mechanics and dynamics. The fundamentals of strength of materials and beam theory, along with stress analysis, buckling, and vibration theory, will be applied to perform structural analysis of spacecraft structures. Students will learn the finite element method and use standard aerospace industry analysis tools. Design considerations specific to spacecraft structures will be presented to examine the engineering of space structures

Prerequisites and Co-Requisites – MA2121 or consent of instructor

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1) Solve fundamental solid mechanics problems.
2) Employ solid mechanics and basic vibration theory in the spacecraft design cycle
3) Perform finite element analysis of space structures using standard aerospace industry analysis tools
4) Determine and perform the appropriate structural analyses necessary for a spacecraft, given the launch vehicle and design phase
5) Examine the engineering of space structures
6) Perform simplified sizing calculations for space structures
7) Perform structural testing that is commonly used in the aerospace industry

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:

1) Learn fundamental solid mechanics concepts
2) Learn basic vibration theory
3) Learn the fundamentals of the finite element method
4) Learn launch vehicle analyses and the spacecraft verification loads cycle
5) Participate in an in-class spacecraft structural design case study
6) Learn space structure design considerations
7) Learn space structure design considerations

Topics Covered

- Review of Statics, Trusses
- Stress, Strain, Mechanical Properties
- Axial Deformation
- Torsion
- Beam Bending, Beam Deflection, Mass Properties
- Transformation of Stress and Strain, Principle Stress/Strain
- Theories of Failure, Failure Modes, Intro to Dynamics
- Intro to Vibration
- Buckling, Intro to Finite Element Analysis
- Spacecraft Design Considerations
- Spacecraft Design Verification Cycle, Case Study

AE3804 THERMAL CONTROL OF SPACECRAFT (3-0)

Contact Hours: Meets three times per week for 50-minute lectures.

Course Coordinator: Brij Agrawal

Textbook(s) and/or other Required Material
Incropera, DeWitt, Bergman & Lavine, *Introduction to Heat Transfer*, 6th Edition, Wiley, 2012.
David G. Gilmore, Ed., *Spacecraft Thermal Control Handbook, Volume 1: Fundamental Technologies*, The Aerospace Press, 2002.
Reference: NASA Engineering Safety Center Academy on-line tutorials

Course (Catalog Description):
A solid foundation in heat transfer is the basis for design, testing, operation and evaluation of spacecraft thermal control systems. Therefore, the course examines the three fundamental modes of heat transfer (conduction, convection and radiation) singly and in combination in one and two dimensions, in unsteady conditions, and involving phase changes, with emphasis on applications to spacecraft design. The course examines thermal environments, thermal design, thermal testing, thermal operation, and integration of thermal design into the overall spacecraft systems. Also considered are unique problems and solutions in spacecraft design integration of thermal control systems.

Prerequisites: None.

Course Requirement: Required.

Course Outcomes:
Design and analyze spacecraft thermal control systems to include both passive and active elements
Analyze the effects of space environments on spacecraft thermal control systems
Integrate these systems into an overall spacecraft design
Completion of assigned homework problems
Mid-term Examination
Spacecraft Thermal Design Report
Final Examination

Student Learning Objectives:
To make students proficient in spacecraft thermal design
Discern the three modes of heat transfer: conduction, convection, and radiation.
Differentiate how and when to apply them either singularly or in combination in spacecraft design.
Analyze spacecraft processes and devices that utilize heat transfer.
Integrate thermal control concepts into spacecraft system design analyses.
Explain different thermal control techniques - passive and active approaches - and their practical implications on spacecraft.

Discuss typical thermal designs, testing, or applications on existing spacecraft, and be able to follow and critique thermal design case studies on spacecraft.

Topics Covered

- Introduction to Spacecraft Thermal Control
- Heat Transfer
- View Factors
- Thermal Analysis, Isothermal Radiators
- Lumped-Parameter Analytical Model
- Thermal Control Techniques
- Spacecraft Thermal design
- Examples of spacecraft Thermal design
- Spacecraft Thermal Testing
- Off-Design Performance Prediction

AE3811 – SPACE SYSTEMS LABORATORY (2-2)

Contact Hours - Meets two times per week for 50-minute lectures and once per week for a 2 hour lab period.

Course Coordinator/Instructor Brij N. Agrawal

Textbook(s) and/or other Required Material
Text: Military Standard: Test Requirements for Launch, Upper-Stage, and Space Vehicles, SMC-1540, Space and Missile Systems Center, Department of Defense, Los Angeles AFB, California, 31 January 2004. MIL-HDBK-340 (USAF), Vol. I and II, July 1985

Course (Catalog) Description
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.

Prerequisites and Co-requisites - Permission of instructor

Course Requirement - Required

Course Outcomes
1. Understanding of basic principles of spacecraft testing at component, subsystem, and system level.
2. Understanding of military standard test requirements for space vehicles.
3. Knowledgeable about the differences in the commercial and military spacecraft testing plans.
4. Experience in performing laboratory experiments.
5. Become familiar with the state-of-art spacecraft testing facilities.
6. Develop oral and written communications skill by presenting evaluation of spacecraft test plans and experimental results.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Explain basic principles of spacecraft testing, such as thermal vacuum, thermal balance, sinusoidal vibration, acoustic, static, shock, and electrostatic discharge tests.
2. Explain different levels of testing, development, qualification, protoflight, acceptance and test margins.
3. Explain component and subsystem qualification, protoflight, and acceptance tests.
4. Explain system level qualification, protoflight, and acceptance tests.
5. Review test plans for different spacecraft, including military and commercial.
6. Review military standard test requirements for space vehicle.

7. Complete a team project to identify deficiencies in given spacecraft test plan at subsystem and system level.
8. Review failures versus test thoroughness index for various USAF and commercial programs.
9. Perform experiments in Spacecraft Research and Design Centers and Satellite Servicing laboratory and make presentations.
10. Visit spacecraft testing and integration facilities to gain knowledge of stat-of-art in spacecraft testing.

Topics Covered

- Introduction to Spacecraft Test Program
- Environmental Levels and Labs
- Test Philosophies and labs
- Environmental Levels and Labs
- Environmental Testing /Launch Environment and Labs
- Environmental Testing/On-Orbit Environment/Labs
- Example of Spacecraft Component Test Programs/ Student Team Example of Spacecraft System Level Program/Student Team
- Example of Spacecraft System Level Program/Student Team
- Test Effectiveness and On-Orbit failures
- Review

AE3815 SPACECRAFT ROTATIONAL MECHANICS (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor –Marcello Romano

Textbook(s) and/or other Required Material
Text: Instructor Notes.

Course (Catalog) Description
Fundamentals of vector and tensor algebra. Rigid shape orientation and its parametrization, Euler's theorem, Direction Cosine Matrix and Rotation Matrix, Orientation Quaternion, Modified Rodriguez Parameters. Change of coordinates for vector and tensors. Rigid shape orientation differential kinematics, angular velocity, Darboux equation. Rigid body spacecraft rotational dynamics: angular momentum, inertia tensor and its transformations, Euler's rotational motion equations, solutions of the Euler's equation in significant cases, spin stabilization, energy-sink analysis. Modeling of environmental torque acting on an orbiting spacecraft: gravity gradient, aerodynamic torque, solar pressure torque. During the two hours per week of laboratory as well as the homework's the students build up sequentially a full software simulator of spacecraft rotational mechanics to be used in subsequent classes

Prerequisites and Co-Requisites - Prerequisites: MA2121

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Introduce concepts and methods for the analysis of spacecraft rotational mechanics.
2. Develop skills of mathematical modeling and numerical simulations of spacecraft rotational motion.
3. Prepare for later classes, in particular AE3818 and AE4870.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Understand and use the fundamental concepts of spacecraft rotational mechanics;
2. Develop analytical model and perform numerical simulations of spacecraft rotational mechanics problems;
3. To develop a software simulator for spacecraft rotational mechanics to be used in successive classes
4. To acquire the fundamentals for other successive 3000 and 4000 level classes

Topics Covered

- Fundamentals of vector and tensor algebra.
- Rigid shape orientation and its parameterization
- Rigid shape orientation differential kinematics
- Rigid body rotational dynamics
- Spacecraft spin stabilization
- Spacecraft environmental torque modeling

AE3818 SPACECRAFT ATTITUDE DETERMINATION AND CONTROL (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor –Marcello Romano

Textbook(s) and/or other Required Material
Text: Instructor Notes, and Space Vehicle Dynamics and Control, Bong Wie, AIAA.

Course (Catalog) Description
Spacecraft attitude linear control: linearized attitude control, three-axis-stabilized spacecraft. Non-linear attitude control design: minimum-time slewing maneuver, quaternion feedback. Actuators for attitude control: Thrusters, Reaction Wheels, Control Moment Gyroscopes, Magnetotorquers, and related topics (thrust modulation and mapping, CMG steering laws and singularities, momentum dumping). Sensors for attitude and rate determination: star sensors, horizon sensor, sun sensor, gyroscopes. Attitude determination methods: deterministic approach (Triad algorithm), statistic approach (Wabha problem), stochastic approach (Multiplicative Extended Kalman Filter). During the two hours per week of laboratory as well as the homework's the students build up sequentially a full software simulator of spacecraft attitude determination and control to be used in subsequent classes At least one of the laboratory includes the utilization of an hardware-in-the-loop spacecraft simulator.

Prerequisites and Co-Requisites - Prerequisites: ME2801 or EC2300, AE3815.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Introduce concepts and methods for the analysis and synthesis of spacecraft attitude determination and control algorithms.
2. Develop skills of mathematical modeling and numerical simulations of spacecraft attitude determination and control subsystems.
3. Prepare for later classes, in particular AE4870 and AE4820.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Understand and use the methods, devices and systems used for spacecraft attitude determination and control.
2. Develop analytical model and perform numerical simulations of spacecraft attitude determination and control problems.
3. To acquire the fundamentals for other successive 3000 and 4000 level classes

Topics Covered

- PID and LQR control for linearized spacecraft attitude model
- State space observer
- Non linear attitude control techniques
- Modeling of spacecraft actuators: thrusters and modulation
- Reaction wheels and their steering logic
- Control moment gyroscopes and their steering logics
- Magnetotorquers and their steering logics
- Attitude sensors
- Multiplicative extended Kalman Filter for attitude estimation

AE3830 SPACECRAFT GUIDANCE AND CONTROL (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor – Isaac M. Ross

Textbook(s) and/or other Required Material
No text. Class notes.

Course (Catalog) Description
Overview and fundamental components of Guidance, Navigation and Control Systems. State-space representation of dynamical systems. Simulation of nonlinear dynamical systems. Sources and effects of navigation and modeling errors on guidance and control systems. Error propagation techniques and Monte Carlo simulations. Review of PID controllers. Introduction to basic optimal control theory. Linear quadratic double-integrator problems and foundations of real-time optimal control (RTOC). Guidance theory via RTOC. Class project on a two-degree of freedom Guidance-Control System architecture..

Prerequisites and Co-requisites - MA 2121, ME2801 or EC 2300

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Understand fundamental, practical and emerging principles in spacecraft guidance and control
2. Acquire first-hand experience in verification and validation of a GNC subsystem (particularly as it applies to future space systems

Student Outcomes Addressed by Course

1. To understand the fundamentals of the state of practice in spacecraft guidance and control
2. To acquire a first-hand experience in the emerging principles for a design of a Guidance & Control subsystem
3. The objectives include the foundations for some prerequisites for follow-on 4000-level courses
4. The design of a 2-DOF Guidance and Control System architecture

Topics Covered

- Overview and Introductory Concepts
- Practical Second-Order Systems
- Systems Approach to Guidance and Control-1
- Systems Approach to Guidance and Control-2
- Exo-Atmospheric Guidance
- Two-DOF Guidance & Control Architecture

AE3851 – Spacecraft Propulsion (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a two-hour lab period.

Course Coordinator/Instructor – Chris Brophy

Textbook(s) and/or other Required Material
Text: *Rocket Propulsion Elements*, George Sutton and Oscar Biblarz, 8th Edition, Wiley, 2010

Course (Catalog) Description
This course 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 H2/O2 and monopropellants are discussed. Electric propulsion schemes (resisto-jets, 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.

Prerequisites and Co-requisites – None.

Course Requirement - Required.

Course Outcomes
Upon completion of AE3851, students should be capable of the following skills:

1. Categorize spacecraft propulsion systems by propellant type, thermodynamic cycle, power source, and mission application.
2. Calculate chemical engine performance given propellant composition, combustion chamber conditions and nozzle configuration.
3. Evaluate the effect of fuel/oxidizer combinations on chemical engine performance.
4. Select and size appropriate engine type given mission requirements (Chemical liquid or solid fuel, or electric propulsion)
5. Differentiate strengths and weaknesses of electric and electromagnetic space propulsion systems.
6. Analyze the effect of staging on chemical space vehicle design.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:

1. Determine nozzle performance parameters given appropriate boundary conditions
2. Analyze the effect of chamber temperature and gas characteristics on chemical rocket performance
3. Evaluate the effect of a flight environment effect on optimum chemical rocket nozzle design

4. Recognize the salient characteristics (strengths and weaknesses) of liquid propellant engine cycles
5. Evaluate solid propellant characteristics on performance and operability in a solid fuel chemical rocket design.
6. Estimate the performance of a solid propellant chemical rocket given propellant composition, grain design, flight conditions, and nozzle configuration.
7. Apply the principles of electrothermal and electrostatic propulsion to specific mission requirements to determine required power, propellant mass, and propellant type.
8. Apply the principles of electromagnetic propulsion to specific mission requirements to determine required power, propellant mass, and propellant type.

Topics Covered

Rocket propulsion concepts and fundamentals
Review of thermodynamics and gas gynamics
Nozzle Theory
Spacecraft flight performance
Chemical rocket fundamentals
Liquid propellant combustion and engine design
Liquid propellant engine cycles
Solid propellant characteristics and grain design
Solid propellant engine design
Electric propulsion fundamentals
Ion propulsion systems and applications
Electro-magnetic propulsion systems and applications

AE3870 –SPACECRAFT DESIGN TOOLS AND SYSTEMS ENGINEERING (2-4)

Contact Hours - Meets two times per week for 50-minute lectures and twice per week for a 2-hour lab period each.

Course Coordinator/Instructor – Brij N. Agrawal

Textbook(s) and/or other Required Material
Text: Instructor's notes and user manuals of computer programs.

Course (Catalog) Description
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.

Prerequisites and Co-Requisites - Permission of instructor

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Become familiar with computational tools for conceptual spacecraft design.
2. Become familiar with computational tools to be used in spacecraft design for analyses, such as structural and thermal analyses
3. Become familiar with the computational tools to be used for developing spacecraft configurations.
4. Become familiar with the computational tools to be used to estimate spacecraft developmental cost.
5. Evaluation of mission requirements for the spacecraft and design drivers.
6. Introduction to system engineering.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Use Aerospace conceptual design center spacecraft design program for conceptual spacecraft design.
2. Use structures and thermal control design tools, such IDEAS.
3. Use spacecraft cost estimating computer programs.
4. Use computer aided design tools such as IDEAS and Solid Works
5. Review mission requirements for spacecraft design project for AE4871
6. Basic knowledge of system engineering
7. Develop oral presentation skills

Topics Covered

- Aerospace Conceptual Design Center program and use as a team
- IDEAS program for structural and thermal control design
- NASA and Air Force spacecraft cost estimating program
- IDEAS and Solid Works programs for computer aided design.
- Mission requirements for spacecraft design project in AE4871
- Introduction to system engineering.

AE4452 – Advanced Missile Propulsion (4-1)

Contact Hours - Meets four times per week for 50-minute lectures and twice per quarter for a 2-hour lab period.

Course Coordinator/Instructor –Christopher M. Brophy

Textbook(s) and/or other Required Material
Text: *Rocket Propulsion Elements*, George Sutton and Oscar Biblarz, 8th Edition, Wiley, 2010, *Tactical Missile Propulsion*, Netzer, D.W. and Jenson, D., AIAA Progress in Aeronautics and Astronautics Series, 1997.

Course (Catalog) Description
Analysis and design of solid propellant rockets, ramjets, dual-combustion ramjets, ducted rockets, and detonation-based propulsion systems. 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 and NASA CEA) and laboratory test firings for comparison with measured performance

Prerequisites and Co-requisites – AE3851 or consent of instructor.

Course Requirement - Required.

Course Outcomes
Upon completion of AE4452, students should be capable of the following skills:
1. Understand the performance and limitations of both rocket and air-breathing propulsion systems, including their thermodynamic cycle, operating envelopes, and mission application.
2. Calculate the motor/engine performance for a given propellant composition, combustion chamber conditions and nozzle configuration utilizing equilibrium combustion codes.
3. Evaluate propellant performance and the effects of non-compositional effects, erosive burning, and temperature sensitivity.
4. Select and size appropriate grain profiles for given mission requirements.
5. Analyze supersonic intake performance for on and off-design flight Mach numbers .
6. Analyze ramjet and scramjet combustor performance including flameholding impact on system specific impulse.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Compare propulsion devices for a particular tactical missile.
2. Determine combustor and overall motor performance as well as operating characteristics and Insensitive Munitions (IM) assessment

3. Propellant/fuel selection, grain design, and internal ballistics calculations (including performance losses).

Topics Covered

- Rocket propulsion concepts and fundamentals
- Combustion and Performance
- Solid Propellant Formulations and Burn-Rate Behavior
- Grain Profile and Internal Ballistics
- Supersonic Diffuser Operation
- Fuels and Combustors
- Flameholding
- Ramjet and Ducted Rocket Operation and Performance
- Scramjets and Detonation-Based Systems

AE4818: ACQUISITION, TRACKING, AND POINTING OF MILITARY SPACECRAFT (3 - 2)

Contact Hours - Meets three times per week for 50-minutes lectures and once a week for 2-hour lab period.

Course Coordinator/Instructor – Brij N. Agrawal, Jae Jun Kim

Textbook(s) and/or other Required Material
Required: Class notes
References :
• "Space Vehicle Dynamics and Control" by Bong Wie
• "Introduction to Dynamics and Control of Flexible Structures" by John Junkins and Youdan Kim
• "Analytical Mechanics of Aerospace Systems" by John Junkins and Hanspeter Schaub
• "Principles of Adaptive Optics" by Robert Tyson
• "Optical beam control", DEPS short course

Course (Catalog) Description
This course covers acquisition, tracking, and pointing (ATP) design for military systems, such as spacecraft and laser beam control systems. It covers effects of structural flexibility and jitter on ATP performance, jitter control, acquisition system, tracking algorithms, laser beam control, laser beam aberration due to atmosphere and its correction by using adaptive optics, and spacecraft attitude control. The course will also cover laboratory examples of ATP designs for military systems.

Prerequisites and Co-Requisites - AE3818, ME3521 or equivalent

Course Requirement – Selective Elective

Course Outcomes
- Understanding of the spacecraft Acquisition, Tracking, and Pointing (ATP) and ATP technology in general
- Understand spacecraft slew maneuvers and fine pointing control design with reaction wheels and control moment gyroscopes
- Understand spacecraft vibration and jitter control
- Understand optical beam control for military applications

Student Learning Objectives
At the completion of the course, students will be able to:
- Review spacecraft kinematics and dynamics
- Develop mathematical model for spacecraft with reaction wheels
- Develop mathematical model for spacecraft with control moment gyroscopes
- Analyze singularity of control moment gyroscope array
- Review singularity avoidance methods for CMG array

- Develop slew maneuver control design
- Develop fine attitude control design for spacecraft pointing
- Review optical beam control hardware

- Develop active jitter control methods
- Develop tracking methods for optical beam
- Develop simple adaptive optics system design and control
- Familiar with large segmented mirror space telescope

Topics Covered

- Introduction to Acquisition, Tracking, and Pointing of Military Systems
- Spacecraft ATP using Control Moment Gyroscopes
- ATP for Flexible Spacecraft
- Introduction to Optical Beam Control
- Target Tracking and Pointing
- Vibration and Jitter Control
- High Energy Laser Beam Control
- Adaptive Optics

AE4850 ASTRODYNAMIC OPTIMIZATION (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor – Isaac M. Ross

Textbook(s) and/or other Required Material
No text. Class notes.

Course (Catalog) Description
This course develops the basic principles of dynamic optimization as applied to Newtonian systems. After a review of optimal control theory, numerical methods and tools to solve boundary value problems (BVPs) are discussed in detail. Students have to develop "home-brewed" solvers as well as apply the latest MATLAB tools to solve BVPs. A sample problem from mechanical and aerospace engineering will be selected to apply BVP tools and assess their performance. Constrained dynamic optimization will be considered to formulate differential-algebraic BVPs. Emphasis will be on verification and validation of computed solutions, formulating the "problem of problems" to assess the impact of changing targeting conditions, model fidelity, and optimization criterion. A significant focus of the course will be on practical methods and numerical techniques. Where appropriate, the course will illustrate systems aspects of mission design.

Prerequisites and Co-Requisites - MA2121, SS3500, AE3815

Course Requirement - Required

Course Outcomes
- Completion of assigned homework problems
- Completion of a Term exam
- Completion of a project

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
- Understand the principles of astrodynamic optimization
- Acquire working knowledge of practical tools used in industry
- Exploit MATLAB-based tools for solving problems in dynamic optimization

Topics Covered
- Introduction to BVPs
- Tools for Solving BVPs
- Low-Thrust Orbit Transfer Problem
- Constrained Dynamic Optimization
- Example Problems
- Term Project

AE4870 – SPACECRAFT DESIGN AND INTEGRATION I (4-0)

Contact Hours - Meets four times per week for 50-minute lectures.

Course Coordinator/Instructor – Brij N. Agrawal/Jennifer Rhatigan

Textbook(s) and/or other Required Material
Text: Larson, W.J., Wertz, J.R., Space Mission Analysis and Design, Microcosm Press, El Segundo, CA, 2005.
Agrawal, RN., Design of Geosynchronous Spacecraft, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1986.

Course (Catalog) Description
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 and Co-Requisites – AE2820, AE3804, AE3851

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Develop expertise in space system engineering, inter-relationship of performance requirements of subsystems.
2. Develop expertise in performing trade-off and select spacecraft configuration and design that best meets the mission requirements.
3. Develop written communication skills by drafting a report on a geosynchronous spacecraft bus design project.
4. Become familiar with the state-of-art of spacecraft sub-system design and associated development risks.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:

1. Describe spacecraft configurations and assess the impact of spacecraft orbit, mission, and launch vehicle.
2. Estimate mass and power requirements for a spacecraft.
3. Describe launch vehicles and their performance.
4. Explain orbit elements, delta V required for station-keeping and station repositioning maneuvers, eclipses, and launch windows.
5. Explain principles of solar arrays, state-of-art of solar arrays, batteries, power conditioning electronics, and design of electric power sub-system.

6. Explain the principles of spin-stabilization, gravity gradient and three-axis reaction wheels system and the preliminary design of attitude control subsystem, sensors, and the estimation of disturbance torques.

Topics Covered

The topics covered in this course include a review of spacecraft configurations and the impact of spacecraft orbit, mission, and launch vehicle; estimation of spacecraft mass and power; launch vehicles; orbits; and preliminary design of spacecraft attitude control, propulsion, electric power, structures, thermal, and communications subsystems, and preliminary design of geosynchronous spacecraft bus.

1. Explain the principles of hydrazine, electro-thermal, bipropellant, and ion thrusters. Perform the preliminary design of a propulsion subsystem.
2. Conduct the preliminary design of a spacecraft structure, launch loads, materials, design criteria, structural configuration, design of structural elements, such as shells, struts, panels. Conduct trade-off of mass, cost and reliability.
3. Conduct the preliminary design of spacecraft thermal control, radiation, solar input, and thermal elements such as radiators, insulation, heat pipes, louvers, calculation of spacecraft temperature. Describe an example of spacecraft thermal control and testing.
4. Conduct the preliminary design of a spacecraft communications subsystem including transponder, antennas, link budget and modulation type.
5. Conduct an individual geosynchronous spacecraft bus design project for a given payload design and mission. Estimate the total spacecraft mass and select an appropriate launch vehicle.

AE4871 – SPACECRAFT DESIGN AND INTEGRATION II (2-4)

Contact Hours - Meets two times per week for 50-minute lectures and discussions and twice per week for a 2-hour lab period each.

Course Coordinator/Instructor – Brij N. Agrawal/Jennifer Rhatigan

Textbook(s) and/or other Required Material
Text: Instructor's notes and reference material

Course (Catalog) Description
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.

Prerequisites and Co-Requisites – AE4870

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Develop expertise in space system engineering, inter-relationship of performance requirements of subsystems.
2. Develop expertise in performing trade-off and select spacecraft configuration and design that best meets the mission requirements.
3. Develop oral and written communication skill by in presenting selected spacecraft design to reviewers, subject matter experts.
4. Become familiar with the state-of-art of spacecraft sub-system design and associated development risks.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Conduct a team spacecraft design project for the specifications provided by a sponsor, equivalent to a response to request for proposal (RFP).
2. Form a team with a project manager with overall responsibility for the project, including schedule, design reviews and final report, system engineer responsible for the spacecraft configurations and system trade-offs, and subsystem engineer, including cost and tests.
3. Explain the specifications provided by the sponsor and identify the areas where modifications may be required and obtain final specifications approved by the sponsor.
4. Identify the primary design drivers for the spacecraft.
5. Perform system trade-offs and select spacecraft configuration, which best meets the specifications, keeping in mind the cost and reliability as important design drivers.

6. Make a presentation at a mid-term design review to the sponsor on system trade-offs and recommended spacecraft configuration and obtain sponsor approval.
7. Perform detailed subsystem designs using the design tools; include the selection of components, manufacturers, masses and sizes and location on the spacecraft, and analysis to meet the performance requirements.
8. Make a presentation of the spacecraft design at the final design review for the sponsor and reviewers from industry, NASA, and DoD; for each subsystem, include performance requirements, design trade-offs, subsystem design description, and performance verification by analyses, mass and power.
9. Based on the comments from reviewers, make modifications to the spacecraft design, if necessary.
10. Write a final project report on the spacecraft design.

Topics Covered

- Spacecraft mission requirements
- Assignment of responsibilities of the team members
- Weekly progress reports, system trade-offs, design drivers, spacecraft configurations
- Requirements for mid-term design review
- Finalization of spacecraft configurations
- Detailed subsystem design
- Requirements for final design review
- Comments from reviewers
- Requirements for the report.

AE4881 AEROSPACE TRAJECTORY PLANNING AND GUIDANCE (2-4)

Contact Hours - Meets two times per week for 50-minute lectures and twice per week for a 2-hour lab period.

Course Coordinator/Instructor – Isaac M. Ross

Textbook(s) and/or other Required Material - No text. Class notes.

Course (Catalog) Description
This course covers the theory, computation and practical implementation of integrated trajectory planning and guidance algorithms for aerospace vehicles. The theory is based on the next generation of dynamical systems in mechanical and aerospace engineering. Examples will be drawn from a sample of DoD problems in space systems, missile engineering and small munitions. After a review of the state of practice, a unified theoretical framework for solving practically constrained trajectory problems will be developed. The Karush-Kuhn-Tucker conditions will form the foundations of constraint violation and validating optimality conditions. Multiplier theory and its use in solving practical problems will be covered from a real-time computational viewpoint. No-fly zones and engineering requirements will be formulated as a mathematical mixture of state and decision-variable constraints. Extensive MATLAB-based mini-projects will form the core of the laboratory experience. These projects are designed for students to learn the process of constructing a flyable trajectory-planning algorithm from first principles to an integrated guidance system.

Prerequisites and Co-requisites – AE4850 or ME4703 or ME4822 or Consent of Instructor

Course Requirement – Not required

Course Outcomes (Course competencies that align with student outcomes)

a. Support a better preparation of students in the MAE Dept (pursuing degrees in either mechanical (570) or astronautical (591) engineering) towards the goal of understanding the emerging challenges and advancements in aerospace systems.
b. Understand the rapid advancements in diverse aerospace systems in a manageable and coherent manner.
c. Provide a unified fundamental foundation in theory so that our graduates can manage and understand the next generation of military systems be it air, space or missile platforms.
d. Provide an avenue to cross-pollinate ideas in engineering and practical military operations using a clear and unified theoretical language supported by mathematical fundamentals

Student Outcomes Addressed by Course

a. Understand and explain the major deficiencies and challenges in current guidance systems in a mathematically justifiable manner.

b. Understand the scientific underpinnings of trajectory planning and guidance.
c. Achieve proficiency at the engineering level of the mathematics of constraint satisfaction, their violations and their impacts on practical flight.
d. Understand first-hand the emerging tools and techniques for verification and validation of prototypical flight codes.
e. Achieve proficiency in implementation of trajectory planning and guidance algorithms.
f. Demonstrate a flyable end-to-end algorithm for a platform of their choice.

Topics Covered

CHAPTER 1 REVIEW OF THE STATE OF PRACTICE

a) Brief history of decision-making hierarchy in dynamical systems
b) Overview of a layered planning framework in space, missile and UAV systems
c) Review of classical guidance: PEG, PN etc.
d) Review of MATLAB/Simulink tools
e) MATLAB Project #1: Numerical implementation of a sample SOP algorithm

CHAPTER 2 MATHEMATICAL INTRODUCTION TO TRAJECTORY PLANNING

a) Introduction to nonlinear vehicle kino-dynamical systems
b) Typical decision variables in kinematic motion planning
c) Formulating full trajectory-planning problems as boundary value problems
d) Solving an unconstrained boundary value problem
e) Review of multiplier theory from optimal control
f) Multiplier theory as a verification and validation tool
g) MATLAB Project #2: Formulating and solving an unconstrained problem

CHAPTER 3 CONSTRAINT HANDLING – 1

a) Introduction to constraints: engineering vs operational.
b) A unified mathematical formulation of constraints.
c) Introduction to duality between cost and constraints
d) Introduction to Karush-Kuhn-Tucker conditions
e) Inner loop considerations for formulating constraints on decision variables
f) MATLAB Project # 3: Formulating and solving a constrained problem -1

CHAPTER 4 CONSTRAINT HANDLING – 2

a) Introduction to state variable inequality constraints
g) Revisiting the Hamiltonian Minimization Condition
h) Modification of the adjoint equations
i) State-variable constraints in space, missile and UAV systems
j) MATLAB Project # 4: Formulating and solving a constrained problem - 2

CHAPTER 5 INTEGRATING TRAJECTORY PLANNING WITH GUIDANCE

a) Impact of open-loop trajectory with closed-loop control
d) Fundamentals of guidance-control interaction: a double-integrator example
e) Adapting the new principles for a real-world dynamical system
f) MATLAB Project #5: Integration of algorithms from previous projects

CHAPTER 6 SELECTION OF CAPSTONE PROJECT

a) A menu of challenge problems in DoD space missions
b) A menu of challenge problems sponsored by NAWCWD
c) A menu of challenge problems sponsored by PMA-242

AE0810 – Thesis Research (0-8)

Contact Hours – Meets once a week for one (1) hour seminar

Course Coordinator/Instructor – Isaac M. Ross

Textbook(s) and/or other Required Material
None assigned.

Course Description
Every student conducting thesis research will enroll in this course.

Prerequisites and Co-Requisites – Selection and approval of thesis topic

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Understand requirements for graduate level research.
2. Demonstrate ability to conduct in depth technical investigation and analyses.
3. Demonstrate ability to clearly present and discuss conclusions of the thesis, both orally and in writing.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Develop skills in conducting graduate level research.
2. Develop problem-solving skills unique to research area under supervision of advisor.
3. Improve time management skills.
4. Find and evaluate technical literature.
5. Enhance abilities in written and oral communication.

Topics Covered
• Unique to student thesis area

ME2501 - Statics (3-0)

Contact Hours - Meets 3 times a week for 50-minute lectures

Course Coordinator/Instructor – Chris Adams

Textbook(s) and/or other Required Material
Text: Engineering Mechanics: Statics (Bedford and Fowler, 5th Edition, Prentice-Hall.

Course Description (from Catalog)
Forces and moments, particles and rigid bodies in equilibrium. Simple structures, friction, first moments and centroids. Prerequisite: MA1113 (may be Forces and moments, particles and rigid bodies in equilibrium. Simple structures, friction, first moments and centroids.

Prerequisites and Co-requisites – ME1115 (may be taken concurrently)

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Completion of assigned homework problems
2. Completion of two exams spaced throughout the quarter
3. Final comprehensive exam

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. To make the students proficient in understanding forces and moments, particles and rigid bodies in equilibrium

Topics Covered
- Introduction to Engineering Mechanics; Vectors
- Vectors
- Forces
- System of Forces and Moments
- Objects in Equilibrium
- Structures in Equilibrium
- Centroids and Centers of Mass
- Moments of Inertia
- Moments of Inertia
- Final

ME2801 - Introduction to Engineering System Dynamics and Control (3-2)

Contact Hours - Meets 3 times per week for 50-minutes lectures and two 50-minute labs per week.

Course Coordinator/Instructor – Brian Bingham

Textbook(s) and/or other Required Material
Text: Katsuhiko Ogata, Modern Control Engineering, 5th edition, Prentice-Hall, 2010.

Course Description (from Catalog)
Review of Laplace Transform, system modeling principles and reduction to mathematical forms. Block diagrams, open- and closed-loop systems, feedback control, Single-Input / Single-Output (SISO) control systems, state-space representation of Multiple-Input / Multiple-Output (MIMO) control systems. Response of first- and second-order systems to standardized aperiodic inputs, transient response, steady-state errors. Complex-plane representation of open-loop systems. Stability methods including Routh-Hurwitz criterion and the root locus method. Design of PID controllers and compensators in the time- and s-plain domains. Introduction to frequency response methods (utilizing Bode, Nyquist and Nichols diagrams) for determining closed-loop stability, gain and phase margins. Loop shaping, phase lead and phase lag compensators design.

Prerequisites and Co-Requisites
AE2440/EC2440 and MA2121

Course Requirement – Required

Course Outcomes - (Course competencies that align with student outcomes)
1. Develop a mathematical model of any Naval engineering system;
2. Express it in terms of transfer function and block-diagram;
3. Analyze its performance in the time- and s-plane domains using root loci;
4. Design a controller/compensator to meet the requirements.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Model simple systems by differential equations, block diagrams, and transfer functions.
2. Construct the state-space representation of a linear dynamic system.
3. Describe the behavior of a linear system by its time history response to various inputs.
4. Recognize the problems a naval engineering system might have in terms of accuracy, relative stability, speed of response.
5. Understand the basic principles of feedback stabilization.
6. Design a control law for a simple system based on the knowledge of the actions of proportional, derivative and integral controllers with respect to transient response and steady-state error.
7. Carry out a PID (proportional-plus-integral-plus-derivative) controller design and

optimize (or improve) it for increased robustness.
8. Produce a root-locus plot of a system in the complex plane, and examine its stability.
9. Apply the concepts of lead, lag, and lead-lag compensation for stabilizing or improving the dynamics of a system and estimate the increase of system's performance.

Topics Covered

- Introduction to System Dynamics; The Laplace Transform; MATLAB/Simulink Refresher
- Mathematical Modeling of Dynamic Systems: Transfer Functions, Block Diagrams, State-Space Representation, Linearization
- Transient and Steady-State Response Analyses of First and Second-Order Systems
- Transient and Steady-State Response Analyses of Higher Order Systems; Solution of the State Equation
- Block Diagram Algebra; Routh's Array and Stability Analysis; Automatic Controllers; Feedback Control Systems
- System's Type; Velocity Feedback Systems; Disturbance Rejection; Tuning Rules for PID Controllers; Modification of PID Control Schemes
- Root-Locus; Stability Analysis; Root Locus for Systems with Transport Lag; Positive-Feedback Systems; Parameter Design and Sensitivity
- Lead, Lag and Lead-Lag Compensators Design by the Root-Locus Method; Parallel Compensation
- Frequency Response; Bode Diagram; System Stability via Bode Diagram
- Nyquist Plot; Nyquist Stability Criterion; Nichols Chart
- Phase Lead, Lag, and Lead-Lag Compensation; Loop Shaping

ME3205 – Missile Aerodynamics (4-1)

Contact Hours - Meets 4 times a week for 50-minute lectures and once weekly for lab.

Course Coordinator/Instructor – Max F. Platzer

Textbook(s) and/or other Required Material
Instructor Notes are provided.
Supplemental Textbook: "Aerodynamics: Selected Topics in the Light of their Historical Development", by Theodore von Karman.

Course Description (from Catalog)
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.

Prerequisites and Co-Requisites – ME3201

Course Requirement – Required for the Missile Track

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the fundamental mechanism enabling the generation of lift on airfoils, finite-span wings and bodies of revolution
2. Understand the fundamental mechanisms causing friction and pressure drag on bodies in viscous flow
3. Understand the mechanism causing induced (vortex) drag on finite-span wings
4. Understand the origin and method of derivation of the equations describing viscous flow, inviscid incompressible and compressible flow, and inviscid irrotational flow
5. Be able to apply potential flow modeling to the determination of the flow over two-dimensional bodies using source/sink/vortex superposition
6. Be able to derive the linearized equations for subsonic and supersonic flow
7. Be able to analyze the flow over slender airfoils in subsonic and supersonic flow
8. Understand the mechanism causing wave drag in transonic/supersonic flight
9. Be able to analyze the flow over missiles using the slender wing/body theory
10. Be able to develop expressions for the lift, drag, and aerodynamic stability of missiles
11. Understand the nature of laminar and turbulent flow and the reasons causing transition from laminar to turbulent flow
12. Be able to derive equations modeling turbulent flow using the Reynolds-averaging concept
13. Understand the nature of attached and separated flow and the reasons causing flow separation

Topics Covered

- Concepts of Low Speed Aerodynamics
- Elements of Incompressible 2-D Potential Flow Analysis
- Concepts of High-Speed Aerodynamics
- Elements of High-Speed Flow Analysis
- Slender Wing/Body Theory
- Concepts of Hypersonic Aerodynamics
- Higher Order methods
- High Angle of Attack Aerodynamics
- Compressible Viscous Flow Analysis
- Introduction to missile aerodynamic design codes

ME3521 - Mechanical Vibrations (3-2)

Contact Hours - Typically meets 4 lectures hours per week, and three 1-hour lab demonstrations, followed by students working in the lab independently.

Course Coordinator/Instructor – Joshua H. Gordis

Textbook(s) and/or other Required Material
Course lecture slides prepared by Course Coordinator. Textbook optional.

Course Description (from Catalog)
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 and Co-Requisites - ME2502, ME2601, MA2121 or equivalent (may be taken concurrently).

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Develop understanding of the physics of mechanical and structural vibration
2. Gain ability to develop analytic vibration models of single- and multi-degree-of-freedom mechanical and structural systems.
3. Develop ability to analyze simple system vibration models and calculate response due to initial conditions and external forcing functions.
4. Gain understanding of fundamental concepts including free and forced response, frequency response.
5. Gain understanding of, and ability to apply matrix methods for the vibration analysis of multi-degree-of-freedom mechanical and structural systems.
6. Gain ability to make basic vibration measurements and analyze the data obtained.
7. Be able to identify critical speeds of simple rotor systems, design isolation systems, and apply orthogonality in the diagnosis and solution of vibration problems.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Model simple systems: Understand the concept of degrees-of-freedom and determine the number of degrees-of-freedom required to model simple systems. Develop differential equation models of simple mechanical and structural systems using both Newton's 2nd Law and Lagrange's equations. Understand and explain damping models in vibration.
2. Model multi-degree-of-freedom systems: Understand and explain the relationship between lumped/discrete parameter models, continuous/distributed parameter models, and how these models are used to represent real structures.

3. Analyze models developed: Solve a single, and set of, 2nd order homogenous and nonhomogeneous differential equation(s), including the application of initial conditions.
4. Understand and explain the concepts of free response, forced response, and frequency response, and their relationships to the homogeneous and particular solutions in the total solution of a vibration problem.
5. Understand and explain the concepts of matrix methods in vibration analysis, including eigenvalues and eigenvectors, modal analysis, and orthogonality.
6. Understand the use of basic experimental equipment and techniques, including the measurement of transient and frequency response, the use of accelerometers, load cells, shakers, and instrumentation. Understand and explain the use of the FFT in analyzing vibration test data.
7. Understand and apply vibration theory: Identify the critical speed of rotating shafts, design vibration isolation, and calculate transmissibility. Understand and apply vibration theory to the solution of Navy and DoD-relevant problems.

Topics Covered

- Module #1 Introduction (1 hours)
- Module #2 Undamped Single Degree-of-Freedom Oscillator (4 hours)
- Module #3 Damped Single Degree-of-Freedom Oscillator (4 hours)
- Module #4 Rayleigh's Energy Method (2 hours)
- Module #5 Harmonic Excitation of SDOF Systems (4 hours)
- Module #6 Introduction to Rotor Dynamics (2 hours)
- Module #7 Support Motion (3 hours)
- Module #8 Vibration Isolation & Transducers (2 hours)
- Module #9 Equivalent Viscous Damping (1 hours)
- Module #10 Multi-Degree-of-Freedom Systems: Free Response (4 hours)
- Module #11 Multi-Degree-of-Freedom Systems: Forced Response (3 hours)

ME4225 – Computational Fluid Dynamics and Heat Transfer (3-2)

Contact Hours - Five hours a week, 3 lecture hours and 2 computer laboratory hours

Course Coordinator/Instructor – Garth V Hobson

Textbook(s) and/or other Required Material
Instructor Notes

Course Description (from Catalog)
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 and Co-Requisites - ME3201, ME3450

Course Requirement - Elective

Course Outcomes
1. The emphasis will be on the numerical solution of sets, of partial differential equations, that describe fluid flow. The philosophy used throughout the course, is the construction and use of computer programs, leading to an understanding of the various algorithms
2. Term project using ANSYS WorkBench to solve fluid flow problems with CFX or Fluent.

Student Learning Objectives
The course will progress along roughly two parallel paths. On the one hand, students will first briefly go over the underlying governing equations of fluid flow, followed by a detailed development of the finite volume methods and their application to these equations. Time marching techniques will be covered in attempt to compute compressible flow with the presence of shock waves. And on the other hand, they will also simultaneously get hands-on experience in the computer lab by working with a typical commercially available CFD package. One of the goals of the course is to synthesize these two approaches.

Topics Covered

- INTRODUCTION: Computational trends and historical perspective
- GOVERNING EQUATIONS OF FLUID DYNAMICS (Inviscid)
- SOLUTION OF THE STEADY ONE-DIMENSIONAL EULER EQUATIONS: Implicit and Explicit schemes for the one-dimensional Euler equations, Flux splitting and upwind differencing, Implementation of boundary conditions
- STEADY STATE SOLUTIONS OF THE TWO-DIMENSIONAL EULER EQUATIONS: Explicit algorithms for the two-dimensional Euler equations, Implicit methods for the solution of the Euler equations
- NUMERICAL METHODS FOR THE NAVIER-STOKES EQUATIONS: Tensors, Reynolds equations for turbulent flow, Introduction to turbulence modeling, Turbulent flows, two-equation turbulence models, Unsteady two-dimensional N-S calculations,

Selected topics (dependent on the selection of term projects), Advanced Topics – Turbulence models

ME4522: Finite Element Methods in Structural Dynamics (4-0)

Contact Hours - Meets for 4 lecture-hours per week.

Course Coordinator/Instructor – Joshua H. Gordis

Textbook(s) and/or other Required Material
Course notes prepared by Course Coordinator.

Course Description (from Catalog)
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 and Co-Requisites - ME3521 Mechanical Vibrations

Course Requirement - Elective.

Course Outcomes (Course competencies that align with student outcomes)
1. Develop understanding of the physics of multi-degree-of-freedom structural dynamic systems.
2. Gain ability to develop analytic vibration models of multi-degree-of-freedom structural dynamic systems using Lagrange's equations. Develop understanding of, and the ability to apply concepts such as matrix symmetry, rank, and definiteness to analyze structural system matrices.
3. Develop basic understanding of the finite element method in dynamics, and ability to write a simple finite element computer program for the analysis of simple structures.
4. Develop ability to use modal superposition to calculate free and forced time domain response of multi-degree-of-freedom linear structural dynamic systems, including the use of mode displacement and mode acceleration formulations.
5. Gain understanding of the concepts of, and ability to calculate steady-state response of multi-degree-of-freedom structural dynamic systems, including impedance and frequency response, using both direct and modal formulations.
6. Understand and manage the error incurred by the use of truncated modal expansions for response calculation.
7. Gain understanding of, and ability to calculate reduced-order models of multi-degree-of-freedom structural dynamic systems.
8. Gain understanding of basic theory of experimental modal analysis.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:

1. Model multi-degree-of-freedom (MDOF) linear structural dynamic systems: Understand the concept of degrees-of-freedom and determine the number of degrees-of-freedom required to model MDOF systems. Develop differential equation models of MDOF systems using Lagrange's equations. Understand and apply proportional damping in MDOF models.
2. Analyze structural matrices of mass, stiffness, and damping for correctness. Apply tests of symmetry, rank, and definiteness to discern properties and correctness of matrices.
3. Understand the major steps in a structural dynamic finite element analysis and write a simple dynamic finite element analysis computer program.
4. Understand and solve the eigenvalue problem. Apply modal superposition to calculate free and forced time domain response of multi-degree-of-freedom linear structural dynamic systems, including the use of mode displacement and mode acceleration formulations.
5. Assess numerically the convergence achieved in a truncated modal superposition calculation for transient and steady-state response.
6. Calculate simple reduced-order models of linear structural dynamic models.
7. Understand and explain the basic theory of experimental modal analysis.
8. Understand and explain the role of computational structural dynamics in the dynamic design of Naval ship structures, as well as ground and air vehicles.

Topics Covered

- Module #1 Introduction
- Module #2 Lagrange's equations and multi-degree-of-freedom systems; Coordinate coupling
- Module #3 Finite element formulation for dynamic beam bending; Properties of structural matrices
- Module #4 Modal analysis for multi-degree-of-freedom systems; Proportional and non-proportional damping; Rigid body modes
- Module #5 Mode Displacement formulation; Transient response
- Module #6 Mode Acceleration formulation
- Module #7 Mode superposition for systems with rigid-body modes; Inertia relief solution
- Module #8 Frequency response
- Module #9 Estimation of mode shapes from frequency response
- Module #10 Model Reduction

ME4550 - Random Vibration and Spectral Analysis (3-2)

Contact Hours - Meets 4 times per week for 50 minutes lectures or in 2 two-hours lectures when taught in the distance-learning (VTC) mode. Lab periods are included.

Course Coordinator/Instructor – Joshua Gordis

Textbook(s) and/or other Required Material
Text Book: Julius S. Bendat and Allan G. Piersol, "Engineering Applications of Correlation and Spectral Analysis," 2nd Edition, John Wiley & Sons, 1993; ISBN: 0471570559
References: D. E. Newland, "An Introduction to Random Vibration, Spectral and Wavelet Analysis," 3rd Edition, Addison-Wesley Pub. Co., ISBN: 0582215846, 1993
Julius S. Bendat and Allan G. Piersol, "Random Data: Analysis and Measurement Procedures," 3rd Edition, John Wiley & Sons, 1993; ISBN: 0471317330

Course Description (from Catalog)
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.

Prerequisites and Co-Requisites – ME3521 or equivalent.

Course Requirement – Elective.

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the concepts of random vibration and spectral analysis.
2. Apply probability concepts to random phenomena and vibration data.
3. Solve excitation-response problems for linear system subjected to random loading.
4. Understand transmission of random vibration into mechanical systems.
5. Predict system response characteristics based on random excitation.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Solve for response in systems involving cross-correlations.
2. Apply statistics of both narrow and wide band processes.
3. Utilize Fourier analysis and Spectral analysis to solve engineering problems.
4. Determine characteristics of random data in realistic physical systems.
5. Estimate the system frequency response function based on excitation-response data.
6. Compare the response of systems subjected to random and forced vibration.

Topics Covered

- Introduction: Characteristics of Random Data
- Physical System Response
- Probability Distribution: moments and average amplitude measures
- Correlations: autocorrelation and cross-correlation
- Fourier Analysis: Fourier integral and complex form of Fourier transform
- Auto(Power) and Cross Spectral Density Functions
- Excitation-response Relations for Linear System
- Frequency Response Function Measurements and Error Analysis
- Transmission of Random Vibration
- Statistics of Narrow Band Process
- Accuracy of Measurements
- Failure due to Random Vibration
- System Identification and Response Prediction
- Source Location and System Estimation

ME4702 – Engineering Risk Benefit Analysis (3-2)

Contact Hours - Meets once a week for three hours of live lecture via Elluminate with a two-hour asynchronous laboratory work

Course Coordinator/Instructor – Mark M. Rhoades

Textbook(s) and/or other Required Material
Modeling Risk + DVD, Mun, Second Edition, Wiley, 2010.
Identifying and Managing Project Risk, Kendrick, Second Edition, AMACOM, 2009
NASA Probabilistic Risk Assessment Guide, NASA, 2002

Course Description (from Catalog)
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.

Prerequisites and Co-Requisites - OS3104/EO4021 or equivalent course in probability, or consent of instructor.

Course Requirement - Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Students will have advanced knowledge in the specialized discipline of risk analysis and management in support of engineering programs, including Mechanical Engineering.
2. Students will have high level of communication skills including technical writing and oral presentation of their risk analysis and risk management recommendations.
3. Students will have the ability to independently identify, formulate and solve risk problems as they relate to engineering problems.
4. Students will have the ability to apply risk related technical knowledge in a leadership role related to national security.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of each of the course modules students will be able to:
1. Define the various parts of Risk Management according to DoD policy.
2. Be familiar with Risk Terminology
3. Be able to articulate the PRA process
4. Be able to predict a systems reliability based on a system's block diagram
5. Perform multiple simulations at once in Risk Simulator
6. Incorporate correlations into Risk Simulator

7. Understand that cost risk and schedule risk is present throughout a product's lifecycle
8. Convert raw data into probability distributions that one can use in risk assessments or decision trees.
9. Define the customer's value and objectives
10. Create a decision table process
11. Discuss why it is important to combine normative and descriptive models

Topics Covered

- DoD Risk Management Policy and Procedures
- Project Risk
- NASA Probabilistic Risk Assessment Process
- Basic Reliability and Technology Risk
- Monte Carlo Analysis including Correlation and Distribution Truncation
- Cost Risk, Schedule Risk and Uncertainty
- Using Data, Forecasting and Subjective Probability
- Basic Decision Analysis
- Multi-Attribute/Multi-Objective Preference Models & Benefit/CAIV Analysis

ME4731 - Engineering Design Optimization (4-0)

Contact Hours - 4 lecture hours/week

Course Coordinator/Instructor – Joshua H. Gordis

Textbook(s) and/or other Required Material
Course notes prepared by Course Coordinator.

Course Description (from Catalog)
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 and Co-Requisites – AE2440, ME2601, MA3232.

Course Requirement - Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Develop ability to formulate engineering design problems as constrained optimization.
2. Develop understanding of, and ability to identify design variables, constrains and objective functions.
3. Develop understanding of Taylor series, and the resulting optimality conditions for functions of one variable.
4. Understand the concept of search directions, and how they can be generated using zeroth-, first- and second-order algorithms.
5. Develop understanding of single variable searching, including bounding phase and interval refinement strategies.
6. Develop understand of Taylor series for multi-variable functions, and the optimality conditions.
7. Develop understanding of linear programming and the simplex algorithm.
8. Understand how to build a simply unconstrained nonlinear optimization program.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Formulate an engineering design problem as an optimization problem, identifying design variables, constraints and objective functions
2. Calculate the gradient and Hessian matrices for single- and multi-variable functions.
3. Use the gradient and Hessian matrices in optimality criteria to identify stationary points and optimal points.
4. Write a single-variable (line search) unconstrained search program.
5. Construct search directions using basic optimization algorithms, including Cauchy's method, Newton's method, conjugate direction method, Powells Method.
6. Write a multi-variable, unconstrained optimization program.

7. Solve linear and nonlinear optimization problems using a commercial optimizer.

Topics Covered

- Introduction
  Sample engineering problems, Basic notation, Problem formulation, Optimum design concepts, case studies
- Unconstrained Problems
  Single variable functions - Properties and optimality, Region elimination methods,
  Polynomial estimation, Line searching, Functions of several variables, Gradient based methods - Cauchy's, Newton's, Conjugate gradient, Quasi-Newton
- Constrained Problems - Linear
  Linear programming, Problem definition, canonical form, Graphical solution
  Linear programming - Simplex method. Sample problems
- Constrained Problems – Nonlinear
  Constrained optimality conditions, Properties, Lagrange multipliers, Kuhn-Tucker conditions, Successive linear programming, Generalized reduced gradient method,
  Multi-objective problems, Sensitivity analysis, Mechanism optimization

ME4751 – Combat Survivability, Reliability and Systems Safety Engineering (4-1)

Contact Hours - Meets 4 times per week for 50 minutes lectures, and once per week for 50-minute separate computer laboratory period is used to perform calculations and have design discussions.

Course Coordinator/Instructor – Christopher A. Adams

Textbook(s) and/or other Required Material
Text: "Fundamentals of Aircraft Survivability Analysis and Design" Robert. E. Ball, 2nd Edition, AIAA Education Series, 2002.
Text: "Fundamentals of Ground Combat System Ballistic Vulnerability/Lethality" Paul Deitz, 1st Edition, AIAA Education Series, 2009.

Course Description (from Catalog)
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 and Co-Requisites - Consent of Instructor.

Course Requirement - Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the essential elements in the study of survivability, reliability and systems safety engineering for combat vehicles.
2. Apply the concepts of survivability design and related technologies
3. Calculate the probabilities of survivability.
4. Demonstrate practical knowledge in the design of battle-ready platforms.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Describe the six survivability enhancement concepts for susceptibility reduction and vulnerability reduction, and give at least one example of a feature for each concept.
2. Explain the Doppler phenomenon; determine a target's radial velocity, the maximum

unambiguous velocity, and blind speeds; and describe MTI and pulse-Doppler radars.
3. Compute the J/S and RB for self-screening jamming.
4. Describe how to reduce the RCS of an aircraft and explain the ways that radar absorbent material absorbs the impinging radar signal.
5. Compute an aircraft's single-hit vulnerable area for a combat system with non-redundant, redundant, non-overlapping, and overlapping critical components.
6. Determine the probability that a combat system is killed when hit by more than one penetrator using the binomial, Poisson, tree diagram, and simplified approach.
7. Conduct a survivability trade study on a combat aircraft, ship or ground vehicle.

Topics Covered

- Topics in Survivability: Set Theory and Event Probabilities; Engagement and Mission Assessment; Enhancement and Effectiveness; Threat Characteristics and Damage Processes; Radar, IR, Susceptibility/Vulnerability Assessment, Design

ME4811 - Autonomous Systems and Vehicle Control II (3-2)

Contact Hours - Meets four times a week (3 hours lecture, 2 hours lab)

Course Coordinator/Instructor – Isaac I. Kaminer

Textbook(s) and/or other Required Material
F. Papoulias, ”Multivariable Control of Ship Systems,” Online Notes, 2001

Course Description (from Catalog)
This course takes students through each stage involved in the design, modeling and testing of an unmanned system. The course is built around the creation og a fully functional command and control system for a typical robotic platform, e.g., unmanned aerial vehicle (UAV), unmanned surface vehicle (USV) or unmanned underwater vehicle (UUV). Students are presented with a challenge for applying unmanned systems to an authentic scenario of naval significance. Students are then guided through development of equations of motion, control design and system performance in the context of solving a real-world problem. Final designs are evaluated in a combination of simulation and experimental environments as appropriate.

Prerequisites and Co-Requisites – ME3801

Course Requirement - Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Analysis of linear systems
2. Synthesis of state and output feedback compensators for linear systems using Linear Quadratic Gaussian Theory
3. Lyapunov based analysis of nonlinear systems
4. Lyapunov based synthesis of nonlinear compensators
5. Implement and test all the designs in Matlab/Simulink software environment
6. Analysis of limit cycle behavior

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Design a compensator (controller and observer) for a linear system and verify its response using simulations,
2. Design a disturbance estimation and compensation control law
3. Perform an integral control design in state space
4. Set up the LQR/LQG optimization problems and solve using MATLAB/SIMULINK
5. Utilize Lyapunov functions to analyze nonlinear control systems
6. Utilize Lyapunov functions to design simple compensators for nonlinear systems
7. Analyze limit cycle behavior

Topics Covered

- State Feedback Control Law Design.
- Observer Design.
- Tracking Systems.
- Disturbance Estimation.
- Optimal/Sliding Mode Control.
- Linear Quadratic Gaussian Compensators.
- Effects of Noise.
- Analysis of Nonlinear Systems using Lyapunov Techniques
- Design of Nonlinear Systems using Lyapunov Techniques
- Analysis of Limit Cycles

ME/AE5810 – Dissertation Research (No Credit) (0-8)

Contact Hours – Meets on an adhoc basis

Course Coordinator/Instructor – Marcello Romano

Textbook(s) and/or other Required Material
None.

Course Description
Dissertation research for doctoral students. Required in the quarter following advancement to candidacy and then continuously each quarter until dissertation is approved by the Academic Council.

Prerequisites and Co-Requisites - Advancement to Candidacy

Course Requirement - Required (for doctoral program)

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the research being conducted by Mechanical Engineering Faculty.
2. Understand the NPS dissertation process.
3. Understand the library and other special resources available for research.
4. Be familiar with MAE laboratories and research programs.
5. Understand the fundamentals of giving a technical presentation.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Know our doctor of philosophy degree and dissertation requirements.
2. Be able to present intermediate research milestones to doctoral committee
3. Understand Navy, DoD, Industry, and Academia perspectives of R&D.
4. Be able to successfully defend ones dissertation.

Topics Covered
- Dissertation Requirements
- Dissertation Research Methods
- Dissertation Presentations

MS2201 – Introduction to Materials Science and Engineering (3-2)

Contact Hours – Meets three times a week for 50-minute lectures, and for a 2-hour laboratory sessions weekly.

Course Coordinator/Instructor – Claudia Luhrs

Textbook(s) and/or other Required Material
Materials Science and Engineering – an Introduction, 8th edition, William D Callister Jr., David G Rethwisch

Course Description
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 mathematics, physics and chemistry.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Be able to relate the observed characteristics and properties of engineering material to their atomic and crystalline structure, and processing history.
2. Have an understanding of how material classification, selection process, design, production and characterization of properties are viewed through the four major areas.
3. Approach problem solving from a materials design/generation/application perspective as it relates to real life situations.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Understand electronic configuration of atoms, types of primary and secondary bonding.
2. Identify, compare and describe three-dimensional packing of atoms for different types of materials. Recognize the concept unit cell and Bravais lattice, differentiate crystal structures, and examine basic X-ray diffraction patterns. Justify knowledge on crystallography and propose materials for specific applications.
3. Recognize, illustrate structures of polymeric materials – calculate molecular weight and % of crystallinity.
4. Identify type of defects and recognize effects in materials properties.
5. Understand fundamental laws of diffusion. Identify and contrast diffusion mechanisms and estimate values for concentration or time in diffusion problems. Examine factors that influence diffusion.
6. Learn basic principles of stress and strain, and related mechanical properties of materials.

Given an engineering stress-strain diagram determine modulus of elasticity, yield strength, tensile strength and estimate percentage of elongation. Compute ductility in terms of elongation and area reduction for material loaded in tension to fracture. Identify and compare hardness testing techniques.
8. Understand slip systems and their implication in plastic deformation. Review plastic deformation of ceramic and polymer materials.
9. Describe and differentiate strengthening mechanisms and heat treatment of metals.
10. Examine fundamentals of failure mechanism of materials – crack propagation and stress concentration. Describe impact fracture testing techniques.
11. Explain and perform computations related to phase transformation including lever rule, interpretation and construction of phase diagrams. Revise Iron-carbon phase diagram and identify microstructural implications.
12. Recognize nanomaterial and nanotechnology definitions, exemplify uses for materials at nanoscale and identify basic approaches to nanomaterials production.

Topics Covered

- Introduction
- Atomic Structure and Bonding
- Structure of Metals
- Structure of Ceramics
- Imperfections in Solids and Diffusion
- Mechanical Properties
- Dislocations and Strengthening Mechanisms
- Failure
- Phase Diagrams
- Phase Transformations

MS3202 – Properties, Performance and Failure of Engineering Materials (3-2)

Contact Hours - Meets 3 times per week for 50-minute lectures. Meets once per week for a two-hour laboratory section.

Course Coordinator/Instructor – Claudia Luhrs

Textbook(s) and/or other Required Material
Materials Science and Engineering: An Introduction, (W.D. Callister and D.G. Rethwisch), 8th Edition, Wiley 2009.
Recommended: Failure Analysis and Prevention, Metals Handbook Vol.11
Recommended: Failure Analysis and Prevention, Metals Handbook Vol.11

Course Description
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.

Prerequisites and Co-Requisites – MS2201 or equivalent or consent of instructor.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Be able to apply a rigorous failure analysis process to a failed structural component.
2. Be able to calculate stress states in complex geometries and predict ductile failure from the results.
3. Be able to quantitatively use fracture mechanics concepts and formulas to predict the failure of metallic and ceramic materials.
4. Understand the effects of environment on the potential failure of metallic structures.
5. Be able to qualitatively and quantitatively analyze fatigue failures in terms of mechanics and materials.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Write a failure analysis plan for a failed structural component.
2. Describe the concept of ductile-to-brittle-transitions in carbon steel and the technological importance thereof.
3. Be able to metallographically prepare a specimen for optical and electron microscopy.
4. Identify, by name and composition, the most common and important metallic alloys
5. Use Mohr's circle to calculate the relationships between complex stresses.
6. Quantitatively predict fracture in metallic and ceramic components using linear elastic

fracture mechanics.
7. Describe and differentiate between the fundamental types of corrosion, the chemistry and physics that control them, and basic means of mitigating them.
8. Quantitatively predict fatigue failures from either a stress-cycle approach or a crack growth rate approach.

Topics Covered

- Course Introduction and failure modes
- Fracture Mechanics and impact testing
- Fatigue, creep and wear
- Corrosion
- How to conduct a FA (study cases)
- Review of phase diagrams and transformations (ITT and CCT)
- Processing and classification of metal alloys
- Processing of ceramics and polymers
- Properties of Materials: electric, thermal and magnetic
- Final projects-study cases presentations

MS4312 - Characterization of Advanced Materials (3-2)

Contact Hours - Meets 3 times per week for 50-minute lectures. Meets once per week for a two-hour laboratory section.

Course Coordinator/Instructor – Andy Nieto

Textbook(s) and/or other Required Material
Microstructural characterization of Materials: D. Brandon & W. D. Kaplan
Elements of X-ray diffraction: BD Cullity
Transmission Electron Microscopy: A textbook for Materials Science by D. B. Williams & B. C. Carter

Course Description (from Catalog)
This course is structured to provide an insight into the various tools available for advanced physical examination of engineering materials. Topics covered include thermal analysis, X-ray diffraction, and optical, scanning, transmission and scanning transmission electron microscopies as well as various spectroscopic techniques.

Prerequisites and Co-Requisites – MS2201

Course Requirement – Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the operational fundaments of Thermal Analysis methods (TA), X-ray Diffraction techniques (XRD), Scanning and Transmission Electron Microscopy (SEM and TEM) and Spectroscopy.
2. Identify the capabilities and limitations for each technique.
3. Analyze samples with the mentioned characterization techniques and interpret the outcome data.
4. Analyze journal articles and how the techniques are used to aid material design, selection, quality control or applicability.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Understand the basic operational principles of thermal analysis, electron microscopy, X-ray diffraction techniques and basics of spectroscopy.
1. Realize the capabilities and limitations of these materials characterization methods.
2. Gain first-hand experience on sample preparation and instrument operation.
3. Develop the skills to obtain qualitative and quantitative data from various techniques through the development of a laboratory project.
4. Analyze the data outcome of the use of the techniques and recognize how that data could aid material selection for a given application, provide quality evaluation or insight of materials properties.
5. Appreciate the choice of using appropriate techniques including complimentary methods in materials evaluation.

6. Understand how other scientists and engineers use the techniques through a literature review (journal articles presented in class).

Topics Covered

- Introduction
- Optical Microscopy
- Crystallography
- X-ray Diffraction Method
- Thermal Analysis
- Electron Microscopy Fundamentals
- Spectroscopy techniques
- Focus Ion Beam

MS4410 Advanced Energy Materials (4-0)

Contact Hours - Meets 4 times per week for 50-minute lectures.

Course Coordinator/Instructor – Jonathon Phillips

Textbook(s) and/or other Required Material
None; class notes

Course Description (from Catalog)
As the Navy moves toward 'all electric ships' engineers will be responsible for dramatic changes in key electric systems. Officers responsible for designing and/or selecting electric systems for novel weapons to drive trains will need a thorough grounding in fundamentals in order to fully understand newly developed options and possible problems. The course provides the physics and engineering essentials of capacitors, batteries and fuel cells. For capacitors, topics include electric fields, voltage, Gauss's Law, the development of the fundamental equations for capacitors, equivalent circuits. Batteries are treated as electrical systems that convert the free energy change of reaction into electrical energy. The first fundamental topic is a review of the First and Second Laws of Thermodynamics, leading to the concept of free energy. The students are introduced to both modern (e.g. Li ion) and classic (e.g. Pb acid) battery systems. The effect of phase change, temperature, dilution, etc. on actual energy delivered is explored. Fuel cells are introduced as devices that act primarily like batteries that is they convert chemical energy into electrical energy, but with independent fuel supplies. Energy analysis of pertinent Navy-relevant examples are developed, such as the energy and power requirements of rail guns, electromagnetic launch systems (EMALS) and laser systems.

Prerequisites and Co-Requisites – MS3202

Course Requirement - Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the physics of capacitors.
2. Will become familiar with means to increase energy density including longer dipole formation in dielectrics, high surface area electrodes.
3. Ability to build and characterize performance of capacitors.
4. Knowledge of mechanisms of failure, leakage, saturation, and simple capacitor circuits.
5. Understanding of chemical to electrical energy conversion in batteries
6. Understanding of 1st/2nd Law of Thermodynamics leading to free energy, application to batteries.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Develop an understanding of the needs of future all-electric navy.

2. Students will be able to explain why both capacitors and batteries will play a key role in all electric navy.
3. The student will be able to apply the basic physics (fields, volts, Gauss law, polarization, etc) of capacitors, the fundamentals of the relationship between geometry and capacitance.
4. Apply fundamental physics to the analysis solid-state dielectric structures and transport behavior of super-dieletric materials and supercapacitors.
5. The student will be able to evaluate the impact on power delivery and energy efficiency using equivalent circuits, battery and capacitor circuits.
6. Perform computations to convert free energy of chemical reactions into electric energy.
7. Understand the thermodynamics and kinetics of batteries.
8. Contrast the behavior of Pb-acid and Li ion batteries and fuel cells.

Topics Covered

- Future Energy Needs/Capacitor Fundamentals/Fields and Forces
- Capacitors Circuits/Capacitance as a function of Geometry/Dielectrics
- How Dielectrics work/Real Dielectrics/Equivalent circuits
- Ion Transport/Leakage/Ionic Solids Structure
- Alternative Transport Model: Percolation/Charges on Electrodes/Supercapacitors
- Electrochemistry-Battery/1st Law Thermo/Chemical Energy Balance Examples
- 2nd Law of Thermo/Example Problems/Free Energy
- Computing Chemical Equilibrium/Charge and Ionic Transport in Batteries

MS4811– Mechanical Behavior of Engineering Materials (4-0)

Contact Hours - Meets 4 times per week for 50-minute lectures.

Course Coordinator/Instructor – Emre Gunduz

Textbook(s) and/or other Required Material
Mechanical Behavior of Materials, (M.A. Meyers and K.K. Chawla), 2nd Edition, Cambridge University Press 2008.
Mechanical Behavior of Materials, (T.H. Courtney), 2nd Edition, Waveland Press, 2005.
Behavior of Materials, Dowling, 3rd Edition.

Course Description (from Catalog)
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.

Prerequisites and Co-Requisites – MS3202 and MS3214

Course Requirement - Elective

Course Outcomes (Course competencies that align with student outcomes)
1. Be able to explain the physics and quantitatively estimate the connection between atomic bonding and elastic modulus
2. Be able to use tensors to quantitatively describe anisotropy
3. Be able to qualitatively and quantitatively describe dislocations and their importance in the deformation of crystalline materials.
4. Be able to explain the major strategies for strengthening metallic materials, predict their impact on strength, and make design choices for different alloy families
5. Appreciate, understand, and be able to weigh the major mechanical testing techniques
6. Understand and predict how metallic materials deform at high temperatures.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Calculate quantities such as elastic modulus, equilibrium bond distance, and bonding energy from a diatomic bonding curve.
2. Describe how different types of bonding give different thermo-elastic responses.
3. Manipulate and use tensors to calculate elastic properties in anisotropic materials
4. Describe the basic types and crystallography of dislocations in the FCC, BCC, HCP metallic structures.
5. Be able to calculate the physical quantities of dislocations including self-energies, interaction forces, bowing forces and stresses, and reaction energies.
6. Be able to qualitatively and quantitatively compare and contrast the four basic strengthening strategies for metallic alloys.
7. Quantitatively analyze data from tensile testing experiment to extract quantities such as

yield strength, ultimate tensile strength, and elastic modulus.
8. Construct and use deformation mechanism maps to predict the high temperature behavior of metallic and ceramic materials.

Topics Covered

- Bonding Energy, Hookes Law/Anisotropy
- Sound propagation, Dislocation properties
- Dislocation Crystallography
- Dislocation motion, Dislocation interaction
- Solid Solution Strengthening
- Work hardening
- Grain Refinement
- Dispersion Strengthening
- Mechanical Testing
- High-temperature mechanisms

EC2820 – DIGITAL LOGIC CIRCUITS (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor – Douglas J. Fouts

Textbook(s) and/or other Required Material
Text: *Fundamentals of Digital Logic with Verilog Design*, S. Brown and Z. Vranesic, 2nd Edition, McGraw-Hill Higher Education, 2008.

Course (Catalog) Description
An introductory course in the analysis and design of digital logic circuits that are the basis for military and civilian computers and digital systems. No previous background in digital concepts or electrical engineering is assumed. Topics include data representation, Boolean algebra, logic function minimization, the design and application of combinatorial and sequential SSI, MSI, and LSI logic functions including programmable devices, ROMs, RAMs, and the fundamentals of finite state machine design and applications. Laboratories are devoted to the analysis, design, implementation, construction, and debugging of combinatorial and sequential logic circuits using SSI, MSI, LSI, and programmable logic devices.

Prerequisites and Co-requisites - None

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. The student will be able to analyze and design digital logic circuits at an intermediate level.
2. The student will be able to model and simulate digital logic circuits and digital systems and an introductory level.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Binary number representation formats, including integer and fractional positional number systems.
2. Binary codes for data representation, logic testing, and error checking, including ASCII, EBCDIC, Grey, parity, and excess codes.
3. Boolean algebra, including the laws, axioms, and theorems necessary to manipulate and minimize Boolean expressions, including DeMorgan's Theorem and canonical, S-O-P, and P-O-S forms.
4. Minimization techniques, including Karnaugh mapping and the Quine-McCluskey algorithm.
5. The design and implementation of SSI, MSI, and LSI combinatorial logic circuits and their applications, including inverters, NOR gates, NAND gates, AOI gates, multiplexers, demultiplexers, decoders, adders/subtractors, and carry lookahead circuits.

6. Programmable logic devices, ROMs and RAMs, and their applications.
7. The design and implementation of flip-flops, registers, shift registers, and counters, and their applications.
8. Finite state machines, including both the Mealy and the Moore model.
9. The fundamentals of finite state machine design, implementation, and application, including state tables, transition diagrams, state minimization, and flip-flop excitation.

Topics Covered

- Binary number representation formats, including integer and fractional positional number systems.
- Binary codes for data representation, logic testing, and error checking, including ASCII, EBCDIC, Grey, parity, and excess codes.
- Boolean algebra, including the laws, axioms, and theorems necessary to manipulate and minimize Boolean expressions, including DeMorgan's Theorem and canonical, S-O-P, and P-O-S forms.
- Minimization techniques, including Karnaugh mapping and the Quine-McCluskey algorithm.
- The design and implementation of SSI, MSI, and LSI combinatorial logic circuits and their applications, including inverters, NOR gates, NAND gates, AOI gates, multiplexers, demultiplexers, decoders, adders/subtractors, and carry lookahead circuits.
- Programmable logic devices, ROMs and RAMs, and their applications.
- The design and implementation of flip-flops, registers, shift registers, and counters, and their applications.
- Finite state machines, including both the Mealy and the Moore model.
- The fundamentals of finite state machine design, implementation, and application, including state tables, transition diagrams, state minimization, and flip-flop excitation.

EC3230 – Space Power and Radiation Effects (3-1)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a one-hour lab period.

Course Coordinator/Instructor – Sherif Michael

Textbook(s) and/or other Required Material
Text: Instructor Notes

Course (Catalog) Description
Fundamentals of different power systems utilized in spacecraft; photovoltaic power technology; solid-state physics, silicon solar cells, solar cell measurement and modeling, gallium arsenide cells and II-V compounds in general, array designs and solar dynamics. Radiation effects on solid-state devices and materials. Survivability of solar cells and integrated circuits in space environment and annealing method. Other space power systems including chemical and nuclear (radioisotope thermoelectric generators and nuclear reactors). Energy storage devices and power conversion. Spacecraft power supply design.

Prerequisites and Co-Requisites - None

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
Students will gain familiarization with spacecraft power system components and different techniques utilized in modern spacecraft power system design.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Select appropriate type of power system to satisfy spacecraft design criteria: mission, orbit, payload, and survivability.
2. Select appropriate types and sizes of solar cells and storage batteries.
3. Select appropriate electronic power processors for system design and define the necessary building blocks.
4. Develop and design electrical power systems for different spacecraft to meet various communication, military and scientific needs.

Topics Covered
1. Spacecraft power systems
2. Solar power
    a. Solid state physics
    b. Silicon solar cell and photovoltaic power
    c. Solar cells measurements and modeling
    d. Array design
    e. Space environment and radiation effects

    f. Other state-of-the-art solar cells
    g. Solar Dynamics
3. Spacecraft alternative power systems
4. Space nuclear power
5. Energy storage systems
6. Power conditioning and processing
7. A project for designing a complete satellite power system

EO2525 - PROBABILISTIC ANALYSIS OF SIGNALS AND COMMUNICATIONS SYSTEMS (4-1)

Contact Hours - Meets four times per week for 50-minute lectures and once per week for a 50-minute lab period

Course Coordinator/Instructor – Frank Kragh

Textbook(s) and/or other Required Material
Communications Systems, A. Bruce Carlson and Paul B. Crilly, 5th edition, McGraw-Hill, 2010, ISBN = 978-0-07-338040-7.

Course (Catalog) Description
Basic analog and digital communications techniques are discussed. The foundations of signals and systems are developed from probabilistic and statistical approaches. Emphasis is on communication systems relevant to military applications. Topics include AM, FM, probability, random variables, probability density and distribution functions; deterministic versus nondeterministic signals; expectation, the dc and rms values of nondeterministic signals, correlation and covariance; LTI systems, transformation of random variables, and the central limit theorem.

Prerequisites - MA2121 and PH1322

Course Requirement - Required

Course Outcomes
1. Quantitatively analyze communications systems and signals using time domain and frequency domain techniques
2. Use link budgets to determine if and how to close a communications link
3. Analyze non-deterministic signals and noise to quantify the effects of noise on a communications system.
4. Analyze signal processing for communications systems via computer programming.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Analyze periodic signals, including fundamental period, power, Fourier series, constituent frequencies, power in a given frequency range, bandwidth
2. Calculate and compare bandwidths (absolute, noise equivalent, 99% power, 3 dB)
3. Analyze aperiodic signals including instantaneous power, energy, Fourier transform, constituent frequencies, energy in a given frequency range, bandwidth
4. Use the Dirac impulse function including definition, sampling, and Fourier transform.
5. Convolve two signals.
6. Calculate the impulse response, frequency response, power transfer function, and bandwidth of LTI systems and filters.

7. Calculate link budgets including antenna gain, EIRP, footprint, free space loss, effective noise temperature, bandwidth, noise power, signal power, SNR, Eb/N0, BER, data rate and dB vs. linear units.
8. Relate signal power, energy per bit, and data rate
9. Analyze random signals including power spectral density, autocorrelation function, stationarity, bandwidth, white noise, power, and expectation.
10. Analyze sampled signals including Nyquist sampling theorem, Nyquist sampling rate, over sampling, aliasing,
11. Analyze random variables including cumulative distribution functions, probability density functions, probability mass function, probabilities, expectations, sums of random variables, standard normal random variable, Q() function, and Central Limit Theorem.
12. Analyze filtered white Gaussian noise including mean and variance.
13. Analyze complex envelopes including communications signals, conversion back and forth between complex envelope and bandpass forms.

Topics Covered

- Frequency domain analysis of signals and systems
- Time domain analysis of signals and systems
- Digital communications modulators and demodulators
- Link budgets
- Random variables and random processes
- Analysis of noise, communications signals, and receiver performance

EO3525 Communications Engineering (4-1)

Contact Hours - Meets four times per week for 50-minute lectures and once per week for a 1-hour lab period.

Course Coordinator/Instructor – Tri Ha

Textbook(s) and/or other Required Material
Digital Communications, Bernard Sklar, Second Edition, Prentice Hall, 2001

Course (Catalog) Description
The influence of noise and interference on the design and selection of digital communications systems is analyzed. Topics include link budget analysis and signal-to-noise ratio calculations, receiver performance for various digital modulation techniques, bandwidth and signal power trade-offs, an introduction to spread spectrum communications, and multiple access techniques. Examples of military communications systems are included.

Prerequisites and Co-Requisites – EO3525

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Develop an understanding of the engineering principles behind the wireless communication of information;
2. Understand the application of those principles to the design of satellite systems.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Understand the various techniques for digital communication of information;
2. Apply those techniques to the design of a communications link;
3. Understand the unique requirements space missions with respect to communications;
4. Be able to contribute to the design of the communications link for a satellite design project.

Topics Covered
- Modulation and Coding
- Link Analysis
- Multiple Access techniques
- Spread Spectrum
- Detection Theory
- Receiver Operating Characteristics
- Bandwidth-Efficient Modulation
- SATCOM Examples.

MA2121 –DIFFERENTIAL EQUATIONS (4-0)

Contact Hours - Meets four times per week for 50-minute lectures.

Course Coordinator/Instructor – Carlos Borges

Textbook(s) and/or other Required Material
Elementary Differential Equations and Boundary Value Problems, 9th edition, W. E. Boyce and R. C. DiPrima, Wiley, 2008

Course (Catalog) Description
Ordinary differential equations: linear and nonlinear (first order) equations, homogeneous and non-homogeneous equations, linear independence of solutions, power series solutions, systems of differential equations, Laplace transforms. Applications include radioactive decay, elementary mechanics, mechanical and electrical oscillators, forced oscillations and resonance.

Prerequisites and Co-Requisites – MA1114 or permission of instructor

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)

- Understand the fundamental concepts of differential equations
- Learn some important methodologies of solving differential equations
- Introduce some examples of differential equation applications in engineering and science

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:

- Classify differential equations with respect to linearity and order
- Solve linear differential equations of a single unknown
- Solve separable equations and exact equations
- Learn examples of modeling and applications using ODE's
- Understand the existence and uniqueness of solutions for nonlinear equations
- Solve second order linear equations, homogeneous equations with constant-coefficients, find fundamental solutions
- Understand linear independence and the Wronskian
- Solve second order equations with complex roots or repeated roots
- Use methodologies of reduction of order, undetermined coefficient, and variation of parameters
- Analyze oscillations: free and forced
- Convert higher-order linear equations into a first order system of equations

- Find series solutions using power series
- Solve initial value problems using Laplace transformation
- Use step functions, dirac delta function, and Laplace convolution to solve initial value problems with discontinuous or impulse forcing function
- Solve systems of differential equations using matrices and eigenvalues and eigenvectors

Topics Covered

- Solution of ordinary differential equations
- Development of Laplace transforms
- Systems of differential equations

MA3046 MATRIX ANALYSIS (4-1)

Contact Hours - Meets four times per week for a 50-minute lecture and once per week for a one-hour lab period.

Course Coordinator/Instructor – Francis Giraldo

Textbook(s) and/or other Required Material
Trefethen and Bau, Numerical Linear Algebra, 1st Ed.

Course (Catalog) Description
This course provides students in the engineering and physical sciences curricula with an applications-oriented coverage of major topics of matrix and linear algebra. Matrix factorizations (LU, QR, Cholesky), the Singular Value Decomposition, eigenvalues and eigenvectors, the Schur form, subspace computations, structured matrices. Understanding of practical computational issues such as stability, conditioning, complexity, and the development of practical algorithms.

Prerequisites and Co-Requisites - MA2043 and EC1010

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Understand the fundamental theorem of linear algebra
2. Understand the SVD and its relation to FTLA
3. Understand basics of Krylov space methods
4. Familiarity with structured eigenvalue problems

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Apply the fundamental theorem of linear algebra
2. Use the SVD to solve practical problems
3. Implement a Krylov space algorithm
4. Solve structured eigenvalue problems

Topics Covered
- Fundamentals - Introduction.
- Review of Vectors, Matrices, and Matrix-Vector Operations.
- Inner, Products, Orthogonality and Norms.
- The Singular, Value Decomposition, Practical Considerations – Floating Point Numbers and Computational Accuracy. Influences of Hardware and Software Architecture.
- QR Factorization and Least Squares – Projectors.
- QR Factorization.

- Gram-Schmidt Methods, Householder and Givens Methods.
- Orthogonal, Triangularization.

MN3331 SYSTEM ACQUISITION AND PROGRAM MANAGEMENT (5-1)

Contact Hours - Meets five times per week for 50-minute lectures and once per week for a one-hour lab period.

Course Coordinator/Instructor – William R. Fast

Textbook(s) and/or other Required Material
Defense Acquisition Guidebook (DAG), Office of the Under Secretary of Defense for Acquisition, Technology and Logistics.
Defense Acquisition, Technology, and Logistics Life Cycle Management System Wallchart, Defense Acquisition University, Defense Acquisition University Press.
Introduction to Defense Acquisition Management, Defense Acquisition University, Defense Acquisition University Press.
Operation of the Defense Acquisition System, DoDI 5000.02, Department of Defense.
Program Managers Tool Kit, Defense Acquisition University, Defense Acquisition University Press.
The Defense Acquisition System, DoDD 5000.01, Department of Defense.

Course (Catalog) Description
This course provides the student with an understanding of the underlying concepts, fundamentals and philosophies of the Department of Defense systems acquisition process and the practical application of program management methods within this process. The course examines management characteristics and competencies, control policies and techniques, systems analysis methods and functional area concerns. Techniques for interpersonal relationships will be examined in team exercise settings. Topics, from a program management perspective, include the evolution and current state of systems acquisition management, the system acquisition life cycle, requirements analysis, systems engineering, contract management, resource management, test and evaluation, user-producer acquisition management disciplines and activities; and program planning, organizing, staffing, directing and controlling. Case studies are used to analyze various acquisition issues. Defense Acquisition University (DAU) has granted MN3331 equivalency for ACQ 101, ACQ 201, PMT 251, PMT 257, BCF 102 and BCF 103.

Prerequisites and Co-Requisites - none

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Acquire and use an expanded vocabulary of defense systems acquisition, resource allocation/budgeting, and requirements generation terminology.
2. Critically assess and evaluate the effectiveness and relevancy of the principles, concepts, and policies of defense systems acquisition and program management.
3. Compare and contrast the differing perspectives, interests, objectives, roles, responsibilities, and ideas that the user (warfighter), the program manager, the Congress, the Executive Branch, and the defense industry bring to the acquisition process.

4. Employ various interpersonal management and communication techniques through participation as an Integrated Process Team (IPT) leader or IPT member.

5. Employ program management tools as part of the course labs.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:

- Describe a system, acquisition and management
- Define integrated process and product development
- Describe and define concepts regarding Joint Capabilities Integration & Development System (JCIDS) and affordability
- Explain principles in the acquisition management framework
- Discuss acquisition organizations & management documents and acquisition strategy and project scheduling
- Understand the systems engineering process in the defense environment
- Identify, explain and compare aspects of the procurement process and contract types, source selection, contract administration, cost estimation, cost analysis, budget formulation and defense resource allocation
- Discuss congressional enactment & budget execution and Earned Value Management (EVM)
- Explain test & evaluation planning/developmental test & evaluation, operational test & evaluation/test & evaluation master plan
- Understand software acquisition management, acquisition logistics & facilities engineering, and producibility & quality in production
- Formulate contracting strategy, cost estimates budgets, testing strategies, and life cycle sustainment plans

Topics Covered

- Introduction to Systems Acquisition and Program Management
- Integrated Product and Process Development and Acquisition Reform
- Requirement Generation and JCIDS
- DoD Acquisition Management Framework
- Acquisition Organizations and Management
- Acquisition Strategy and Project Scheduling
- Work Breakdown Structure & Intro to Systems Engineering Process
- Systems Engineering Process: Risk Management
- Procurement Process and Contract Types
- Source Selection, Cost Estimation and Cost Analysis
- Budget Formulation and Defense Resource Allocation
- Earned Value Management (EVM)
- Test and Evaluation Planning / Developmental Test and Evaluation
- Operational Test and Evaluation / Test and Evaluation Master Plan Operational

Test & Evaluation; Live Fire Test & Evaluation; Interoperability Testing

- Software Acquisition Management, Acquisition Logistics and Facilities Engineering
- Producibility and Quality in Production
- Congressional Enactment and Budget Execution

PH2514 INTRODUCTION TO THE SPACE ENVIRONMENT (4-0)

Contact Hours - Meets four times per week for 50-minute lectures.

Course Coordinator/Instructor: – Christopher Smithtro/Steven H. Tackett

Textbook(s) and/or other Required Material
Introduction to the Space Environment (Olsen, notes)

Course (Catalog) Description
Plasma concepts. Solar structure and magnetic field, particle and electromagnetic emissions from the sun, the geomagnetic field, and the magnetosphere, radiation belts, structure and properties of the earth's upper atmosphere, ionosphere, implications of environmental factors for spacecraft design

Prerequisites and Co-Requisites - A course in basic electricity and magnetism.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Students recognize the impact of the space environment on satellite operations
2. Students recognize the impact of the space environment on satellite design

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Define the space environment for important orbital regimes (LEO, GEO, HEO), with respect to:
    - Radiation (energetic electrons and ions, aka the Van Allen Belts)
    - Cosmic Rays
    - Photons (visible-uv-xray)
    - Plasma (energetic plasmas, as important for spacecraft charging effects)
    - Earth’s upper atmosphere
2. Predict the impact of the space environment on satellite behavior, particularly with respect to:
    - Spacecraft charging, arcing, and satellite degradation
    - Radiation effects, solar array lifetime, satellite logic upsets
    - Specialized issues wrt the South Atlantic Anomaly
    - Impact of the earth’s upper atmosphere, particularly atomic oxygen
    - Orbital debris
3. Understand the impact of environmental factors on satellite electronics, and system design
4. Understand the nature and variations of the earth’s magnetic field, particularly wrt issues affect satellite attitude control.

Topics Covered

1. Modern Physics
2. Plasma Physics
3. Solar Physics
4. Solar Wind
5. Geomagnetism
6. Earth's Magnetosphere
7. Earth's Atmosphere
8. Earth's Ionosphere
9. Spacecraft-Environment Interactions-Spacecraft Charging
10. Spacecraft-Environment Interactions-debris and atmospheric effects
11. Spacecraft-Environment Interactions-Radiation Effects

PH3052 – Physics of Space and Airborne Sensor Systems

Contact Hours - Meets four times per week for 50-minute lectures.

Course Coordinator/Instructor – Richard Christopher Olsen

Textbook(s) and/or other Required Material
Text: Remote Sensing from Air and Space; RC Olsen, SPIE Press Monograph Vol. PM162SC, First Edition, SPIE, 2007.

Course (Catalog) Description
This interdisciplinary course explores the physical principles underlying the sensor systems needed for satellites and tactical aircraft, as well as limitations imposed by the atmosphere and operating environment on these systems and their communication links. Topics include: satellite orbits, the satellite environment, ionospheric interactions and atmospheric propagation, phased array and pulsed compressed radars, imaging synthetic aperture and inverse synthetic aperture radars, noise resources, thermal radiation, principles of semiconductor devices, optical and infrared imaging detector systems, and their resolution limitations and bandwidth requirements. Prerequisites: Basic physics class. Must be familiar with the concepts of energy and wave motion.

Prerequisites and Co-Requisites – Basic physics class. Must be familiar with the concepts of energy and wave motion.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Knowledge of remote sensing technologies, as appropriate for system design
2. Knowledge of remote sensing capabilities, as appropriate for utilization of such systems
3. Knowledge of current technology levels, particularly with respect to satellite systems

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Calculate the spatial resolution of an optical or radar system, in particularly with respect to sensor/satellite system size, power, and orbit
2. Conduct basic analysis of remote sensing data in terms of elements of information
3. Analyze the potential utility of varying satellite orbits for coverage
4. Define appropriate remote sensing technology to meet mission specific requirements

Topics Covered

Introduction, Sample Imagery, Order of Battle

Basics of Electromagnetism, waves, photoelectric effect

Optical Systems Basics

- Detectors
- Physical & Geometrical Optics
- Historical Systems (Corona)
- Modern systems (Hubble, Ikonos)

Orbital mechanics

Spectral and Polarimetric Imagery

Image processing - basic techniques

Thermal imaging

Synthetic Aperture Radar

Light Detection and Ranging (LIDAR)

SS3001 Military Applications of Space (3-2)

Contact Hours - Meets three times per week for 50-minute lectures and once per week for a 2-hour lab period.

Course Coordinator/Instructor – Herschel H. Loomis

Textbook(s) and/or other Required Material
Instructor's notes

Course (Catalog) Description
Space Systems and technologies of interest to the military. Strategic and tactical imagery and SIGINT requirements. Tasking and use of national space systems and ground support elements. Vulnerability considerations and impact of current R&D programs.

Prerequisites and Co-requisites – SS3400 or SS3500, EO3525 or SS3610 and PH3052 and familiarity with ENVI, STK, and MATLAB. Classification: TOP SECRET clearance with access to SCI.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Detailed Outcomes beyond Catalog Description is not publicly releasable.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Detailed Learning Objectives beyond Catalog Description is not publicly releasable.

Topics Covered
Detailed Topic List is not publicly releasable.

SS3051 Military Applications of DoD and Commercial Space Sysgtems (4-0)

Contact Hours - Meets four times per week for 50-minute lectures.

Course Coordinator/Instructor – Scott Moore

Textbook(s) and/or other Required Material
Joint Publication 3-14 Space Operations (29 May 2013)
AU-18 Space Primer, Air University Press, Maxwell AFB, AL, September 2009.

Course (Catalog) Description
This course covers joint space doctrine and military applications of DoD and commercial space systems. Topics include the space mission areas of space situational awareness, space force enhancement, space control and space support. The space force enhancement section of the course includes intelligence, surveillance, and reconnaissance, missile tracking, launch detection, environmental monitoring, satellite communication, positioning, navigation and timing, and navigation warfare. Additional topics include space law, policy and strategy, incorporating space based capabilities in military operations, threats to U.S. space systems, foreign space capabilities, and space support to friendly force tracking, combat search and rescue and maritime domain awareness. Requires a SECRET clearance.

Prerequisites and Co-Requisites – SS3011 and Secret Clearance

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
- Understand current space law, policy and doctrine and the associated impacts to space operations
- Gain a familiarity with national security space organizations
- Understand current national security, civil and commercial space capabilities and how they can be applied to support military operations
- Understand the vulnerabilities of current space systems and potential mitigation capabilities

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
- At the completion of the course students will be able to:
- Describe the strengths and weaknesses of the use of space
- Identify and describe the various military space systems including GPS, DMSP, DSP, SBIRS, WGS, AEHF, MUOS and others.
- Describe current joint space doctrine along with relevant space laws and policies
- Know how space capabilities are incorporated into an OPLAN
- Recognize elements of the Air Force Satellite Control Network and Space Surveillance Network
- Interpret GPS dilution of position plots for best and worst strike times
- Recognize the elements and implications of commercial space systems

- Participate in discussions of current space related issues

Topics Covered

- Space law, policy and doctrine
- National security space organizations
- Space Situational Awareness
- Force enhancement including satellite communications, missile warning, precision navigation and timing, intelligence, surveillance and reconnaissance and environmental monitoring.
- Space control including offensive and defensive space control and counterspace threats.
- Application of space capabilities to military operations

SS3500 ORBITAL MECHANICS AND LAUNCH SYSTEMS (4-2)

Contact Hours – Meets four times per week for fifty-minute lectures and once per week for a two-hour lab period.

Course Coordinator/Instructor – James H. Newman

Textbook(s) and/or other Required Material
Text: Orbital Mechanics for Engineering Students, Howard D. Curtis, 2nd Edition, Elsevier, 2010.

Course (Catalog) Description
Provides a fundamental understanding of Orbital Mechanics through study of conic sections, coordinate systems, coordinate transformations, and time. Calculation of orbital elements of the two-body problem is covered. Other Orbital Mechanics topics include: Newton's laws, Kepler's equation, orbital perturbations, and orbital maneuvering, including rendezvous and proximity operations. Launch systems topics include: the rocket equation, single and multi-stage rockets, launch windows, launch profiles, ascent and payload delivery performance, and mission design. Supporting lab work utilizes the Satellite Tool Kit (STK) as an orbit analysis tool. The use of Excel and / or MATLAB for solving problems is encouraged.

Prerequisites and Co-requisites – none.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Understand rotating earth effects on ground tracks and orbits.
2. Understand elliptical, parabolic, and hyperbolic orbits and their uses.
3. Design and analyze orbit trajectories for two-body and J2 perturbations.
4. Analyze orbital state vectors and determine classical orbital elements.
5. Design transfer orbits from low earth orbit to geosynchronous orbits, including plane changes.
6. Design and analyze single stage and multi-stage rockets for particular applications including low earth orbit and geo-synchronous transfer orbits.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Calculate orbital parameters for two body orbits.
2. Explain the effects of the earth’s oblateness on an orbit’s right ascension of the ascending node and the argument of perigee.
3. Calculate the true anomaly as a function of time and time as a function of true anomaly.
4. Analyze a ground track and accurately estimate the inclination, semi-major axis, and period of the displayed orbit.

5. Calculate the delta velocities required to transfer from low earth orbit to geosynchronous orbit, including any required plane changes.
6. Discuss the practical considerations for single and multi-stage rockets, including the effects of specific impulse and engine type on thrust and propellant requirements.

Topics Covered

Dynamics of point masses
The two-body problem
Orbital position as a function of time
Orbits in three dimensions
Preliminary orbit determination
Orbital maneuvers
Relative motion and rendezvous
Interplanetary trajectories
Rocket vehicle dynamics

SS3861 Spacecraft Payload Design I (2-4)

Contact Hours - Meets twice per week for 50-minute lectures and twice per week for 2-hour lab periods.

Course Coordinator/Instructor – Jim Newman / Wenschel Lan

Textbook(s) and/or other Required Material
Instructor's notes

Course (Catalog) Description
This course focuses on the software and hardware associated with payload design with an emphasis on hands-on lab experience. Students will learn basic payload computing (software and electrical) concepts through lecture and by designing and building a payload to be flown on a high-altitude balloon. Systems engineering principles will be introduced and applied to the payload design. Principles of payload requirements, including design and bus interface requirements, as well as payload integration and testing will be introduced. This course culminates in a preliminary design review and functional prototype of the payload.

Prerequisites and Co-requisites – AE2820, ME2801, PH2514, PH3052, EO3525 or Consent of Instructor.

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Evaluate increasingly complex systems, such as spacecraft, by understanding the fundamental concepts and technologies.
2. Understand, and be able to participate meaningfully in, the payload design process from concept through flight operations.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
1. Understand and apply basic payload computing (software and electrical) concepts to payload design and bus interface requirements.
2. Utilize computer-aided design (CAD) and simulation engineering tools at a fundamental skill level in the payload design process.
3. Apply design-thinking, systems engineering, integration, and testing principles and best practices to design a payload that will be flown on a near-space platform.

Topics Covered
- High altitude balloon flight physics
- Fast Fourier transform
- Systems engineering concepts, mission requirements and objectives derivation
- Design-thinking concepts
- Number systems and information encoding, programming, serial communications
- Basic circuits, soldering, transistors, digital logic, switches

- General-purpose input/output (GPIO)
- Spacecraft bus subsystems
- Assembling, integration, and testing (AI&T)
- Computer-aided design (CAD) modeling
- Communication network topologies for the space-ground segment

SS4861 Spacecraft Payload Design II (2-4)

Contact Hours - Meets twice per week for 50-minute lectures and twice per week for 2-hour lab periods.

Course Coordinator/Instructor – Jim Newman / Wenschel Lan

Textbook(s) and/or other Required Material
Instructor's notes

Course (Catalog) Description
This course builds on the skills, knowledge, and project work gained in SS3861 and focuses on the hands-on experience in the lab, including functional and environmental testing at the payload and integrated system levels, and in the field, culminating in a high-altitude balloon flight of the payload. Payload-specific design consideration topics, including radiation effects, and reliability and fault tolerance, will be covered, along with payload cryogenic cooling. The design of current and planned space-based mission payloads of national interest will be discussed, and case studies will be presented about each payload type.

Prerequisites and Co-requisites – SS3861

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Solve real-world problems with current and future space-based systems by applying the experience gained in this course.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
1. Understand, through hands-on experience, the mission life cycle of a payload including design, assembly, integration, test, launch, and flight operations.
2. Recognize computer systems and processor architecture, as well as the effects of radiation hardening and the fundamentals of reliability and fault tolerance on these systems.
3. Analyze the design of current and planned space-based mission payloads.

Topics Covered
- Computer systems and processor architecture
- Effects of radiation hardening, reliability and fault tolerance
- Systems engineering concepts, mission requirements and objectives validation and verification
- Payload design, assembly, integration, and testing (AI&T) with a bus
- Spaceflight planning and operations

SS4000 Space Systems Seminar (0-1)

Contact Hours - Meets once per week for 50 minute presentations.

Course Coordinator: – Stephen Tackett

Textbook(s) and/or other Required Material - None

Course (Catalog) Description
Seminars consist of lectures to provide perspective on Space Systems and to expose the student to various space activities such as industry, NASA and DoD laboratories and commands

Prerequisites and Co-requisites - None

Course Requirement - Required

Course Outcomes (Course competencies that align with student outcomes)
1. Students will gain understanding of the practical aspects of Space Systems as found in various Industry, Academic, Civil, Commercial and Department of Defense organizations.

Student Learning Objectives (Specific Knowledge, Skills & Abilities)
At the completion of the course students will be able to:
1. Explain how key aspects of Space Systems design are implemented at specific Space related organizations and companies.

Topics Covered
1. Naval Space Operations Center
2. Overview of NASA's Space Launch System
3. NASA's Mars Curiosity Rover
4. Overview of MUOS communications satellite
5. University of Hawaii Space Flight Laboratory
6. Overview of JFCC – Space (Vandenberg AF)

And numerous others…

Appendix A-2 – Theses listing for AY2018

Student Full Name	Thesis Title	Advisors / Committee	OT
Atwood, Adam Linck	Flexible Multi-Body Spacecraft Simulator: Design, Construction, and Experiments	Isaac Ross (Second Reader), Mark Karpenko (Advisor)	N
Bradstreet, Andrew Robert	Design, Integration, and Testing of an Autonomous Multi-Body Spacecraft Simulator for Low Gravity Hopping and Grasping	Marcello Romano (Advisor), Josep Virgili-Llop (Second Reader)	N
Eddy, Janet Leola	Impact of Actuator Arrangement and Density on Optical Performance of an Actuated Hybrid Mirror (AHM) Using Zernike Polynomials	Brij Agrawal (Advisor), Jae Jun Kim (Co-Advisor)	N
Koeppen, Nicholas Ryan	WELL-CONDITIONED PSEUDOSPECTRAL OPTIMAL CONTROL METHODS AND THEIR APPLICATIONS	Lucas Wilcox (Co-Advisor), Isaac Ross (Advisor), Ronald Proulx (Co-Advisor)	Y
Lippman, Travis Allan	Enhancing the Science Collection Capability of NASA's Lunar Reconnaissance Orbiter (LRO)	Isaac Ross (Co-Advisor), Mark Karpenko (Advisor)	N
Ozeck, Luke Charles	Performance of a Staggered Orifice Ring Injector in a Rotating Detonation Engine	Christopher Brophy (Advisor), Andrew Chaves (Second Reader)	N
Pandya, Neehar	Convex Optimization and Control of Aggregating and Disaggregating Spacecraft	Marcello Romano (Advisor), Josep Virgili-Llop (Second Reader)	N
Roncoroni, Mark	Improving Mid-Course Flight Through an Application of Real-Time Optimal Control	Isaac Ross (Co-Advisor), Ronald Proulx (Advisor)	N
Roush, Angela Marie	Low-Cost, Software-Only Modifications for Improved Guidance and Control of Tactical Missiles	Isaac Ross (Second Reader), Mark Karpenko (Advisor)	N
Sundey, Sean Michael	Design and Implementation of an Optical Sparse Aperture Testbed for Small Satellite Formation Space-Based Remote Sensing	Brij Agrawal (Advisor), Jae Jun Kim (Co-Advisor)	N
Wright, Robert G	MODELING AND CHARACTERIZATION OF THE MK74 GAS GENERATOR FLOW FIELD	Christopher Brophy (Advisor), David Dausen (Second Reader)	N

OT – Outstanding Thesis

Appendix B – Faculty Vitae

Faculty resumes in the prescribed format are provided for members of the MAE Department, and other faculty having involvement through supporting programs such as the SSAG, PH, ECE and MA Departments and others.

Name: **Christopher A. Adams**

Education

Degree	Discipline	Institution	Year
BS	Aerospace Engineering	Boston University	1988
MS	Aerospace Engineering	Naval Postgraduate School	1997

Service activities

Director of the Center for Survivability and Lethality, Director of the Center for Survivability and Lethality, October 1, 2014 - September 30, 2017

Chairperson, MAE Associate Chairman for Facilities and Infrastructure, October 1, 2014 - September 30, 2017

Program Coordinator, Program manager curric 613, October 1, 2014 - September 30, 2017

Board of Directors, National Defense Industrial Association (NDIA), October 1, 2014 - September 30, 2017

Principal publications and presentations in the last five years

Adams, C. A., Kwon, Y. W., Yang, K., Liu, D. (in press). Modeling and Simulation of Hydrodynamic Ram for Aircraft Survivability. *Aircraft Survivability Journal*.

Adams, C. A., Kwon, Y. W., Yang, K. (2016). Modeling and Simulation of High Velocity Projectile Impact on Storage Tank. *Journal of Pressure Vessel Technology, Vol. 138.*(Aug 2016).

Name: **Brij N. Agrawal**

Education

Degree	Discipline	Institution	Year
BS		Baranes University-India	1964
PhD	Mechanical Engineering	Syracuse University	1970

Certifications or professional registrations

Registered Professional Engineer, State of Maryland, 1978 - Present

Current membership in professional organizations

Associate Editor, AIAA

Fellow, AIAA

Principal publications and presentations in the last five years

Agrawal, B., Kim, J. J. (2014). *Surface Control of Active Hybrid Space Mirrors*. 65th International Astronautical Congress.

Agrawal, B., Kim, J. J., Allen, M. (2015). *Cost-effective Large Apertures for Future Imaging Satellites* (AIAA 2015-4494 ed.). AIAA SPACE 2015 Conference and Exposition.

Allen, M., Kim, J. J., Agrawal, B. (2015). *Correction of an active space telescope mirror using a gradient approach and an additional deformable mirror* (Proc. SPIE 9602 ed., vol. 96020B). UV/Optical/IR Space Telescopes and Instruments: Innovative Technologies and Concepts VII.

Kim, J. J., Allen, M., Agrawal, B. (2015). *Cost-effective Aperture with Deformable Mirror for Imaging Satellites*. 66th International Astronautical Congress.

Allen, M., Kim, J. J., Agrawal, B. (2016). Correction of an active space telescope mirror using a deformable mirror in a woofer-tweeter configuration. *Journal of Astronomical Telescopes, Instruments, and Systems, 2*(2).

Kim, J. J., Mueller, M., Brij, A. (2016). *Impact of Large Field Angles on the Requirements for Deformable Mirror in Imaging Satellites*. 67th International Astronautical Congress (IAC).

Agrawal, B. N., Kim, J.-J. (2017). *Dynamics and Control Challenges for Imaging Satellites*. IAA Conference on Dynamics and Control of Space Systems.

Kim, J.-J., Agrawal, B. N. (2017). *Demonstration of Sparse Aperture Configuration for Imaging Satellites*. 68th International Astronautical Congress (IAC).

Kim, J. J., Muller, M., Martinez, T., Agrawal, B. (2018). Impact of large field angles on the requirements for deformable mirror in imaging satellites. *Acta Astronautica, 145*, 44-50.

Kim, J. J. (Author & Presenter), DeSandre, L. (Author), Agrawal, B. (Author), 17th Annual Directed Energy Symposium, "Adaptive Optics Control for Strong Turbulence Using Iterative Wavefront Reconstruction," DEPS. (March 5, 2015).

Kim, J. J. (Author), Brij, A. (Author & Presenter), Advanced High Power Lasers Beam Control Conference, "Acquisition, Tracking, Pointing and Adaptive Optics for the High Energy Laser Beam Control Research Testbed," DEPS, Colorado Springs, CO, United States. (June 2016).

Name: **Oscar Biblarz**

Education

Degree	Discipline	Institution	Year
BS	Engineering	University of California Los Angeles	1959
MS	Engineering	University of California Los Angeles	1963
PhD	Mechanical Engineering	Stanford University	1968

Honors and Awards

Hughes Master Fellow
Ford Foundation Plasma Fellow
Lady Davis Fellow
Navy Superior Service Award

Publications

P Sutton and O. Biblarz, “Rocket Propulsion Elements”, 8th Edition, John Wiley & Sons, N.J., 2010.

Name: **Brian S. Bingham**

Education

Degree	Discipline	Institution	Year
BS		Missouri State University	1996
MS		Massachusetts Institute of Technology	1998
PhD		Massachusetts Institute of Technology	2003

Academic experience

Institution	Title/Rank/Position	Dates Held	FT/PT
Department of Ocean and Resources Engineering, University of Hawaii at Manoa	Cooperating Faculty	2009 - 2015	
Department of Mechanical Engineering, University of Hawaii at Manoa	Associate Professor	2013 - 2015	
Woods Hole Oceanographic Institution	Visiting Scientist	2005 - Present	

Current membership in professional organizations

Member, IEEE

Member, MTS

Honors and awards

TJ Tarn Best Application Paper Award, July 8, 2018

Service activities

University Senate Service, Alternate Faculty Council Representative, 2016

Assistant Department Chair, Assistant Department Chair, October 1, 2016 - March 31, 2017

University Senate Service, Faculty Council Representative for MAE, January 1, 2017 - December 31, 2017

University Senate Service, Faculty Council Representative for MAE, January 1, 2018 - December 31, 2018

Assistant Department Chair, Assistant Department Chair, June 1, 2018 - December 31, 2018

Committee Member, Tenure Track Search Committee, June 1, 2018 - December 31, 2018

Editorial Review Board Member, Marine Technology Society (MTS) Journal, 2011 - 2014

Workshop Organizer, IEEE/MTS OCEANS Conference, September 19, 2016 - September 22, 2016

Editor, Associate Editor, IEEE Journal of Oceanic Engineering, January 1, 2016 - December 31, 2018

Principal publications and presentations in the last five years

Edwards, M. H., Shjegstad, S. M., Wilkens, R., King, J. C., Carton, G., Bala, D., Bingham, B. S., Bissonnette, M. C., Briggs, C., Bruso, N. S., others (2016). The Hawaii undersea military munitions assessment. *Deep Sea Research Part II: Topical Studies in Oceanography, 128*, 4–13.

Fitzpatrick, L., Trimble, A. Z., Bingham, B. S. (2017). *VERIFICATION OF A MARINE POLLUTANT SURFACE PLUME MODEL FOR USE IN THE DEVELOPMENT OF AUTONOMOUS VEHICLE TRACKING SYSTEMS.*

Fahad, M., Guo, Y., Bingham, B. S., Krasnosky, K., Fitzpatrick, L., Sanabria, F. A. (2017). Evaluation of ocean plume characteristics using unmanned surface vessels. *OCEANS 2017 - Anchorage* (pp. 1-7).

Fahad, M., Guo, Y., Bingham, B. S., Krasnosky, K., Fitzpatrick, L., Sanabria, F. A. (2017). Robotic experiments to evaluate ocean plume characteristics and structure. *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 6098-6104).

Fahad, M., Guo, Y., Bingham, B. S., Krasnosky, K., Fitzpatrick, L., A. Sanabria, F. (2018). *Ocean Plume Tracking with Unmanned Surface Vessels: Algorithms and Experiments*.

Fahad, M., Guo, Y., Bingham, B. S. (2018). Simulating Fine-Scale Marine Pollution Plumes for Autonomous Robotic Environmental Monitoring. *Frontiers in Robotics and AI, 5*, 52. https://www.frontiersin.org/article/10.3389/frobt.2018.00052

Bingham, B. S., CRUSER TechCon, "Developing Single Sortie Detect to Engage Multi-Vehicle Autonomy with Ground-Based Testbed," CRUSER. (2016).

Name: **Christopher M. Brophy**

Education

Degree	Discipline	Institution	Year
BS	Aerospace Engineering	Pennsylvania State University	1991
MS	Aerospace Engineering	Pennsylvania State University	1993
PhD	Mechanical Engineering	University of Alabama-Huntsville	1997

Current membership in professional organizations

Senior Member

Co-Chair

Honors and awards

Postdoctoral Fellowship, ONR

Service activities

Committee Chair, Heat Transfer Faculty Search Committee, January 1, 2014 - December 30, 2015

Committee Member, Thermo-Fluids Commitee, May 1, 2014 - December 30, 2016

Faculty Advisor, 613 Academic Associate, October 1, 2014 - December 30, 2016

Committee Member, Explosive Saftey Board Member, May 10, 2015 - December 30, 2016

Editor, Journal Editor, AIAA, October 1, 2014 - December 30, 2015

Committee Chair, AIAA PGC, October 1, 2014 - December 30, 2015

Committee Chair, JHU ERG (JANNAF), October 1, 2014 - December 30, 2015

Principal publications and presentations in the last five years

Chaves, A. D., Brophy, C. M. (2015). *Performance Sensitivity Study for Rotating Detonation Engines*.

Muss, J. A., Brophy, C., Luhrs, C. C., Aldridge, B. (2016). *Soot Deposit Characterization In Fuel Film Cooled Kerosene Rocket Engines*. Phoenix AZ:.

Chaves, A. D., Brophy, C. M., 63rd JANNAF Propulsion Meeting, "Mixing Characteristics and Impact on the Operation and Performance of Rotating Detonation Wave Combustors." (May 2016).

Chaves, A. D. (Presenter), Brophy, C. M. (Presenter), AIAA Propulsion & Energy 2016, "Mixing Characteristics and Impact on the Operation and Performance of Rotating Detonation Wave Combustors." (July 2016).

Muss, J. A. (Author & Presenter), Brophy, C. M. (Author), Luhr, C. C. (Author), Aldridge, B. M. (Author), Liquid Propulsion Subcommittee Meeting, "Soot Deposition Characterization in Fuel Film Cooled Kerosene Rocket Engines," JANNAF, Phoenix, AZ, Phoenix, AZ, United States. (December 10, 2016).

Name: **Douglas J. Fouts,** Professor of Electrical and Computer Engineering

Education

Degree	Discipline	Institution	Year
BA	Computer Science	Univ. of California at Berkeley	1980
MS	Electrical and Computer Engineering	Univ. of California at Santa Barbara,	1984
PhD	Electrical and Computer Engineering	Univ. of California at Santa Barbara,	1990

Current membership in professional organizations

Registered Professional Electrical Engineer, State of California, E16158

Honors and awards

Academic Service Award, Graduate School of Engineering and Applied Sciences, Naval Postgraduate School, 2012
Alan Berman Research Publications Award, Naval Research Laboratory, 2003
Menneken Award for Excellence in Scientific Research, 2002
Outstanding Service Award, Hardened Electronics and Radiation Technology Conference, 2002
Outstanding Research Achievement Award for the Department of Electrical and Computer Engineering, 1997
Meritorious Paper Award, Government Microelectronics Applications Conference, 1997
Outstanding Instructional Performance award for the Space Systems Academic Group, 1996
Granted academic tenure by the Naval Postgraduate School, Monterey, CA, July 1996
Outstanding Research Achievement award for the Space Systems Academic Group, 1993

Service activities

Naval Postgraduate School, Interim Dean of Research, 1/2012-7/2012, full time
Naval Postgraduate School, Associate Dean of Research, 2008-2012, half time

Principal publications and presentations in the last five years

Most recent publications are classified TS//SI/NOFORN.

D.J. Fouts and B.L. Luke, "Automatic Clock Synchronization in Counterflow-clocked Pipelined Circuits", *ISAST Transactions on Electronics and Signal Processing*, Vol. 4, No. 1, 2009, pp. 20-29.

D.J. Fouts and B.L. Luke, "Automatic Clock Synchronization and Distribution Circuit for Counter Clock Flo Pipelined Systems", U.S. Patent No. 8,085,817, Dec. 27, 2011.

Name: **Vladimir N. Dobrokhodov**

Education

Degree	Discipline	Institution	Year
MS	Aerospace Engineering Sciences	Moscow State Aviation Institute-Moscow	1991
MS	Operations Research	Zhukovsky Air Force Engineering Academy-Moscow	1993
PhD	Aerospace Engineering Sciences	Zhukovsky Air Force Engineering Academy-Moscow	1999

Current membership in professional organizations

Senior Member, AIAA, January 2002 - Present

Member, IEEE, January 2004 - Present

Service activities

Committee Member, UCSC, Baskin School of Engineering,, June 2015 - June 2018

Principal publications and presentations in the last five years

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Xargay, E., Choe, R., Hovakimyan, N., Aguiar, A. P., Pascoal, A. M. (2015). Cooperative Path Following of Multiple Multirotors Over Time-Varying Networks. *IEEE Transactions on Automation Science and Engineering, 12*(3), 945-957.

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Xargay, E., Choe, R., Hovakimyan, N., Pedro Aguiar, A., Pascoal, A. M. (2015). Cooperative Path Following of Multiple Multirotors Over Time-Varying Networks. *Transactions on Automation Science and Engineering, 12*(3), 945–957.

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Hovakimyan, N. (2015). Coordinated vision-based tracking for multiple UAVs. *2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 656-661).

Dobrokhodov, V. N. (2015). Kinematics and Dynamics of Fixed-Wing UAVs. *Handbook of Unmanned Aerial Vehicles* (pp. 243–277). Springer.

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Hovakimyan, N. (2015). Coordinated vision-based tracking for multiple UAVs. *Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on* (pp. 656–661).

Jones, K. D., Dobrokhodov, V. N., Dillard, C. (2016). Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part I – platform design. *OCEANS 2016 MTS/IEEE Monterey*.

Dobrokhodov, V. N., Jones, K. D., Dillard, C., Kaminer, I. I. (2016). Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part II – onboard intelligence. *OCEANS 2016 MTS/IEEE Monterey* (pp. 1-9).

Dobrokhodov, V. N. (2017). *The Hybrid Tiger Long Endurance Solar/Fuel Cell/Soaring Unmanned Air Vehicle*. Tampa: International mechanical Engineering Congress and Exposition (IMECE2017).

Walton, C., Kaminer, I. I., Dobrokhodov, V. N., Jones, K. D. (2017). *New Insights into Autonomous Soaring*. IEEE.

Stroman, R., Edwards, D., Dobrokhodov, V. N. (2018). *The Hybrid Tiger: A Long Endurance Solar/Fuel Cell/Soaring Unmanned Aerial Vehicle*. Denver, Colorado:. http://www.powersourcesconference.com/Power%20Sources%202018%20Digest/docs/19-1.pdf

Leary, P. R., Dobrokhodov, V. N., Smith, K. B., Jones, K. D. (2018). *An affordable open-source DAQ system for real-time multi-channel acoustic signal processing*. 3rd Australasian Conference on Wave Science, KOZWaves, February 2018.

Leary, P. R., Dobrokhodov, V. N., Smith, K. B., Jones, K. D. (2018). *A flexible, open-source DAQ for real-time multi-channel signal processing on autonomous platforms*. Kobe: OCEANS'18 MTS/IEEE, Kobe Japan, May 2018.

Dobrokhodov, V. N., Jones, K. D., OCEANS 2016 MTS/IEEE Monterey, "Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part I - platform design," Monterey, CA, United States. (February 2, 2017).

Dobrokhodov, V. N., Jones, K. D., OCEANS 2016 MTS/IEEE Monterey, "Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part II - onboard intelligence," Monterey, CA, United States. (February 2, 2017).

Dobrokhodov, V. N., International mechanical Engineering Congress and Exposition (IMECE2017), "The Hybrid Tiger Long Endurance Solar/Fuel Cell/Soaring Unmanned Air Vehicle," Tampa, FL. (November 2017).

Leary, P. R., Dobrokhodov, V. N., Smith, K. B., Jones, K. D., OCEANS'18 MTS/IEEE, Kobe Japan, May 2018, "A flexible, open-source DAQ for real-

time multi-channel signal processing on autonomous platforms," IEEE, Kobe, Japan. (May 2018).

Dobrokhodov, V. N., 48th Power Sources Conference, "The Hybrid Tiger: A Long Endurance Solar/Fuel Cell/Soaring Unmanned Aerial Vehicle," Denver, CO. (June 2018).

Name: **Bautista R. Fernandez**

Education

Degree	Discipline	Institution	Year
BS		UNIVERSITY OF CALIFORNIA-SANTA CRUZ	2004
MS		UNIVERSITY OF CALIFORNIA-SANTA CRUZ	2007
PhD		UNIVERSITY OF CALIFORNIA-SANTA CRUZ	2011

Name: **Anthony J. Gannon**

Education

Degree	Discipline	Institution	Year
BSC	Mechanical Engineering	University of Natal-Durban	1994
MSC	Mechanical Engineering	Stellenbosch-South Africa	1996
PhD	Mechanical Engineering	Stellenbosch-South Africa	2002

Certifications or professional registrations

Professional Engineer, California

Current membership in professional organizations

Honors and awards

Best paper award, Heating and Cooling Division

Best Paper Award – ASME TurboExpo, Microturbines Division;
Gannon, A. J., Hobson, G. V., Shea, M. J., Clay, C. S., Millsaps, K. T. (2013).
MEMS-Scale Turbomachinery Based Vacuum Roughing Pump

Service activities

Committee Member, Academic Council, October 1, 2015 - Present

Principal publications and presentations in the last five years

Hobson, G. V., Gannon, A. J., Holmes, W., McCormick, M., Capece, V. (2014). Experimental and numerical performance characterization of a transonic compressor rotor operating behind an inlet-guide vane with variable flap angles. *ASME Turbo Expo 2014: Turbine Technical Conference and Exposition* (pp. V02AT37A056–V02AT37A056).

Gannon, A. J., Hobson, G. V., Hedges, C. R., Descovich, G. L. (2014). Investigation and Prediction of Steam-Induced Stall-Margin Reduction in Two Transonic Rotor Fans. *Journal of Fluids Engineering, 136*(11), 111101.

Gannon, A. J., Hobson, G. V., Shea, M. J., Clay, C. S., Millsaps, K. T. (2014). MEMS-scale turbomachinery based vacuum roughing pump. *Journal of Turbomachinery, 136*(10), 101002.

Gannon, A. J., Ponder, J., Hobson, G. V. (2014). Optimization of Vertical Axis Wind Turbine Arrays.

Hobson, G. V., Gannon, A. J., Drayton, S. (2015). Design and test of a transonic axial splittered rotor. *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition* (pp. V02BT39A029–V02BT39A029).

Turner, M. G., Nemnem, A., Gannon, A. J., Hobson, G. V., Sanz, W. (2015). Measured Heat Transfer in a Transonic Fan Rig at Casing With Implications on Performance. *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition* (pp. V02AT37A039–V02AT37A039).

Pollman, A. G., Gannon, A. J. (2015). Multi-Physics Energy Approach and Demonstration Facility. *ASME 2015 9th International Conference on Energy Sustainability collocated with the ASME 2015 Power Conference, the ASME 2015 13th International Conference on Fuel Cell Science, Engineering and Technology, and the ASME 2015 Nuclear Forum* (pp. V001T03A001–V001T03A001).

Gannon, A. J., Hobson, G. V., Turner, M. G., Sanz, W. (2015). Performance of a splittered transonic rotor with several tip clearances. *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition* (pp. V02AT37A040–V02AT37A040).

Hawxhurst, K., Williams, J., Pollman, A. G., Gannon, A. J. (2017). Renewable-Powered HVAC with Thermal Storage. *ASHRAE Journal*.

Willis, R., Pollman, A. G., Gannon, A. J., Hernandez, A. D.S. (2018). *Preliminary Modeling of a Building-scale Liquid Air Energy Storage System with Aspen HYSYS*. MORS.

Howe, T. A., Pollman, A. G., Gannon, A. J. (2018). Operating Range for a Combined, Building-Scale LAES and Expansion System: Energy and Exergy Analysis. *Entropy*, *20*(10).

Pollman, A. G., Gannon, A. J., UC Davis - Mechanical & Aerospace Engineering Colloquim, "Mitigating Intermittency on a Renewable-Powered Micro-Grid." (November 2017).

Name: **Francis X. Giraldo,** Professor of Applied Mathematics

Education

Degree	Discipline	Institution	Year
BSE	Mechanical and Aerospace Engineering	Princeton University	1987
PhD	Mechanical and Aerospace Engineering	University of Virginia,	1995

Current membership in professional organizations

National Unified Operational Prediction Capability (NUOPC), 2010-Present
Society for Industrial and Applied Mathematics, 2002-Present

Honors and awards

Menneken Award for Scientific Excellence, Naval Postgraduate School, 2007
Alan Berman Publication Award, Naval Research Laboratory, 2001

Service activities

Naval Postgraduate School, Professional Practices Committee of the Faculty Council, Member, 2013-2016
Naval Postgraduate School, Faculty Council, Chair, 2011-2012
Naval Postgraduate School, Faculty Council, Secretary, 2010-2011
Naval Postgraduate School, Faculty Council, Executive Board Member, 2008-2014

Principal publications and presentations in the last five years

1. S. Kang, F.X. Giraldo, and T. Bui-Thanh, IMEX HDG-DG: A coupled implicit hybridized discontinuous Galerkin and explicit discontinuous Galerkin approach for shallow water systems, Journal of Computational Physics (in review, 2018) (ResearchGate)(arXiv).
2. B. Bonev, J.S. Hesthaven, F.X. Giraldo, and M.A. Kopera, Discontinuous Galerkin scheme for the spherical shallow water equations with applications to tsunami modeling and prediction, Journal of Computational Physics, Vol. 362, 425-448 (2018) (ResearchGate)(PDF and Movies).
3. Gianmarco Mengaldo, Andrzej Wyszogrodzki, Michail Diamantakis, Sarah-Jane Lock, Francis X. Giraldo, Nils P. Wedi, Current and emerging time-integration strategies in global numerical weather and climate prediction, Archives of Computational Methods in Engineering, https://doi.org/10.1007/s11831-018-9261-8 (2018) (ResearchGate).
4. S. Marras, M. Kopera, E.M. Constantinescu, J. Suckale, F.X. Giraldo, A continuous/discontinuous Galerkin solution of the shallow water equations with dynamic viscosity, high-order wetting and drying, and implicit time integration, Advances in Water Resources, Vol. 114, 45-63 (2018). (ResearchGate) (arXiv).
5. A. Mueller, M. Kopera, S. Marras, L. Wilcox, T. Isaac, F.X. Giraldo, Strong scaling for numerical weather prediction at petascale with the atmospheric model NUMA, International Journal for High-Performance Computing Applications, https://doi.org/10.1177/1094342018763966 (2018) (ResearchGate) (arXiv).
6. D.S. Abdi, F.X. Giraldo, E.M. Constantinescu, L.E. Carr III, L. Wilcox, T. Warburton, Acceleration of the Implicit-Explicit Non-hydrostatic Unified Model of the Atmosphere (NUMA) on Manycore

Processors, International Journal for High-Performance Computing Applications, https://doi.org/10.1177/1094342017732395 (2017) (ResearchGate) (arXiv).
7. J. Carman, T. Clune, F.X. Giraldo, M. Govett, B. Gross, A. Kamrath, T. Lee, D. McCarren, J. Michalakes, S. Sandgathe, T. Whitcomb, Position Paper on High Performance Computing Needs in Earth System Prediction, National Earth System Prediction Capability, https://doi.org/10.7289/V5862DH3 (2017) (ResearchGate).
8. D.S. Abdi, L. Wilcox, T. Warburton, F.X. Giraldo, A GPU-accelerated continuous and discontinuous Galerkin non-hydrostatic atmospheric model, International Journal for High-Performance Computing Applications, https://doi.org/10.1177/1094342017694427 (2017). (ResearchGate).
9. S. Guimond, J. Reisner, S. Marras, and F.X. Giraldo, The impacts of numerical schemes on asymmetric hurricane intensification, Journal of the Atmospheric Sciences, Vol. 73, 4661–4684 (2016) (ResearchGate).
10. E. Hendricks, M.A. Kopera, F.X. Giraldo, Melinda S. Peng, James D. Doyle, and Qingfang Jiang, Evaluation of the utility of static and adaptive mesh refinement for idealized tropical cyclone problems in a spectral element shallow water model, Monthly Weather Review, Vol. 144, 3697–3724 (2016) (ResearchGate).
11. D.S. Abdi and F.X. Giraldo, Efficient construction of unified continuous and discontinuous Galerkin formulations for the 3D Euler equations, Journal of Computational Physics, Vol. 320, 46-68 (2016) (ResearchGate).
12. G. Theurich, C. DeLuca, T. Campbell, F. Liu, K. Saint, M. Vertenstein, J. Chen, R. Oehmke, J. Doyle, T. Whitcomb, A. Wallcraft, M. Iredell, T. Black, A. DaSilva, T. Clune, R. Ferraro, P. Li, M. Kelley, I. Aleinov, V. Balaji, N. Zadeh, R. Jacob, B. Kirtman, F.X. Giraldo, D. McCarren, S. Sandgathe, S. Peckham, R. Dunlap, The Earth System Prediction Suite: towards a coordinated U.S. modeling capability, Bulletin of the American Meteorological Society, Vol. 97, Issue 7, 1229-1247 (2016) (ResearchGate).
13. S. Marras, J.F. Kelly, M. Moragues, A. Mueller, M.A. Kopera, M. Vazquez, F.X. Giraldo, G. Houzeaux, O. Jorba, A review of element-based Galerkin methods for numerical weather prediction. Finite Elements, Spectral Elements, and Discontinuous Galerkin, Archives of Computational Methods in Engineering, Vol. 23, 673–722 (2016) (ResearchGate).
14. M. Yu, F.X. Giraldo, M. Peng, Z.J. Wang, Localized artificial viscosity stabilization of discontinuous Galerkin methods for nonhydrostatic mesoscale atmospheric modeling, Monthly Weather Review, Vol. 143, 4823-4845 (2015) (ResearchGate).
15. S. Marras, M. Nazarov, and F.X. Giraldo, A conservative, consistent, and grid adaptive stabilized spectral element method based on a dynamic LES model for the compressible Euler Equations: the case of low Mach stratified flow, Journal of Computational Physics, Vol. 301, 77-101 (2015) (ResearchGate).
16. L.E., Carr, C.F. Borges, and F.X. Giraldo, A matrix-free polynomial-based nonlinear least-squares optimized preconditioner and its application to discontinuous Galerkin discretization of the Euler equations, Journal of Scientific Computing, Vol. 66, 917-940 (2015) (ResearchGate).
17. M.A. Kopera and F.X. Giraldo, Mass conservation of unified continuous and discontinuous element-based Galerkin methods on dynamically adaptive grids with application to atmospheric simulations, Journal of Computational Physics, Vol 297, 90-103 (2015) (ResearchGate).
18. S. Marras, and F.X. Giraldo, A parameter-free dynamic alternative to hyper-viscosity for coupled transport equations: applications to the simulation of 3D squall lines using spectral elements, Journal of Computational Physics, Vol. 283, 360-373 (2015) (ResearchGate).
19. S. Marras, M.A. Kopera and F.X. Giraldo, Simulation of shallow water jets with a unified element-based continuous/discontinuous Galerkin model with grid flexibility on the sphere, Quarterly Journal of the Royal Meteorological Society, Vol. 141, 1727-1739 (2015) (ResearchGate).
20. W. Kang, L. Xu, F.X. Giraldo, Partial observability and its consistency for PDEs (unpublished) (2014) (ResearchGate) (arXiv)
21. S.J. Choi, F.X. Giraldo, J. Kim, and S. Shin, Verification of a non-hydrostatic dynamical core using horizontally spectral element and vertically finite difference methods: 2D aspects, Geoscientific Model Development, Vol. 7, 2717-2731 (2014) (ResearchGate).
22. S.J. Choi and F.X. Giraldo, Development and evaluation of a hydrostatic dynamical core using the spectral element/discontinuous Galerkin methods, Geoscientific Model Development, Vol. 7, 4119-4151 (2014) (ResearchGate).

23. M.A. Kopera and F.X. Giraldo, Analysis of adaptive mesh refinement for IMEX discontinuous Galerkin solutions of the compressible Euler equations with application to atmospheric simulations, Journal of Computational Physics Vol. 275, 92-117 (2014) (ResearchGate).
24. L. Yelash, A. Mueller, M. Lukacova-Medvidova, F.X. Giraldo, V. Wirth, Adaptive discontinuous evolution Galerkin method for dry atmospheric flow, Journal of Computational Physics Vol. 268 106-133 (2014) (ResearchGate).

Name: Joshua H. Gordis

Education

Degree	Discipline	Institution	Year
BS		University of Vermont	1983
MS		Rensselaer Polytechnic Institute	1987
PhD		Rensselaer Polytechnic Institute	1990

Current membership in professional organizations

Reviewer

Service activities

Faculty Advisor, Academic Associate, January 1, 2006 - Present

Faculty Advisor, Academic Associate, January 1, 2006 - Present

Committee Member, Academic Council department representative, October 1, 2014 - Present

Reviewer, Journal Article, Journal of Sound & Vibration, October 1, 2014 - Present

Principal publications and presentations in the last five years

Gordis, J. H., Shin, J.-C., Bouwense, M. D. (2018). Minimum condition number by orthogonal projection row selection of artificial boundary conditions for finite element model update and damage detection. *Journal of Sound and Vibration, 433*(27), 179-197.

Gordis, J. H., Quarterly Seabasing Integration Division meeting, "Modeling & Simulation of Fleet/Force Sustainment," Marine Corps, Combat Development and Integration, Dumfries, VA, United States. (December 14, 2014).

Recent professional development activities

Took a class at NPS, ME4700 - Weaponeering, Naval Postgraduate School, Monterey, April 3, 2018 - June 15, 2018

Name: **Ibrahim E. Gunduz**

Education

Degree	Discipline	Institution	Year
MS		MIDDLE EAST TECHNICAL UNIVERSITY	1999
BS		MIDDLE EAST TECHNICAL UNIVERSITY	2001
PhD		NORTHEASTERN UNIVERSITY	2006

Current membership in professional organizations

MRS, 2005 - Present

Phi Kappa Phi, 2005 - Present

TMS, 2005 - Present

Principal publications and presentations in the last five years

Olokun, A., Prakash, C., Gunduz, I. E., Tomar, V. (2019). Interface chemistry dependent mechanical properties in energetic materials using nano-scale impact experiment. *Dynamic Behavior of Materials, Volume 1* (pp. 147--152). Springer, Cham.

Prakash, C., Olokun, A., Gunduz, I. E., Tomar, V. (2019). Interface Mechanical Properties in Energetic Materials Using Nanoscale Impact Experiment and Nanomechanical Raman Spectroscopy. *Nano-Energetic Materials* (pp. 275--290). Springer, Singapore.

Prakash, C., Gunduz, I. E., Tomar, V. (2019). Uncertainty Quantification in Nanoscale Impact Experiment in Energetic Materials. *Model Validation and Uncertainty Quantification, Volume 3* (pp. 257--263). Springer, Cham.

Prakash, C., Gunduz, I. E., Tomar, V. (2019). Interface Chemistry and Strain Rate Effect on Fracture in Energetic Material Interfaces.

Name: **Garth V. Hobson**

Education

Degree	Discipline	Institution	Year
BS	Aeronautical Engineering	University of Witwatersand-South Africa	1979
ME	Mechanical Engineering	University of Witwatersand-South Africa	1983
PhD	Aerospace Engineering	Pennsylvania State University	1989

Current membership in professional organizations

Associate Fellow, AIAA

Member, ASME

Awards

Best Paper Award – ASME TurboExpo, Microturbines Division;
Gannon, A. J., Hobson, G. V., Shea, M. J., Clay, C. S., Millsaps, K. T. (2013).
MEMS-Scale Turbomachinery Based Vacuum Roughing Pump

Certificate of Recognition for Outstanding Performance in Instruction

Director's Award for Innovative Engineering, Council for Scientific and Industrial Research

Service activities

Chairperson, Chair, October 1, 2014 - September 30, 2015

Committee Member, Sabbatical Selection Committee, Oct, 2014 - Sep, 2015

Chairperson, Administration, October 2015 - September 2016

Chairperson, ASME Turbo Expo Session Organizer, January 2016 - June 2016

Principal publications and presentations in the last five years

Hobson, G. V., Gannon, A. J., Holmes, W., McCormick, M., Capece, V. (2014). Experimental and numerical performance characterization of a transonic compressor rotor operating behind an inlet-guide vane with variable flap angles. *ASME Turbo Expo 2014: Turbine Technical Conference and Exposition* (pp. V02AT37A056–V02AT37A056).

Gannon, A. J., Hobson, G. V., Hedges, C. R., Descovich, G. L. (2014). Investigation and Prediction of Steam-Induced Stall-Margin Reduction in Two Transonic Rotor Fans. *Journal of Fluids Engineering, 136*(11), 111101.

Gannon, A. J., Hobson, G. V., Shea, M. J., Clay, C. S., Millsaps, K. T. (2014). MEMS-Scale Turbomachinery Based Vacuum Roughing Pump. *Journal of Turbomachinery*, *136*(10), 101002.

Cook, J., Rhyans, S., Roncase, L., Hobson, G. V., Luhrs, C. C. (2014). Microstructural Study of IF-WS2 Failure Modes. *Inorganics*, *2*(3), 377–395.

Gannon, A. J., Ponder, J., Hobson, G. V. (2014). Optimization of Vertical Axis Wind Turbine Arrays.

Hobson, G. V., Gannon, A. J., Drayton, S. (2015). *Design and Test of a Transonic Axial Splittered Rotor*. Monteal, Canada: ASME International Gas Turbine Institute Conference,.

Turner, M. G., Nemnem, A., Gannon, A. J., Hobson, G. V., Sanz, W. (2015). *Measured Heat Transfer in a Transonic Fan Rig with Implications on Performance*. Monteal, Canada: ASME International Gas Turbine Institute Conference,.

Gannon, A. J., Hobson, G. V., Turner, M. G., Sanz, W. (2015). *Performance of a Splittered Transonic Rotor with Several Tip Gap Clearances*. Montreal Canada: ASME International Gas Turbine Institute Conference,.

Hobson, G. V., Gannon, A. J., Drayton, S. (2015). Design and test of a transonic axial splittered rotor. *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition* (pp. V02BT39A029–V02BT39A029).

Turner, M. G., Nemnem, A., Gannon, A. J., Hobson, G. V., Sanz, W. (2015). Measured Heat Transfer in a Transonic Fan Rig at Casing With Implications on Performance. *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition* (pp. V02AT37A039–V02AT37A039).

Gannon, A. J., Hobson, G. V., Turner, M. G., Sanz, W. (2015). Performance of a splittered transonic rotor with several tip clearances. *ASME Turbo Expo 2015: Turbine Technical Conference and Exposition* (pp. V02AT37A040–V02AT37A040).

Name: **Kevin D. Jones**

Education

Degree	Discipline	Institution	Year
BS	Aerospace Engineering Sciences	University of Colorado	1988
MS	Aerospace Engineering Sciences	University of Colorado	1990
PhD		University of Colorado-Boulder	1993

Current membership in professional organizations

Associate Fellow, AIAA, January 1, 1986 - Present

Service activities

Evaluate system safety for UAS at NPS-hosted field experiments, Program support, February 2009 - Present

Reviewer, Journal Article, Aerospace Science & Technology, July 2015 - September 2015

Reviewer, Ad Hoc Reviewer, Outside Ph.D. Dissertation Review, September 2015 - November 2015

Principal publications and presentations in the last five years

Dobrokhodov, V. N., Jones, K. D., Camacho, N. (2014). Cooperative Autonomy of Multiple Solar-Powered Thermaling Gliders. *World Congress* (1st ed., vol. 19, pp. 1222–1227). IFAC.

Camacho, N., Dobrokhodov, V. N., Jones, K. D. (2014). Cooperative Autonomy of Multiple Solar-Powered Thermaling Gliders? *Energy*, *25*, 50.

Jones, K. D., Platzer, M. (2015). Flapping-Wing Propelled Micro Air Vehicles. *Handbook of Unmanned Aerial Vehicles* (pp. 1359–1383). Springer.

Chung, T. H., Clement, M. R., Day, M. A., Jones, K. D., Davis, D. T., Jones, M. J. (2016). *Live-Fly, Large-Scale Field Experimentation for Large Numbers of Fixed-Wing UAVs*. Stockholm: IEEE.

Jones, K. D., Dobrokhodov, V. N., Dillard, C. (2016). Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part I – platform design. *OCEANS 2016 MTS/IEEE Monterey* (pp. 1-10).

Dobrokhodov, V. N., Jones, K. D., Dillard, C., Kaminer, I. I. (2016). Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part II – onboard intelligence. *OCEANS 2016 MTS/IEEE Monterey* (pp. 1-9).

Buettner, R., Davis, D., Jones, K., Jones, M., Giles, K. (2017). *Field Experimentation After Action Report*. https://calhoun.nps.edu/handle/10945/52486

Walton, C., Kaminer, I. I., Dobrokhodov, V. N., Jones, K. D. (2017). *New Insights into Autonomous Soaring*. IEEE.

Leary, P. R., Dobrokhodov, V. N., Smith, K. B., Jones, K. D. (2018). *An affordable open-source DAQ system for real-time multi-channel acoustic signal processing*. 3rd Australasian Conference on Wave Science, KOZWaves, February 2018.

Leary, P. R., Dobrokhodov, V. N., Smith, K. B., Jones, K. D. (2018). *A flexible, open-source DAQ for real-time multi-channel signal processing on autonomous platforms*. Kobe: OCEANS'18 MTS/IEEE, Kobe Japan, May 2018.

Jones, K. D. (Author & Presenter), Wang, Q. (Author), Yamaguchi, R. (Author), Lind, R. J. (Author), 3rd Conference of the International Society for Atmospheric Research using Remotely Piloted Aircraft, "Real-Time METOC Sensing Using Low-Cost, Expendable Unmanned Aerial Vehicles," ISARRA, University of Oklahoma, Norman, CA, United States. (May 21, 2015).

Jones, K. D. (Author & Presenter), Wang, Q., Yamaguchi, R. T., Lind, R. J., 96th AMS Annual meeting and 18th Symposium on Meteorological Observations and Instrumentation, "Small UAS for Atmospheric Surface Layer Measurements,," American Meteorological Society, New Orleans, LA, United States. (January 2016).

Dobrokhodov, V. N., Jones, K. D., OCEANS 2016 MTS/IEEE Monterey, "Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part I - platform design," Monterey, CA, United States. (February 2, 2017).

Dobrokhodov, V. N., Jones, K. D., OCEANS 2016 MTS/IEEE Monterey, "Aqua-Quad - solar powered, long endurance, hybrid mobile vehicle for persistent surface and underwater reconnaissance, part II - onboard intelligence," Monterey, CA, United States. (February 2, 2017).

Leary, P. R., Dobrokhodov, V. N., Smith, K. B., Jones, K. D., OCEANS'18 MTS/IEEE, Kobe Japan, May 2018, "A flexible, open-source DAQ for real-time multi-channel signal processing on autonomous platforms," IEEE, Kobe, Japan. (May 2018).

Yamaguchi, R. T. (Author), Suring, L. (Presenter), Wang, Q., Jones, K. D., Kalogiros, J., International Society for Atmospheric Research using Remotely Piloted Aircraft, "Optical turbulence and mean meteorological measurement capabilities for small UAS Penguin." (July 10, 2018).

Name: **Isaac I. Kaminer**

Education

Degree	Discipline	Institution	Year
BS		University of Minnesota	1983
ME		University of Minnesota	1985
PhD		University of Michigan	1992

Service activities

Department Evaluation Committee, Chair of a DEC, September 2015 - January 2016

Chairperson, DEC, September 2017 - January 2018

reviewer, Automatica, September 2014 - October 2015

reviewer, IEEE, September 2014 - October 2015

Principal publications and presentations in the last five years

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Xargay, E., Choe, R., Hovakimyan, N., Pedro Aguiar, A., Pascoal, A. M. (2015). Cooperative Path Following of Multiple Multirotors Over Time-Varying Networks. *Transactions on Automation Science and Engineering, 12*(3), 945–957.

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Hovakimyan, N. (2015). Coordinated vision-based tracking for multiple UAVs. *2015 IEEE/RSJ International Conference on Intelligent Robotsand Systems (IROS)* (pp. 656-661).

Kaminer, I. I., Xargay, E., Cichella, V., Hovakimyan, N., Pascoal, A. M., Aguiar, P. A., Dobrokhodov, V. N., Ghabcheloo, R. (2015). Time-critical cooperative path following of multiple uavs: Case studies. *Advances in Estimation, Navigation, and Spacecraft Control* (vol. XII, pp. 209–233). Springer.

Cichella, V., Kaminer, I. I., Dobrokhodov, V. N., Hovakimyan, N. (2015). Coordinated vision-based tracking for multiple UAVs. *Intelligent Robots and Systems (IROS), 2015 IEEE/RSJ International Conference on* (pp. 656–661).

Foraker, J., Royset, J. O., Kaminer, I. I. (2015). Search-trajectory optimization: Part I, Formulation and theory. *Journal of Optimization Theory and Applications*, 1–20.

Walton, C., Phelps, C., Kong, Q., Kaminer, I. (2016). *A Numerical Algorithm for Optimal Control of Systems with Parameter Uncertainty (I)* (Issue 18, ed., vol. Volume 49, 2016, , pp. Pages 468–475). IFAC. http://www.sciencedirect.com/science/article/pii/S240589631631789X

Kaminer, I. I., Dobrokhodov, V. N. (in press). *Time-Critical Cooperative Control of Autonomous Air Vehicles* (1st ed., vol. 1). Elsevier. https://www.elsevier.com/books/time-critical-cooperative-control-of-autonomous-air-vehicles/unknown/978-0-12-809946-9

Walton, C., Kragelund, S. P., Kaminer, I. I. (2016). *The application of 'optimal search' to marine mapping* (pp. 1-6). IEEE. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7761182&isnumber=7760990

Walton, C., Kragelund, S. P., Kaminer, I. I. (2017). *Issues in multi-agent search: False positives and Bayesian map updates* (pp. 1-4). IEEE.

Walton, C., Kaminer, I. I., Dobrokhodov, V. N., Jones, K. D. (2017). *New Insights into Autonomous Soaring*. IEEE.

Chicella, V., Kaminer, I., Walton, C., Hovakimyan, N. (2018). Optimal Motion Planning for Differentially Flat Systems Using Bernstein Approximation. *Control Systems Letters*, 181-186.

Kang, W., Kaminer, I. I., Walton, C. (2018). *Observability analysis of an adversarial swarm's cooperation strategy*. IEEE.

PARK, H., GONG, Q., KANG, W., WALTON, C., KAMINER, I. (2018). *Observability Analysis of an Adversarial Swarm's Cooperation Strategy*. IEEE International Conference of Control and Applications.

Walton, C., Kaminer, I., Dobrokhodov, V., Jones, K. (2018). Alternate Strategies for Optimal Unmanned Aerial Vehicle Soaring. *Journal of Aircraft*.

Sands, T., Bollino, K., Kaminer, I., Healey, A. (2018). Autonomous Minimum Safe Distance from Submersed Obstacles in Ocean Currents. *Journal of Marine Scence and Engineering,*.

Walton, C., Lambrianides, P., Kaminer, I., Royset, J., Gong, Q. (2018). Optimal motion planning in rapid-fire combat situations with attacker uncertainty. *Naval Research Logistics*, 101-110.

Walton, C., Lambrianides, P., Kaminer, I. I., Royset, J. O., Gong, Q. (2018). Optimal motion planning in rapid-fire combat situations with attacker uncertainty. *Naval Research Logistics (NRL)*, *65*(2), 101--119.

Name: **Mark Karpenko**

Education

Degree	Discipline	Institution	Year
BS	Mechanical Engineering	University of Manitoba-Canada	2000
MS	Mechanical Engineering	University of Manitoba-Canada	2002
PhD	Mechanical Engineering	University of Manitoba-Canada	2009

Current membership in professional organizations

ASME, January 2001 - December 2018

AIAA, January 2009 - December 2018

AAS, January 2017 - December 2018

SIAM, July 2017 - December 2018

Honors and awards

AIAA Best Presentation in Session Certificate of Merit, AIAA, January 2016

2016 Space X Grand Prize Award, Space X, February 8, 2016

Service activities

Committee Member, PhD Dissertation Committee (External - UC Santa Cruz), April 2016 - March 2018

Reviewer, Journal Article, AIAA Journal of Guidance Control and Dynamics, July 2, 2018

Principal publications and presentations in the last five years

Karpenko, M., Proulx, R. J. (2015). Experimental Implementation of Riemann-Stieltjes Optimal Control for Agile CMG Maneuvering. *25th AAS/AIAA Space Flight Mechanics Meeting , January 11-15, 2015, Williamsburg, VA. Paper number: AAS 15-288.*.

Karpenko, M., King, J. T., Ross, I. M. (2015). Agilitoid-Based Design Analysis of Next Generation Attitude Control Systems. *38th Annual AAS Guidance & Control Conference , January 30 to February, 4, 2015, Breckenridge, CO. Paper number: AAS 15-047.*.

Karpenko, M., Ross, I. M., Stoneking, E., Lebsock,, K. L., Dennehy, N. (2015). A Micro-Slew Concept for Precision Pointing of the Kepler Spacecraft. *AAS/AIAA Astrodynamics Specialist Conference, August 9 – August 13, 2015, Vail, CO. Paper number: AAS-15-628.*

Karpenko, M., King,, J. T. (2015). Agility Envelopes for Reaction Wheel Spacecraft. *AAS/AIAA Astrodynamics Specialist Conference, August 9 – August 13, 2015, Vail, CO. Paper number: AAS-15-620*.

Karpenko, M., Proulx, R. J. (2016). Experimental Implementation of Riemann–Stieltjes Optimal Control for Agile Imaging Satellites. *Journal of Guidance, Control, and Dynamics, 39*(1), 144–150. http://arc.aiaa.org/doi/10.2514/1.G001325

Karpenko, M., Dennehy, C. J., Marsh, H. C., Gong, Q. (2017). Minimum Power Slews and the James Webb Space Telescope. *27th AAS/AIAA Space Flight Mechanics Meeting , February 5-9, San Antonio, TX. Paper number: AAS 17-285.*.

Shaffer, R., Karpenko, M., Gong, Q. (2017). Relationships Between Unscented and Sensitivity Function-Based Optimal Control for Space Flight. *27th AAS/AIAA Space Flight Mechanics Meeting , February 5-9, San Antonio, TX. Paper number: AAS 17-443.*.

King, J. T., Karpenko, M. (2017). Rethinking Orthogonal Reaction Wheel Configurations for Small Satellites. *27th AAS/AIAA Space Flight Mechanics Meeting , February 5-9, San Antonio, TX. Paper number: AAS 17-313.*.

Marsh, H. C., Karpenko, M., Gong, Q. (2017). Electrical-Power Constrained Attitude Steering. *AAS/AIAA Astrodynamics Specialist Conference, Stevenson, WA, August 20 to August 24 2017, Paper number: AAS-17-774.*.

Monk, C. S., Karpenko, M. (2017). Time Optimal Control of a Double Integrator Plant with Feedback Dynamics. *AAS/AIAA Astrodynamics Specialist Conference, August 20 - 24, 2017 Stevenson, WA. Paper number: AAS 17-691.*.

March, H. C., Karpenko, M., Gong, Q. (2018). Relationships Between Maneuver Time and Energy for Reaction Wheel Attitude Control. *Journal of Guidance Control and Dynamics*.

Shaffer, R., Karpenko, M., Gong, Q. (2018). Robust Control of a Flexible Double Gimbal Mechanism. *Proceedings of the American Control Conference* (pp. 6230-6235). IEEE.

Karpenko, M., King, J. T. (2018). Maximizing agility envelopes for reaction wheel spacecraft. *Proceedings of the Institution of Mechanical Engineers Part G: Journal of Aerospace Engineering*.

Karpenko, M., King, J. T., Dennehy, C. J., Ross, I. M. (in press). Agility Analysis of the James Webb Space Telescope. *Journal of Guidance Control and Dynamics*.

Karpenko, M., 25th AAS/AIAA Space Flight Mechanics Meet, "Experimental Implementation of Riemann-Stieltjes Optimal Control for Agile CMG Maneuvering." (January 11, 2015).

Name: **Jae-Jun Kim**

Education

Degree	Discipline	Institution	Year
BS	Mechanical Engineering	State University of New York-Buffalo	1998
MS	Mechanical Engineering	State University of New York-Buffalo	2000
PhD	Mechanical Engineering	State University of New York-Buffalo	2004

Principal publications and presentations in the last five years

Agrawal, B., Kim, J. J. (2014). *Surface Control of Active Hybrid Space Mirrors*. 65th International Astronautical Congress.

Agrawal, B., Kim, J. J., Allen, M. (2015). *Cost-effective Large Apertures for Future Imaging Satellites* (AIAA 2015-4494 ed.). AIAA SPACE 2015 Conference and Exposition.

Allen, M., Kim, J. J., Agrawal, B. (2015). *Correction of an active space telescope mirror using a gradient approach and an additional deformable mirror* (Proc. SPIE 9602 ed., vol. 96020B). UV/Optical/IR Space Telescopes and Instruments: Innovative Technologies and Concepts VII.

Kim, J. J., Allen, M., Agrawal, B. (2015). *Cost-effective Aperture with Deformable Mirror for Imaging Satellites*. 66th International Astronautical Congress.

Allen, M., Kim, J. J., Agrawal, B. (2016). Correction of an active space telescope mirror using a deformable mirror in a woofer-tweeter configuration. *Journal of Astronomical Telescopes, Instruments, and Systems, 2*(2).

Kim, J. J., Mueller, M., Brij, A. (2016). *Impact of Large Field Angles on the Requirements for Deformable Mirror in Imaging Satellites*. 67th International Astronautical Congress (IAC).

Agrawal, B. N., Kim, J.-J. (2017). *Dynamics and Control Challenges for Imaging Satellites*. IAA Conference on Dynamics and Control of Space Systems.

Kim, J.-J., Agrawal, B. N. (2017). *Demonstration of Sparse Aperture Configuration for Imaging Satellites*. 68th International Astronautical Congress (IAC).

Kim, J. J., Muller, M., Martinez, T., Agrawal, B. (2018). Impact of large field angles on the requirements for deformable mirror in imaging satellites. *Acta Astronautica, 145*, 44-50.

Kim, J. J. (Author & Presenter), DeSandre, L. (Author), Agrawal, B. (Author), 17th Annual Directed Energy Symposium, "Adaptive Optics Control for

Strong Turbulence Using Iterative Wavefront Reconstruction," DEPS. (March 5, 2015).

Kim, J. J. (Author), Brij, A. (Author & Presenter), Advanced High Power Lasers Beam Control Conference, "Acquisition, Tracking, Pointing and Adaptive Optics for the High Energy Laser Beam Control Research Testbed," DEPS, Colorado Springs, CO, United States. (June 2016).

Kim, J.-J., Martinez, T., Fernandez, B., Baker, J., DeSandre, L., Directed Energy Systems Symposium, "Laboratory Testing of High Energy Laser Beam Control Research Testbed (HBCRT)." (September 25, 2017).

Name: **Young W. Kwon**

Education

Degree	Discipline	Institution	Year
BS	Mechanical Engineering	Seoul National University-Korea	1981
MS	Mechanical Engineering	Oklahoma State University	1983
PhD	Mechanical Engineering	Rice University	1985

Current membership in professional organizations

Fellow, ASME, 1999 - Present

Honorary Theme Editor, ELOSS, 2006 - Present

Honors and awards

Certificate of Appreciation, ASME, 2014

Plenary Lecture, Canadia's National Composite Conference CANCOM 2015, August 20, 2015

Commendation for Excellence in Teaching, NPS, May 2017

Letter of Commendation, DTRA, June 2017

Menneken Faculty Award for Significant and Sustained Contribution, NPS Foundation, December 2017

Service activities

PVP Division Leadership Team Member, American Society of Mechanical Engineers, 2011 - Present

Officer, Vice President, International Society of Multiphysics, 2011 - Present

Editor, Journal Editor, ASME Journal of Pressure Vessel Technology, 2013 - Present

Editor, Journal Editor, Multiscale and Multidisciplinary Modeling, Experiments and Design, 2017 - Present

Principal publications and presentations in the last five years

Kwon, Y. W., Millhouse, S. C., Arceneux, S. (2015). Study of Composite Plate in Water with Transient and Steady Sate Motions. *Composite Structures, 123*, 393-400.

Kwon, Y. W., Millhouse, S. C., Knutton, S. C., Arceneux, S. (2015). Dynamic Response of Composite Plates Moving in Water. *American Society of Composites 30th Technical Conference*.

Kwon, Y. W. (2016). *Multiscale and Multiphysics Modeling Techniques and Applications*. Boca Raton, FL: CRC Press, Taylor &AFrancis Group.

Kwon, Y. W. (2016). *Chapter 11. Dynamic Loading on Composite Structures with Fluid-Structure Interaction*. Kidlington: Woodhead Publishing (Elsevier).

Kwon, Y. W., Yun, K. (2017). Numerical Parametric Study of Hydrodynamic Ram. *International Journal of Multiphysics, 11*(1).

Kwon, Y. W., Didoszak, J. M., Loomis, J. B. (2017). *Investigation of Critical Port Infrastructure Subjected to UNDEX: Suspension Bridge*. NPS Report NPS-MAE-17-001R.

Kwon, Y. W., Bowling, J. D. (2018). Dynamic Responses of Composite Structures Coupled through Fluid Medium. *Multiscale and Multidisciplinary Modeling, Experiments, and Design, 1*(1), 69-82.

Kwon, Y. W., Darcy, J. (2018). Failure Criteria for Fibrous Composites Based on Multiscale Modeling. *Multiscale and Multidisciplinary Modeling, Experiments, and Design, 1*(1), 3-17.

Kwon, Y. W., Clumpner, B. R. (2018). Multiscale Modeling of Human Bone. *Multiscale and Multidisciplinary Modeling, Experiments, and Design, 1*(2).

Kwon, Y. W., Darcy, J. (2018). *Multiscale Based Failure Criteria for Fibrous Composites*. Athens:.

Kwon, Y. W., Bowling, J. D. (2018). Experimental Study of Vibration of Metallic and Composite Plates inside Channel Driven Cavity Flow. *Multiscale and Multidisciplinary Modeling, Experiments, and Design, 1*(3).

Kwon, Y. W., Darcy, J. (2018). Further Discussion on Newly Developed Failure Criteria for Fibrous Composites. *Multiscale and Multidisciplinary Modeling, Experiments, and Design*.

Kwon, Y. W., University of Naples Federico II, "Analysis of Multiscale and Multiphysics." (May 2017).

Kwon, Y. W., Picatinny Arsenal, "Multiscale Analysis." (August 2017).

Kwon, Y. W., Pusan National University, "Multiscale Analysis of Materials:Composites and Biomaterials." (September 2017).

Name **Dr. Wenschel D. Lan**

Education

Degree	Discipline	Institution	Year
BS	Mechanical Engineering	California Polytechnic State University	2008
MS	Mechanical Engineering	California Polytechnic State University	2008
PhD	Astronautical Engineering	Naval Postgraduate School	2015

Current membership in professional organizations

American Institute of Aeronautics and Astronautics. (January 2014 - Present).

Principal publications and presentations in the last five years

Lan, W. D. (Author & Presenter), Luqi (Author), 86th MORS Symposium, "Effect of Orbital Prediction Models on Satellite Vulnerability Planning," Military Operations Research Society, Naval Postgraduate School, Monterey, CA, United States. (June 20, 2018).

Lan, W. D. (Author), Swintek, P. C. (Author & Presenter), Minelli, G. (Other), Newman, J. H. (Author), 2018 CubeSat Developers' Workshop, "Critical Vulnerabilities in the Space Domain: Using Nanosatellites as an Alternative to Traditional Satellite Communications," California Polytechnic State University, San Luis Obispo, CA, United States. (April 30, 2018).

Lan, W. D., Kaushish, V., Newman, J. H., 29th Annual AIAA/USU Conference on Small Satellites, "Progress in Reducing Vibration Levels on NPSCuL," SSC15-X-4, Logan, UT. (August 4, 2015).

Lan, W. D., Kaushish, V., Newman, J. H., 12th Annual CubeSat Workshop, "Progress in Reducing the Vibration Levels on NPSCuL," California Polytechnic State University, San Luis Obispo, CA. (April 23, 2015).

Name **Herschel H. Loomis, Jr.,** (Emeritus) Distinguished Profesor of Electrical and Computer Engineering

Education

Degree	Discipline	Institution	Year
BEE	Electrical Engineering	Cornell University	1957
MSEE	Electrical Engineering	University of Maryland	1959
PhD	Electrical Engineering	Massachusetts Institute of Technology	1963

Current membership in professional organizations

Registered Professional Engineer, California, Electrical

Principal publications and presentations in the last five years

LTJG Athanasios Gavros, Hellenic Navy, Prof. Herschel H. Loomis, Jr., Prof. Alan A. Ross, "Reduced Precision Redundancy in a Radix-4 FFT Implementation on a Field Programmable Gate Array," *Proceedings of the 2011 IEEE Aerospace Conference*, Big Sky, Montana, March 5-12, 2011

Capt. Margaret A. Sullivan, USAF, Professor Herschel H. Loomis, and Professor Alan A. Ross, "Employment of Reduced Precision Redundancy for Fault Tolerant FPGA Applications," *Proceedings of the IEEE Symposium on Field-Programmable Custom Computing Machines*, 5-7 April 2009, Napa, CA, pp 283-286

Name: **Claudia C. Luhrs**

Education

Degree	Discipline	Institution	Year
BS		Monterrey Institute of Technology and Higher Education	1993
MS	Materials Science	University of Barcelona-Spain	1995
PhD	Materials Science	University of Barcelona-Spain	1997

Current membership in professional organizations

Member, ACS, January 1, 2014 - December 31, 2015

Member, MRS, January 1, 2012 - Present

Member, MSA, January 1, 2015 - Present

Member, TMS, January 1, 2016 - Present

Honors and awards

Carl E. and Jessie W. Menneken Faculty Award for Excellence in Scientific Research, NPS Foundation, October 2014

Fulbright Award, United States Department of State, February 11, 2016

Fulbrigth Awardee to visit Spanish Naval Academy, Department of State, December 21, 2016

Service activities

Chairperson, Dean of Research Reappointment Committee, August 8, 2015 - October 20, 2015

Principal publications and presentations in the last five years

Luhrs, C. C., Menon, S., Vilardi, N. (2015). *Graphite Oxide and Graphene as Enhancers of Energetic Mixtures* (2132750th ed.).

Celis-Salazar, P., Zea, H., Luhrs, C. C., Phillips, J., Ramirez, J. (2015). Iron on Carbon Catalaysts for the Photocatalytic Degradation Orange II. *Journal of Advanced Oxidation Technologies, 18*(2), 295–302.

Leseman, Z., Luhrs, C. C., Phillips, J., Soliman, H. (2016). *Aerosol reduction/expansion synthesis (A-RES) for zero valent metal particles*.

Camargo, A., Menon, S. K., Luhrs, C. C., Mariella, R. (2016). Inclusions and the Color of Obsidian. *Microscopy and Microanalysis, 22*(S3), 1814–1815.

Muss, J. A., Brophy, C., Luhrs, C. C., Aldridge, B. (2016). *Soot Deposit Characterization In Fuel Film Cooled Kerosene Rocket Engines*. Phoenix AZ:.

Tirano, J., Zea, H., Luhrs, C. C. (2018). *Morphology Evolution in Titanium Dioxide Nanotubes Arrays Prepared By Electrochemical Anodization* (vol. 11, pp. 204).

Lee, T. L., Adams, R. A., Luhrs, C. C., Arora, A., Pol, V. G., Wu, C.-H., Phillips, J. (2018). High-stability tin/carbon battery electrodes produced using reduction expansion synthesis. *CARBON*, *132*, 411-419.

MENON, S. (Author & Presenter), Luhrs, C. C. (Author), Mariella Jr, R. P. (Author), DTRA Meeting, "Characterization of Particles formed via Laser-Driven Hydrothermal Processing," DTRA, Washington DC, Washington DC, DC, United States. (July 20, 2015).

Luhrs, C. C. (Presenter), Monthly Seminar NPS Energy Academic Group, "Graphene Electrodes For Supercapacitor And Battery Devices.," NPS, MAE Auditorium, Monterey, CA, United States. (February 15, 2016).

Luhrs, C. (Author), Park, C. (Presenter), Dominguez, C. (Author), TMS minerals, metals, and materials society, "Fabrication and Mechanical Behavior of Carbon Nanofiber foam core-polymeric shell structures.," The minerals, metals, and materials society, TMS2016, Nashville, TN, United States. (February 2016).

Luhrs, C. (Author), Menon, S. K. (Author), De la Fuente, R. (Author), TMS 2016, "Structure and Mechanical Properties of Nickel Nanoparticles," TMS minerals, metals, and materials society, TMS 2016, Nashville, TN, United States. (February 2016).

MENON, S. (Author & Presenter), Luhrs, C. C. (Author), Ray, M. J. P. (Author), 2016 DTRA Basic Research Technical Review, "Characterization of Particles formed via Laser Driven Hydrothermal Processing," DTRA, Review Center, Waterford at Springfield, Springfield, VA, United States. (July 19, 2016).

MENON, S. (Author & Presenter), Luhrs, C. C. (Author), Andres, C. (Author), Ray, M. J. P. (Author), Microscopy & Microanalysis 2016, "Inclusions and the color of obsidian," Microscopy Society of America, Columbus Convention Center, Columbus, OH, United States. (July 24, 2016).

Wu, C.-H., Luhrs, C., Interagency Technical Nuclear Forensics Program Review 2017, "Characterization of Particles formed via Laser-Driven Hydrothermal Processing," DTRA. (July 25, 2017).

Luhrs, C. C. (Author & Presenter), American Chemical Society - Monterey Bay Chapter, "Design, Fabrication and Testing of Functional Nanomaterials," ACS, Cabrillo College, Aptos, CA, United States. (October 27, 2017).

Name: **James H. Newman**

Academic experience

Degree	Discipline	Institution	Year
BA		Dartmouth College	1978
MA	Physics	Rice University	1982
PhD	Physics	Rice University	1984

Current membership in professional organizations

Associate Fellow, American Institute of Aeronautics and Astronautics. (1992 - Present).

American Physical Society. (1984 - Present).

Sigma Xi. (1984 - Present).

Honors and awards

Navy Superior Civilian Service Award, Naval Postgraduate School. (September 27, 2016).

Service activities

Chairperson, NPS Administration. (October 1, 2017 - September 30, 2018).

Chairperson, NPS Administration. (October 1, 2016 - September 30, 2017).

Acting Provost, NPS Administration. (September 5, 2015 - August 28, 2016).

Faculty Chair, Service to the Faculty and NPS. (December 10, 2014 - October 3, 2015).

Editor, Journal Editor, Journal of Small Satelliets. (October 1, 2016 - September 30, 2019).

Principal publications and presentations in the last five years

Lan, W. D. (Author), Swintek, P. C. (Author & Presenter), Minelli, G. (Other), Newman, J. H. (Author), 2018 CubeSat Developers' Workshop, "Critical Vulnerabilities in the Space Domain: Using Nanosatellites as an Alternative to Traditional Satellite Communications," California Polytechnic State

University, San Luis Obispo, CA, United States. (April 30, 2018).

Newman, J. H., Sea - Air - Space 2016, "LOE Green," Navy League, Gaylord National Convention Center, National Harbor, MD, United States. (May 18, 2016).

Lan, W. D., Kaushish, V., Newman, J. H., 29th Annual AIAA/USU Conference on Small Satellites, "Progress in Reducing Vibration Levels on NPSCuL," SSC15-X-4, Logan, UT. (August 4, 2015).

Lan, W. D., Kaushish, V., Newman, J. H., 12th Annual CubeSat Workshop, "Progress in Reducing the Vibration Levels on NPSCuL," California Polytechnic State University, San Luis Obispo, CA. (April 23, 2015).

Name: **Andy Nieto**

Academic experience

Degree	Discipline	Institution	Year
BS	Aerospace Engineering	University of Maimi	2011
MS	Materials Science	Florida International University	2013
PhD	Materials Science	University of California Davis	2016

Certifications or professional registrations

Fundamentals of Engineering (FE), Florida Board of Professional Engineers

Current membership in professional organizations

TMS, January 2013 - Present

MRS, September 2013 - Present

Service activities

Alternate Representative for MAE Department, Academic Council, December 2018 - Present

Reviewer, Journal Article, Materials Science & Engineering C, 2018 - Present

Reviewer, Journal Article, Silicon, 2018 - Present

Reviewer, Book, Springer, 2018 - Present

Principal publications and presentations in the last five years

Ghoshal, A., Murugan, M., Walock, M., ***Nieto, A.***, Barnett, B., Pepi, M., Swab, J., Zhu, D., Kerner, K., Rowe, C., Shiao, C.-Y., Hopkins, D., Gazonas, G.A., "*Molten Particulate Impact on Tailored Thermal Barrier Coatings for Gas Turbine Engine*", **Journal of Engineering for Gas Turbines and Power**, Vol. 140, 022601, 2018.

Nieto, A., Yang, H., Jiang, L., Schoenung, J.M., "*Reinforcement Size Effects on the Abrasive Wear of Boron Carbide Reinforced Aluminum Composites*", **Wear,** Vol. 390-391, pp. 228-235, 2017

Nieto, A., Jiang, L., Kim, J., Kim, D.-E., Schoenung, J.M., "*Synthesis and Multi Scale Tribological Behavior of WC-Co/Nanodiamond Nanocomposites*", **Scientific Reports**, Vol. 7, 7060, 2017

Nieto, A., Bisht, A., Lahiri, D., Zhang, C., Agarwal, A., "*Graphene Reinforced Metal and Ceramic Matrix Composites – A Review*", **International Materials Reviews**, Vol. 62, pp. 241-302, 2017

Murugan, M., Ghoshal, A., Walock, M., ***Nieto, A.***, Barnett, B., Pepi, M., Swab, J., Pegg, R.T., Rowe, C., Zhu, D., Kerner, K., "*Microstructure based material-sand particulate interactions and assessment of coatings for high temperature turbine blades*", ASME Paper GT2017-64051, ASME Turbo Expo 2017: Turbomachinery Technical Conference & Exposition, June 26-30, 2017, Charlotte, North Carolina

Nieto, A., Kim, J., Penkov, O., Kim, D.-E., Schoenung, J.M., "*Elevated Temperature Wear Behavior of Thermally Sprayed WC-Co/Nanodiamond Composite Coatings*", **Surface and Coatings Technology**, Vol. 315, pp. 283-293, 2017

Penkov, O.V., Khadem, M., ***Nieto, A.***, Kim, T.-H., Kim, D.-E., "*Design and construction of a tribotester for high precision in-situ wear measurements*", **Micromachines**, Vol. 8, pp. 103, 2017

Nieto, A., "*Synthesis, Mechanical Behavior, and Multi-Scale Tribological Performance of Carbon Nanoparticle Reinforced Ceramic Composites*", **ProQuest Electronic Thesis and Dissertations**, 2016

Nieto, A., Zhao, J.M., Han, Y.-H., Hwang, K.H., Schoenung, J.M., "*Microscale Tribological Behavior and In Vitro Biocompatibility of Graphene Nanoplatelet Reinforced Alumina*", **Journal of the Mechanical Behavior of Biomedical Materials**, Vol. 61, pp. 122-134, 2016

Nieto, A., "*Exploring nature, history, and nano-diamonds in Korea*", **American Ceramic Society Bulletin**, Vol. 95, pp. 56, 2016.

Zhang, C., ***Nieto, A.***, Agarwal A., "*Ultrathin Graphene Tribofilm Formation during Wear of Al2O3-Graphene Composites*", **Nanomaterials and Energy**, Vol. 5, pp. 1-9, 2016.

Koller, M., Seiner, H., Landa, M., ***Nieto, A.***, Agarwal, A., "*Anisotropic Elastic and Acoustic Properties of Bulk Graphene Nanoplatelets Consolidated by Spark Plasma Sintering*", **Acta Physica Polonica A**, Vol. 128, pp. 670-674, 2015

Nieto, A., Dua, R., Zhang, C., Boesl, B., Ramaswamy, S., Agarwal, A., "*Three Dimensional Graphene Foam – Polymer Hybrid as a High Strength Biocompatible Scaffold*", **Advanced Functional Materials**, Vol. 25, pp. 3916-3924, 2015

Nieto, A., Huang, L., Han, Y.-H., Schoenung, J.M., "*Sintering Behavior of Spark Plasma Sintered Alumina with Graphene Nanoplatelet Reinforcement*", **Ceramics International**, Vol. 41, pp. 5926-5936, 2015

Name: **Richard C. Olsen**, Professor of Physics

Academic experience

Degree	Discipline	Institution	Year
BSc	Physics	University of Southern California,	1974
MS	Physics	University of California, San Diego,	1976
PhD	Physics	University of California, San Diego,	1980

Current membership in professional organizations

American Geophysical Union (AGU)
Institute of Electrical and Electronics Engineers (IEEE)
SPIE (formerly Society of Photographic Instrumentation Engineers)
American Society of Photogrammetry and Remote Sensing (ASPRS)

Honors and awards

Hamming Faculty Award for Interdisciplinary Achievement, NPS, 2012
American Geophysical Union
Trustee Scholar, University of Southern California
Phi Beta Kappa

Principal publications and presentations in the last five years

Kim, A.M., Olsen, R.C., Borges, C.F., Simulating full-waveform LIDAR. Proceedings of SPIE, Vol. 7684: Laser Radar Technology and Applications XV, Monte D. Turner; Gary W. Kamerman,, 2010.

Kim, A.M., Olsen, R.C., Lee, K.R., Using panchromatic imagery in place of multispectral imagery for kelp detection in water. Proceedings of SPIE, Vol. 7678: Ocean Sensing and Monitoring II, Weilin (Will) Hou; Robert A. Arnone, 2010.

Kruse, F.A., Olsen, R.C., Variability analysis and change characterization of HSI data for urban mapping. *Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XVI, Proceedings of the SPIE, Vol. 7695,* edited by Sylvia S. Shen and Paule E. Lewis, 2010.

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Kim, A.M., Olsen, R.C., Simulated lidar waveforms for understanding factors affecting waveform shape. *Laser Radar Technology and Applications XVI,*

Proceedings of the SPIE, Vol. 8037,edited by Monte D. Turner and Gary W. Kamerman, 2011.

Lee, K.R., Kim, A.M., Olsen, R.C., Kruse, F.A., Using WorldView-2 to determine bottom-type and bathymetry, Proceedings of SPIE, Proceedings Vol. 8030; *Ocean Sensing and Monitoring III*; 2011; Editors: Weilin W. Hou; Robert Arnone. 2011.

Bradley L. McCarthy; Richard C. Olsen; Angela M. Kim; Creation of bathymetric maps using satellite imagery, Proceedings of SPIE, Proceedings Vol. 8030; *Ocean Sensing and Monitoring III*; Editors: Weilin W. Hou; Robert Arnone. 2011.

Olsen, Richard C., Angela M. Kim, Cecelia McConnon ; High spatial resolution bidirectional reflectance retrieval using satellite data; Vol. 8048: Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XVII, Sylvia S. Shen; Paul E. Lewis, Editors. 2011.

Name: **Jennifer L. Rhatigan**

Education

Degree	Discipline	Institution	Year
BS		UNIVERSITY OF FLORIDA	1982
MS		NORTH CAROLINA STATE UNIVERSITY	1987
PhD		CASE WESTERN RESERVE UNIVERSITY	2001

Honors and awards

Michael J. Smith and William C. McCool Space Systems Chair Professorship, Naval Postgraduate School (NPS) in Monterey, CA via agency-wide competition (2011).

NASA Special Act Award (2010) for outstanding leadership in development of the historic ISECG Reference Architecture for Human Lunar Exploration (2010)

NASA Blue Marble, Highest agency award for energy and environment (2008)

Principal publications and presentations in the last five years

Rhoades, M. M., Rhatigan, J. L., Tackett, S. H., Worden-Buckner, K. K. (2018). *REDUCING HUMAN RADIATION RISKS ON DEEP SPACE MISSIONS*. Monterey: IEEE.

Co-author with Spacecraft Design Students, "Drag-enhancing Deorbit Devices for Mid-sized Spacecraft Self-Disposal", accepted to the IEEE Aerospace Conference, Big Sky, MT, March 2019. This paper resulted from the 2018 591 capstone design project.

Worden-Buckner, K. A., Rhatigan, J.L., Tackett, S., and Rhodes, M., "Reducing Human Radiation Risk on Deep Space Missions", IEEE Aerospace Conference, Big Sky, MT, March 2018.

Thomas, L.D., Hanley, J.M., Rhatigan, J.L., and Neubek, D., NASA's Constellation Program: The Final Word, Systems Engineering, December 2012.

Name: **Marcello Romano**

Education

Degree	Discipline	Institution	Year
BS	Aerospace Engineering	Milan Polytechnic University-Italy	1997
MS	Aerospace Engineering	Milan Polytechnic University-Italy	1997
PhD	Aerospace Engineering	Milan Polytechnic University-Italy	2001

Current membership in professional organizations

AAS, January 1, 2018 - December 31, 2022

Honors and awards

Best Paper at ESA/ICATT Conference 2016, March 2017

Service activities

Chairperson, Departmental Ph.D. Committee, January 1, 2014 - Present

Committee Chair, NPS-MAE Departmental PhD Committee, January 1, 2014 - Present

Chairperson, Astronautical Engineering Technical Committee, January 1, 2016 - Present

Guest Speaker, University of Torino, June 15, 2015 - June 19, 2015

Principal publications and presentations in the last five years

Ciarcià, M., Grompone, A., Romano, M. (2014). A NEAR-OPTIMAL GUIDANCE FOR COOPERATIVE DOCKING MANEUVERS. *Acta Astronautica*.

Crane, W. M., Newman, J. H., Romano, M. (2014). Characterization of a shape memory alloy interference coupling. *Smart Materials and Structures, 23*(11), 115011.

Ventura, J., Romano, M. (2014). Exact Analytic Solution for the Spin-up Maneuver of an Axially Symmetric Spacecraft. *Acta Astronautica*.

Ventura, J., Ciarcià, M., Romano, M., Walter, U. (2016). An Inverse Dynamics-Based Trajectory Planner for Autonomous Docking to a Tumbling Target. *AIAA Guidance, Navigation, and Control Conference* (pp. 0876).

Romano, M. (in press). : Ventura J., Ciarcia' M., Romano M., Walter U., A fast and near-optimal guidance for docking to uncontrolled target, Accepted for Publication. To appear. Journal of Guidance, Control, and Dynamics.

Romano, M. (2016). : Wilde M., Ciarcia' M., Grompone, A., Romano M., Experimental Characterization of Inverse Dynamics Guidance and Control in Docking with a Rotating Target, Journal of Guidance, Control, and Dynamics, Vol. 39, No. 6, pp. 1173-1187, 2016.

Romano, M. (2016). Halis C. Polat, Josep Virgili-Llop, and Marcello Romano, Survey, Statistical Analysis and Classification of Launched CubeSat Missions with Emphasis on the Attitude Control Method. JoSS: Journal of Small Satellites, Vol. 05, No. 03, 2016, pp. 513–530. *JoSS: Journal of Small Satellites*.

Chesi, S., Gong, Q., Romano, M. (2017). Aerodynamic Three-Axis Attitude Stabilization of a Spacecraft by Center-of-Mass Shifting. *JOURNAL OF GUIDANCE CONTROL AND DYNAMICS*, *40*(7), 1613-1626.

Zappulla, Richard, II, Virgili-Llop, J., Zagaris, C., Park, H., Romano, M. (2017). Dynamic Air-Bearing Hardware-in-the-Loop Testbed to Experimentally Evaluate Autonomous Spacecraft Proximity Maneuvers. *JOURNAL OF SPACECRAFT AND ROCKETS*, *54*(4), 825-839.

Ciarcia, M., Cristi, R., Romano, M. (2017). Emulating Scaled Clohessy-Wiltshire Dynamics on an Air-Bearing Spacecraft Simulation Testbed. *JOURNAL OF GUIDANCE CONTROL AND DYNAMICS*, *40*(10), 2496-2510.

Ventura, J., Ciarcia, M., Romano, M., Walter, U. (2017). Fast and Near-Optimal Guidance for Docking to Uncontrolled Spacecraft. *JOURNAL OF GUIDANCE CONTROL AND DYNAMICS*, *40*(12), 3138-3154.

Virgili-Llop, J., Drew, J. V., Zappulla, Richard, II, Romano, M. (2017). Laboratory experiments of resident space object capture by a spacecraft-manipulator system. *AEROSPACE SCIENCE AND TECHNOLOGY*, *71*, 530-545.

Zappulla, R., Virgili-Llop, J., Romano, M. (2017). Spacecraft Thruster Control via Sigma-Delta Modulation. *JOURNAL OF GUIDANCE CONTROL AND DYNAMICS*, *40*(11), 2928-2933.

Romano, M., NASA/ESA 6th International Conference on Astrodynamics Tools and Techniques, "Experimental Evaluation of Model Predictive & Inverse Dynamics Control for Spacecraft Prox./Docking Maneuvers." (March 2017).

Name: **Isaac M. Ross**

Education

Degree	Discipline	Institution	Year
BS		Pennsylvania State University	1985
MA		Pennsylvania State University	1989
PhD		Pennsylvania State University	1990

Current membership in professional organizations

Book Review Editor

Service activities

GNC Technical Discipline Team - Represent DoN/DoD to NASA, NASA Engineering and Safety Council, October 1, 2014 - September 30, 2018

Principal publications and presentations in the last five years

King, J. T., Karpenko, M., Ross, I. M. (2015). Rapid Collection of Large Areas for Imaging Spacecraft. *25th AAS/AIAA Space Flight Mechanics Meeting , January 11-15, 2015, Williamsburg, VA. Paper number: AAS 15-379.*.

Karpenko, M., King, J. T., Ross, I. M. (2015). Agilitoid-Based Design Analysis of Next Generation Attitude Control Systems. *38th Annual AAS Guidance & Control Conference , January 30 to February, 4, 2015, Breckenridge, CO. Paper number: AAS 15-047.*.

Ross, I. M., Karpenko, M., Proulx, R. J. (2015). A Lebesgue-Stieltjes framework for optimal control and allocation. *Proceedings of the American Control Conference, Chicago, IL, July 1-3, 2015*.

Ross, I. M., Proulx, R. J., Karpenko, M. (2015). Unscented guidance. *Proceedings of the American Control Conference, Chicago, IL, July 1-3, 2015.*.

Ross, I. M., Proulx, R. J., Karpenko, M., Gong, Q. (2015). Riemann–Stieltjes Optimal Control Problems for Uncertain Dynamic Systems. *Journal of Guidance, Control, and Dynamics, 38*(7), 1251–1263.

Karpenko, M., Ross, I. M., Stoneking, E., Lebsock,, K. L., Dennehy, N. (2015). A Micro-Slew Concept for Precision Pointing of the Kepler Spacecraft. *AAS/AIAA Astrodynamics Specialist Conference, August 9 – August 13, 2015, Vail, CO. Paper number: AAS-15-628*.

Frontera, P., Karpenko, M., Proulx, R. J., Ross, I. M. (2015). Analysis of Hyper-Pseudospectral Transformation of Random Variables. *AAS/AIAA Astrodynamics Specialist Conference, August 9 – August 13, 2015, Vail, CO. Paper number: AAS-15-630*.

Ross, I. M., Proulx, R. J., Karpenko, M. (2015). Unscented Optimization. *AAS/AIAA Astrodynamics Specialist Conference, August 9 – August 13, 2015, Vail, CO. Paper number: AAS-15-607*.

Ross, I. M., Proulx, R. J., Karpenko, M. (2016). Monte Rey Methods for Unscented Optimization. *AIAA Guidance, Navigation, and Control Conference, January 4-8, 2016, San Diego, CA.*. AIAA.

Ross, I. M., Proulx, R. J., Greenslade, J., Karpenko, M. (2016). Dynamic Optimization for Satellite Image Collection. *26th AAS/AIAA Space Flight Mechanics Meeting , February 14-18, 2016, Napa, CA.*.

Frontera, P. J., Proulx, R. J., Karpenko, M., Ross, I. M. (2016). Effect of Update Frequency on EKF and UKF Performance. *26th AAS/AIAA Space Flight Mechanics Meeting, February 14-18, 2016, Napa, CA.*.

McGrath, C. B., Karpenko, M., Proulx, R. J., Ross, I. M. (2016). Unscented Evolution Strategies for Solving Trajectory Optimization Problems. *26th AAS/AIAA Space Flight Mechanics Meeting, February 14-18, 2016, Napa, CA.*.

Ross, I. M., Karpenko, M., Proulx, R. J. (2016). Path Constraints in Tychastic and Unscented Optimal Control: Theory, Application and Experimental Results. *Proceedings of the American Control Conference, Boston, MA, July 6-8, 2016.*.

Ross, I. M., Karpenko, M., Proulx, R. J. (2016). A Nonsmooth Calculus for Solving Some Graph-Theoretic Control Problems. *10th IFAC Symposium on Nonlinear Control Systems NOLCOS 2016 Monterey, California, USA, 23—25 August 2016*.

McGrath, C., Karpenko, M., Proulx, R. J., Ross, I. M. (2016). An Unscented Natural Evolution Strategy for Solving Trajectory Optimization Problems. *AIAA/AAS Astrodynamics Specialist Conference, September 13 - 16, 2016 Long Beach, CA.*.

Minelli, G., Karpenko, M., Ross, I. M., Newman, J. H. (2017). Autonomous Operations of Large-Scale Satellite Constellations and Ground Station Networks. *AAS/AIAA Astrodynamics Specialist Conference, August 20 - 24, 2017 Stevenson, WA. Paper number: AAS 17-761*.

Ross, I. M., Gong, Q., Karpenko, M., Proulx, R. J. (2017). Scaling and Balancing for Faster Trajectory Optimization. *AAS/AIAA Astrodynamics Specialist Conference, August 20 - 24, 2017 Stevenson, WA. Paper number: AAS 17-675*.

Karpenko, M., King, J. T., Dennehy, C. J., Ross, I. M. (in press). Agility Analysis of the James Webb Space Telescope. *Journal of Guidance Control and Dynamics*.

Ross, I. M., Gong, Q., Karpenko, M., Proulx, R. J. (2018). Scaling and Balancing for High-Performance Computation of Optimal Controls. *Journal of Guidance Control and Dynamics*.

Appendix C – Equipment

The Department of Mechanical and Aerospace Engineering has extensive, well-equipped laboratories that support both course work and thesis and doctoral dissertation research. The rough replacement value of the capital equipment is $50 million. This amount excludes the approximately $100M of mostly donated equipment in the Center of Excellence in Adaptive Optics.

The following major equipment is representative and is not an exhaustive list of equipment used specifically for the instruction of students within the MSME Degree Program. The primary course number is listed following in parenthesis.

- Optical Relay Mirror Laboratory (AE4816 and AE4818)
- Three-Axis Simulator 1 (AE4816 and AE4818)
- Three-Axis Simulator 2 (AE3811, AE4816 and AE4818)
- Laser Jitter Control Testbed (AE3811, AE4818)
- Adaptive Optics Test Bed (AE3811, AE4818)
- Smart Structures Laboratory (AE3811, AE4816)
- NPS Space Truss (AE4816)
- Ultra Quiet Platform (AE4816 and AE4818)
- Precision Pointing Hexapod (AE4816 and AE4818)
- Spacecraft Attitude Dynamics and Control Laboratory (AE3830)
- Flexible Spacecraft Simulator (FSS) (AE4816)
- FLTSATCOM Laboratory (AE3811)
- Spacecraft Design Laboratory (AE3870, AE4870 and AE4871)
- Adaptive Optics Beam Control Laboratory (AE4818)
- High Energy Laser Beam Control Testbed 1 (AE4818)
- High Energy Laser Beam Control Testbed 2 (AE4818)
- High Energy Laser Adaptive Optics Testbed (AE0810 – Thesis)
- Segmented Mirror Telescope Laboratory (AE3811, AE0810 - Thesis)
- SCIF (Sensitive Compartmented Information Facility) used for classified courses, design projects and research

Appendix D - Table of Contents

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1. The Institution

1.1 Name and address of the institution:
Naval Postgraduate School, 1 University Circle, Monterey, CA 93943

1.2 Name and title of the chief executive officer of the institution:
VADM Ann Rondeau, USN (Ret.) President

1.3 Name and title of the person submitting the self-study report:
VADM Ann Rondeau, USN (Ret.) President

1.4 Name the organizations by which the institution is now accredited and the dates of the initial and most recent accreditation evaluations.

NPS is currently accredited by one regional organization and three programmatic organizations. The list of organizations and initial/renewal dates are as follows:

Accreditor	Initial Accreditation	Most Recent Renewal	Next Review
WSCUC	1955	2010	Review Fall 2020
ABET			
Astronautical Engineering	1996	2014	2019
Electrical Engineering	1973	2014	2019
Mechanical Engineering	1973	2014	2019
Systems Engineering	2010	2014	2019
Systems Engineering (DL)	2010	2014	2019
AACSB	2000	2015	2020
NASPAA	1980	2015	2022

2. Type of Control

NPS Description of the type of managerial control of the institution, e.g., private-non-profit, private-other, denominational, state, federal, public-other, etc.

NPS is a federally funded institution within the Department of the Navy. The President of the Naval Postgraduate School is the academic coordinator for all graduate education programs in the Navy. The President administers fully-funded graduate educational programs at NPS, other service graduate schools and civilian universities.

NPS is assisted and advised by a Board of Advisors, a federal advisory committee, composed of not more than ten members who are eminent authorities in the field of academia, business, national defense and the

defense industry, management, leadership, and research and analysis. All Board members are appointed by the Secretary of Defense, and are appointed to provide advice on behalf of the government on the basis of their best judgment without representing any particular point of view and in a manner that is free from conflict of interest. Those members who are not full-time or permanent part-time federal employees are appointed as experts and consultants under the authority of 5 U.S.C. § 3109, and these individuals serve as special government employees.

The purpose of the Board, under the provisions of the Federal Advisory Committee Act (FACA) of 1972, as amended, shall provide the Secretary of the Navy, through the Chief of Naval Operations and the Presidents of the Naval Postgraduate School (NPS) and the Naval War College (NWC) independent advice and recommendations on matters pertaining to the educational, doctrinal, and research policies and activities of the NPS and the NWC. The Secretary of the Navy or designated representative, on behalf of the Secretary of Defense, may act upon the Board's advice and recommendations.

The board meets at least once a year (fall) in the Washington, DC metro area. The board presents a written report with its advice and recommendations to the Secretary of the Navy, via the Chief of Naval Operations and the Presidents of the NPS and NWC. The Committee Chairperson may present its report in person to the Secretary of the Navy. Website for the Board is at https://my.nps.edu/web/board-of-advisors .

One of the Board's two subcommittees focusses on matters concerning the Naval Postgraduate School and is comprised of no more than 15 members. This subcommittee meets a minimum of twice annually. The spring meeting shall be held at the campus of the NPS and the fall meeting shall be held in the Washington, DC metro area concurrent with the main committee meeting.

The Chief of Naval Operations ensures that NPS is provided the appropriate resources and policy guidance to accomplish its mission.

3. Educational Unit

Describe the educational unit in which the program is located including the administrative chain of responsibility from the individual responsible for the program to the chief executive officer of the institution. Include names and titles. An organization chart may be included.

The President of the Naval Postgraduate School is the academic coordinator for all graduate education programs in the Navy. The President administers fully-funded graduate educational programs at the Naval Postgraduate School, other service graduate schools and civilian universities.

Reporting to the President on the academic side is the Provost and Academic Dean, who is in turn the supervisor for all four school deans (Graduate School of Engineering and Applied Science, Graduate School of Operational and Information Sciences, School of International Graduate Studies, and the Graduate School of Business and Public Policy) as well as the Vice Provost of Academic Affairs, the Dean of Research, the Dean of Students, and the University Librarian. Among the administrative staff are: Associate

Provost for Faculty Management and Administration, Associate Provost for Graduate Education, Associate Provost for Educational Effectiveness, Director of Academic Administration and Registrar, Director the Center for Educational Design, Development, and Distribution. An organization chart for upper level administration within the school is shown below in Figure 1.

3.1 Overview

The engineering educational unit at NPS is the Graduate School of Engineering and Applied Sciences (GSEAS). GSEAS consists of seven academic departments (Applied Mathematics, Electrical and Computer Engineering, Mechanical and Aerospace Engineering, Meteorology, Oceanography, Physics and Systems Engineering) and three Academic Groups (Space Systems Academic Group, Undersea Warfare Academic Group, and the Energy Academic Group). The chart showing the internal organization of the engineering educational unit (GSEAS) is shown in Figure 2 below.

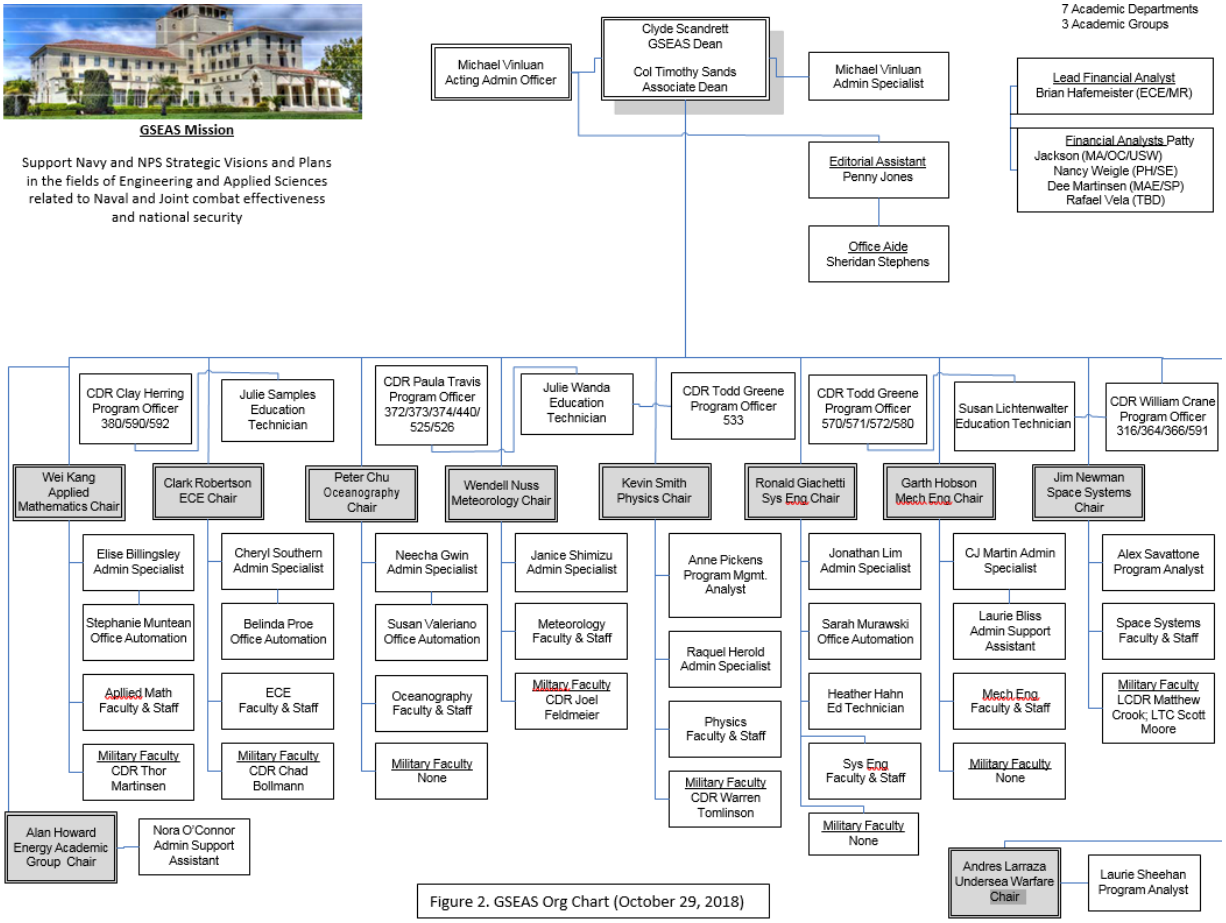


Figure 2. GSEAS Org Chart (October 29, 2018)

Within the Naval Postgraduate School, GSEAS supports the Navy and DoD by educating future leaders to lead, innovate and manage in a rapidly changing, highly technological world, and by conducting research recognized internationally for its relevance to national defense and academic quality. More specifically, and in support of the mission of NPS and the strategic needs of the Department of the Navy, GSEAS provides advanced technical and scientific knowledge and understanding so graduates:

- understand the capabilities and limitations of current and future technologies in battle space environments;
- understand and apply emerging and advanced technologies to enhanced war fighting capabilities;
- are able to learn, anticipate, respond and lead in future**,** complex and rapidly changing technological environments;
- are able to represent their organization's technical needs and interests with and within myriad constituencies, to include DoD, the Joint Staff, and industry.

3.2 Traditional Academic Degrees

GSEAS accomplishes the above by offering high quality, traditional academic degrees that include:

- Science and engineering curricula tailored to the needs of naval communities and other DoD constituents;
- Research programs funded by the defense community, aligned to future capabilities--integrated into curricula and courses;
- Education linked to real-world experiences in laboratories, experiments, testing--frequently classified;
- Blending current operational experience of students, emerging technologies, and cutting-edge faculty in both joint and international cultures;
- Life changing education--transforming officers into circumspect technical generalists, sub-specialists and war fighters.

Sustaining cutting edge faculty supported by laboratories aligned to future naval capabilities and enabling technologies that result in up-to-date curricula and programs is essential to assure that graduates are capable of leading and managing future assignments in support of enhanced war fighting and national security.

The Department of Applied Mathematics and the Department of Physics teach mathematics and physics courses in support of engineering programs and perform considerable basic and applied research. The Department of Electrical and Computer Engineering, the Department of Mechanical and Aerospace Engineering, the Department of Systems Engineering, and the Space Systems Engineering Academic Group teach engineering subjects and conduct engineering research.

Clyde Scandrett, Professor and Dean, is the administrative head of the principal education unit for engineering education, GSEAS. There are no additional administrative units within GSEAS.

3.3 Additional Engineering Programs

Within GSEAS there are several engineering programs that are not ABET accredited:

- Master of Engineering (Computer Engineering) and MS in Computer Engineering offered by the Electrical & Computer Engineering Department.
- MS in Electronic Warfare Systems Engineering offered by the Electrical & Computer Engineering Department.
- MS in Engineering Acoustics offered by the Physics Department.
- MS in Systems Engineering Management offered by the Systems Engineering Department.
- MS in Engineering Systems offered by the Systems Engineering Department.
- MS in Space Systems Engineering offered by the Space Systems Academic Group.
- MS in Engineering Science offered by many departments.

Other engineering programs at NPS not offered within GSEAS that have also not been reviewed by ABET are:

- MS Information Warfare Systems Engineering offered by the Department of Information Sciences, Graduate School of Operational and Information Sciences.
- MS Electronic Warfare Systems Engineering offered by the Department of Information Sciences, Graduate School of Operational and Information Sciences.
- MS Software Engineering offered by the Department of Computer Science, Graduate School of Operational and Information Sciences.
- MS in Systems Engineering Analysis offered in collaboration between the Operations Research and Systems Engineering Departments.

3.4 Engineering Enrollment and Degree Data

Enrollment and degree statistics for the engineering educational unit as a whole and for each program being evaluated for the current and preceding five (5) academic years are shown in Table D-1 (Parts 1-6).

3.5 Engineering Personnel

The number of personnel, both full-time and part-time, for the Departments of Electrical and Computer Engineering, Mechanical and Aerospace Engineering, and the Systems Engineering Program is shown in Table D-2 (Parts 1-3).

3.6 Admission of Students

The general criteria and procedures for admitting students to engineering programs:

i. The NPS Admissions Office evaluates applicants based on three criteria. The result is the assignment of an Academic Profile Code (APC). This is a three-

digit code, which summarizes pertinent portions of a student's prior college performance. The three independent digits reflect an individual's cumulative Grade-point Average (GPA), referred to as Quality Point Rating (QPR); exposure to and performance in calculus-related mathematics courses; and exposure to and performance in selected science/engineering areas.

First Digit:

The first digit indicates overall academic performance based on a recalculated* GPA from all previous college transcripts. The first digit is derived from the following table:

Code	QPR Range
0	3.60-4.00
1	3.20-3.59
2	2.60-3.19
3	2.20-2.59
4	1.90-2.19
5	0.00 -1.89

*Failures and repeated courses are included in the QPA calculation.

Second Digit:

The second digit represents mathematical background according to the following criteria and is described in the table below:

Code	Meaning
0	Math Major/Minor, Quantitative Economics Degree with B or better average; math taken less than or equal to 7 years ago.*
1	Lower Level, Upper level, Linear Algebra with a GPA of at least a 3.5; math taken less than or equal to 5 years ago.
2	Lower Level, Upper Level with average between C+ and B+ ; math taken less than or equal to 5 years ago. No Linear Algebra
3	Lower Level Calculus Sequence with a C or better; or if math taken greater than 5 years ago.
4	Calculus for Business/Social Sciences with a C or better. 1 Lower Level Calculus Course with at least a C-. Two Pre-Calculus with a B or better.
5	One pre-Calculus with C- or better grade.
6	No pertinent college-level math with C- or better grade.

*All math courses from calculus through post-calculus are considered when evaluating the transcripts for the second digit. A minimum calculus sequence is Calculus I and II.

Third Digit:

The third digit represents previous course coverage in science and technical fields according to the following criteria:

Code	Eng/Tech GPA	Meaning
0	3.00 - 4.00	ABET EAC accredited, BS Eng Degree (regardless of time passed)
1	> = 2.30	Non-ABET EAC accredited, Eng Degree (regardless of time passed)
2	> = 2.30	Any BS Tech degree (regardless of time passed)
3	> = 3.00	Completed calculus-based physics sequence with a B average or above
4	> = 2.00	One calculus-based physics course with at least a C
5	< = 1.99	No pertinent technical courses.

Engineering Degrees include: Aero/Astro, Computer/Electrical, Mechanical, Materials, Marine, Naval, Ocean, Systems, Industrial, Chemical, and Bioengineering and Naval Architecture. **This list is not exhaustive.**

Technical degree to include: Applied Physics, Engineering Physics, Physics

Engineering/Technical GPA is based upon a 4.0 scale.

General Engineering and EE/ME Technology degrees are not counted as engineering degrees/technical degrees for purposes of calculating an APC.

When calculating the APC, if the record cannot meet all the requirements to obtain Code 0 (i.e., GPA is 2.75 but all other requirements are met) the Code drops to a 1 automatically but no further.

A first digit code of 0, 1, 2 or 3 (as appropriate) will be assigned only if transcripts provided exhibit at least 75 semester-hours or 112 quarter-hours of actual graded classroom instruction. Grades of Pass/Fail, Credit/No Credit will not count toward the 75/112 hour requirement.

A technical code of 1 or 0 ordinarily is assigned only to an Officer whose undergraduate major was Physics, Aeronautical, Electrical, Mechanical or Naval Engineering, or whose undergraduate technical major is consistent with the Officer's designated occupational specialty. General Engineering degrees and Engineering Technology degrees are specifically excluded from this list of engineering degrees.

If a waiver of the APC is requested, the appropriate Academic Department makes the acceptance decision through the Program Officer and Academic Associate, and the Dean if ultimately required.

ii. There is no history of admission standards for freshmen -- NPS does not

enroll students directly from high school.

iii. Advanced placement credits are not utilized by Admissions for evaluating undergraduate transcripts. If there is an inordinate amount of AP credits, the Director of Admissions annotates such on the academic record evaluation.

iv. There are no special admission requirements for entry into the upper division or professional programs in the engineering educational unit, since all NPS students are admitted into Master's programs.

v. Policies regarding admission of transfer students from other institutions to the engineering programs are as follows:

The admissions process for all transfer students to NPS, to include engineering programs, is the same process used for all students. An Academic Profile Code is established and the Department reviews the applicant's package for acceptance or denial. Since the process is the same for both transfer students and all others, the fact that a student is transferring into NPS is transparent to the Admissions Office.

Upon entry to the Naval Postgraduate School, each student's academic record will be evaluated for possible transfer of credit or for exemption from portions of the curricular program by validation of course work previously completed. Twelve hours of graduate-level courses previously completed may be accepted for transfer credit. These include graduate-level courses taken after completion of the baccalaureate degree and those taken in the last term before award of the baccalaureate and certified to be in excess of degree requirements.

NPS generally allows a maximum of 12 graduate-level quarter-credits to be transferred for purposes of earning a graduate degree. However, an additional 12 quarter-credits may be transferred from the Air Force Institute of Technology (AFIT) in Dayton, Ohio. This is in addition to the normal transfer allowed (12), bringing the total to a maximum of 24 quarter-credits transferable from AFIT to NPS.

Permission to transfer a specific course to serve as a substitute for a degree requirement will be determined by the Department Chairman or equivalent person responsible for nominating candidates for degrees at NPS and must be pre-approved in a coherent plan of study for the student. Regardless of transfer credits allowed, all NPS master's degrees still require at least 20 quarter-credits be earned directly from NPS.

vi. There is no history of transfer engineering student statistics -- NPS does not generally categorize students as transfer students. All students are admitted into graduate degree programs. Some credits may be transferred as described above.

3.7 Programs Offered for Accreditation and Degrees Granted

The five programs to be evaluated and the focus of this accreditation process are the following:

1. MS in Astronautical Engineering
2. MS in Electrical Engineering

[3] MS in Mechanical Engineering
[4] MS in Systems Engineering
[5] MS in Systems Engineering, DL

3.8 Requirements for Graduation

The processes used to certify that graduation requirements complying with Engineering Accreditation Commission (EAC) criteria have been met by each graduate are within the engineering departments, not at the college and/or university level. Samples of work sheets or check-off sheets used for this purpose are available in each engineering department. Meeting EAC criteria is beyond scope of the general Registrar processes at NPS.

3.9 Information Regarding Administrators

Current summary *curriculum vitae* for the administrative head of the engineering educational unit and associates or assistants who have faculty status or are in responsible charge of a major service unit are provided below.

President Ann E. Rondeau, Ed. D.
Vice Admiral, U. S. Navy, Retired
Naval Postgraduate School
Monterey, California

Retired Vice Adm. Ann E. Rondeau will be appointed as President, Naval Postgraduate School on January 29, 2019. She brings to the assignment an unparalleled record of leadership and achievement within the military and academia in the areas of education, training, research, executive development, change management, and strategic planning. Prior to her appointment, Adm. Rondeau served as the sixth president of the College of DuPage. Her most recent military position was as the President of the National Defense University, a consortium of five colleges and nine research centers in Washington, DC.

Rondeau has extensive leadership experience in significant military and educational roles. In 1985, she was selected and served as a White House Fellow in the Reagan Administration and went on to serve as the Deputy Commander of the U.S. Transportation Command in Illinois, Pentagon Director/Chief of Staff for the U.S. Navy Staff, Commander of the Navy Personnel Development Command in Virginia, Commander of the Naval Service Training Command at Great Lakes, Ill., Pacific Fleet Staff Chief of Staff in Hawaii, Commanding Officer of Naval Support Activity in Tennessee and other staff and commanding responsibilities with policy, support and student service. Rondeau retired from the U.S. Navy as a three-star admiral in 2012 and was the second woman to have achieved that rank in the Navy**.** She then served as a partner and later an independent consultant with the IBM Watson group.

Rondeau holds a B.A. from Eisenhower College (NY), an M.A. from Georgetown University (DC) and an Ed.D. from the College of Education at Northern Illinois University in DeKalb. She also holds an honorary Doctorate in Public Service from Carthage College (Kenosha, WI) and an honorary Doctorate in Humane Letters from Rosalind Franklin University of Medicine and Science (Chicago, IL).

She is proud member of the Arizona State University Flag Officer Advisory Council, the National Museum of the American Sailor Foundation Board of Directors, the Military Advisory Board (under the aegis of Center for Naval Analysis), the Dwight D. Eisenhower Memorial Commission, the Chicago Regional Growth Corporation Board, Choose DuPage Board of Directors, and the Council for Higher Education Accreditation. Additionally, Dr. Rondeau serves on the Executive Board of the U.S. Navy “Education for Seapower Study” —a clean-sheet review of naval learning.

Dr. Steven R. Lerman
Provost, Naval Postgraduate School
Naval Postgraduate School
Monterey, California

Dr. Steven R. Lerman assumed the position of Provost and Academic Dean of the Naval Postgraduate School on August 29, 2016.

Dr. Lerman comes to the Naval Postgraduate School following more than 40 years of experience in higher education, most recently serving as Provost and Executive Vice President of Academic Affairs at The George Washington (GW) University (2010-2015) and A. James Clark Professor of Civil and Environmental Engineering (2010-2016). As Provost, Dr. Lerman was responsible for GW's 10 schools and colleges, athletics (24 Division I varsity sports, club sports and intramurals), the Division of Student Affairs and the University Library. Approximately 4,900 full and part-time faculty and staff report up through these units with a combined budget of $580 million. Dr. Lerman was also responsible for all academic and student life aspects for three GW campuses (Foggy Bottom, Mt. Vernon and the Virginia Science and Technology Campus) as well as at the university's three learning centers.

Prior to GW, Dr. Lerman served as Dean for Graduate Education (2007-2010) and Vice Chancellor (2008-2010), at his alma mater, the Massachusetts Institute of Technology (MIT). In this capacity, Dr. served as the chief deputy to the Chancellor who has responsibility for student affairs, undergraduate education and graduate education.

Dr. Lerman has served as Director of the Center for Educational Computing Initiatives, the research unit of an MIT-wide research center devoted to studying the application of computational and communication technologies on education. He held the Class of 1922 Professorship at MIT, chaired the Faculty Advisory Boards of the MIT OpenCourseWare initiative and Academic Media Production Services, and was Deputy Director of the Singapore-MIT Alliance, MIT's largest distance education program. He served as the Chair of the MIT faculty from 1998 to 2001 and as Associate Chair of the Faculty from 1996 to 1998.

Dr. Lerman is a past Lilly Teaching Fellow, and the recipient of several teaching awards during his time at MIT, including the Maseeh Teaching Award, as well as the Advisor of the Year award through the National Association of Graduate and Professional Students. He has both chaired and served as a member of countless academic, industry and government advisory boards, and has broadly published in his field of transportation systems analysis.

Dr. Lerman received his Bachelor of Science and Master of Science degrees in Civil Engineering, and his Doctorate in Transportation Systems Analysis, from the Massachusetts Institute of Technology.

Dr. Clyde L. Scandrett
Dean, Graduate School of Engineering and Applied Sciences
Naval Postgraduate School
Monterey, CA

Dr. Clyde Scandrett was appointed Dean of the Graduate School of Engineering and Applied Science in December 2014. He is a former chair of the Department of Applied Mathematics (2002-2008) and twice Chair of the Undersea Warfare Academic Group (2000-2002 and 2011-2014).

Dr. Scandrett received his undergraduate degree from the California Institute of Technology in 1976, and received his doctorate in Engineering Sciences and Applied Mathematics from Northwestern University in 1985. His research interests are primarily in the field of wave propagation having several publications in the Journal of the Acoustical Society of America, Wave Motion, and the Journal of Computational Physics. Dr. Scandrett continues his support of the Mine Warfare Community in his involvement with biennial symposia focused on the Mine problem and in editing past proceedings. Prior to his arrival at the Naval Postgraduate School in 1987, Dr. Scandrett also worked for two years as an assistant research scientist at the Supercomputer Computations Research Center at Florida State University.

COLONEL Timothy A. Sands, USAF
Associate Dean, Graduate School of Engineering and Applied Science
Naval Postgraduate School
Monterey, CA

Colonel Timothy Sands is the Associate Dean of the Graduate School of Engineering and Applied Sciences with a faculty appointment at the rank of Associate Professor. The Associate Dean serves the graduate education of more than nine-hundred students in resident & distance-learning programs; managing daily operations of more than two-hundred fifty faculty and staff in seven academic departments; and ensuring safe operations of ninety scientific laboratories including planning and execution of the school's $20M+ annual mission-budget, overseeing externally funded research programs exceeding $35M; and furthermore serving as the senior Air Force officer & liaison on the Navy installation, advising the university President on air force collaboration and students.

Colonel Sands entered active military service in 1993 as program manager for the acquisition of space systems. He later became a career electronic warfare officer and flew combat missions in the B-52 heavy bomber in Serbia, Kosovo, Afghanistan, and Iraq. Dr. Sands served as a weapons officer, an instructor, an evaluator, a professor and researcher, and research center director, associate provost, chief academic officer, and dean. He earned the bachelors, masters, and professional degrees in mechanical engineering from NC State University, Stanford University, and Columbia University respectfully, and the doctorate in astronautical engineering from the Naval Postgraduate School.

Garth V. Hobson
Professor and Chairman
Department of Mechanical and Aerospace Engineering
Naval Postgraduate School
Monterey, CA

Dr. Hobson is a professor and chair in the Department of Mechanical and Aerospace Engineering specializing in experimental and computational turbomachinery problems. He has more than 60 journal and refereed conference publications in this field. His current research interests are in transonic fan and compressor aerodynamics, stall precursors, inlet distortion, cross flow fan propulsion, mini gas turbines for UAV propulsion, transitional flows in compressor cascades, erosion of compressor blades due to sand ingestion, high cycle fatigue and signature suppression. He has been the director of the Turbopropulsion Laboratory since 2005 and had managed a yearly budget of more than $1.0M. He joined the Naval Postgraduate School in 1990 as an associate professor in the Department of Aeronautical and Astronautical Engineering. This after received his PhD in Aerospace Engineering at the Pennsylvania State University in 1989. His thesis was on the Fully Elliptic Calculation of Turbomachinery Flows. Prior to that he worked at the National Institute for Aeronautics and Systems Technology as head of the Aerothermodynamics Group. He oversaw the design of the turbine, or hot section, of a small gas turbine. Prior to that he worked on modification of aircraft exhaust systems for passive countermeasures against heat-seeking missiles. His design using transpiration cooling earned him the Directors award for Innovative Engineering. He received his MSc in Mechanical Engineering (1983) and BSc in Aeronautical Engineering (1979) both from the University of the Witwatersrand, Johannesburg. His Masters thesis was on transpiration cooled boundary layers. Dr Hobson has been a consultant to DENA (Duke Energy).

Ronald E. Giachetti
Professor and Chairman
Department of Systems Engineering
Naval Postgraduate School
Monterey, CA

Dr. Ronald E. Giachetti, is the Chair and Professor of Systems Engineering at the Naval Postgraduate School (NPS) in Monterey, California. He teaches and conducts research in the design of enterprise systems, systems modeling, and system architecture. He has published over 50 technical articles on these topics including a textbook on the *Design of Enterprise Systems: Theory, Methods, and Architecture*.

At the Naval Postgraduate School he leads the systems engineering department consisting of 45 faculty and staff serving 450 students in resident and distance learning programs. In addition to managing the department, he teaches courses in system of systems engineering and system architecture.

He is internationally known for his work in enterprise systems, having lectured in Colombia, Peru, Mexico and other countries, participating in the National Research Foundation of Chile, and as a member of IFAC's technical committee on enterprise integration. Prior to joining NPS, he was an Associate Professor of Industrial and Systems Engineering at Florida International University in Miami, FL. At FIU he developed and led the MS in Information Systems program and actively taught in external programs in Jamaica, Mexico, Colombia, and Peru. He has conducted $1M in externally funded research for the Navy, NSF, US Army, US Air Force, Royal Caribbean Cruise Lines, Carnival Cruise Lines, and other Florida companies. He was a National Research Council postdoctoral researcher in the Manufacturing Systems Integration Division at the National Institute of Standards and Technology (NIST) in Gaithersburg, MD. He earned a Ph.D. in Industrial Engineering from North Carolina State University in Raleigh, NC in 1996; a MS in Manufacturing Engineering from Polytechnic University in Brooklyn, NY in 1993; and a BS in Mechanical Engineering from Rensselaer Polytechnic Institute in Troy, NY in 1990.

Douglas J. Fouts
Professor and Chairman
Department of Electrical and Computer Engineering Naval Postgraduate School
Monterey, CA

Douglas J. Fouts has been the Chair of the Department of Electrical and Computer Engineering since April 1, 2019. Prior to that he served the ECE department as the Associate Chair for Research from September 2017 until April 2019 and as the Associate Chair for Instruction from July 2015 until September 2017. He has been a Professor in the department since 2003, was an Associate Professor from 1996 until 2003, an Assistant Professor from 1990 until 1996, and he has held a secondary appointment in the Space Systems Academic Group since 1991. He has also served as the Naval Postgraduate School Interim Vice President and Dean of Research from January 2012 until Jul 2012 and as the Associate Dean of Research from July 2006 until January 2012. He also worked in industry as a design engineer at Burroughs Corporation (now Unisys) from 1980 to 1983 and at The Aerospace Corporation in 1979. Prof. Fouts received his PhD and MS in Electrical and Computer Engineering from the University of California at Santa Barbara in 1990 and 1984, respectively, and his bachelor's degree in Computer Science from the University of California at Berkeley in 1980. The primary area of teaching and research for Prof. Fouts is Computer Engineering, although he also teaches courses in electronics. Over the years he has been successful at keeping the Computer Engineering courses offered by the department current with rapidly-developing new technology by developing courses in Fault Tolerant Computing (EC4810), VLSI Design (EC4870), Advanced Computer Architecture (EC4820), FPGA Design (EC4830), Embedded Computer Systems (EC3800), and Spacecraft Computing (SS3035). Prof. Fouts has had a very active research program over the years that includes both unclassified and classified work. His current research interests include reconfigurable computing, FPGA design, embedded computer systems, and reverse engineering. His unclassified research has resulted in the publication of over 45 papers in scholarly journals and refereed conferences and he holds 6 US patents. He has advised or co-advised over 100 MSEE theses and PhD dissertations at the NPS. Prof. Fouts received the Menneken Award for Excellence in Scientific Research in 2002, the Outstanding Research Achievement Award for the Department of Electrical and Computer Engineering in 1997, the Outstanding Instructional Performance Award for the Space Systems Academic Group in 1996, and the Outstanding Research Achievement Award for the Space Systems Academic Group in 1993. He is a member of the Institute of Electrical and Electronics Engineers, the American Radio Relay League, and he is a registered professional Electrical Engineer in the state of California. He is also an accomplished trombonist and the Scoutmaster for Boy Scout troop 93.

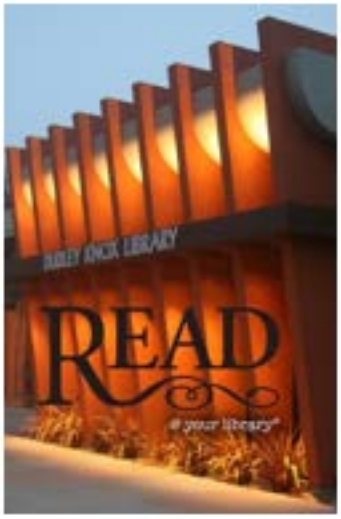
4. Academic Supporting Units

Supporting academic departments that provide required portions of the instruction for engineering students in the programs being evaluated are the Department of Operations Research in the Graduate School of Operational & Information Sciences, the Space Systems Academic Group, the Department of Physics, and the Department of Applied Mathematics, the latter three in GSEAS.

5. Non-Academic Support Units

There are no non-academic support units at NPS that support only the engineering academic programs. All non-academic support units that support academic programs at NPS are consolidated at NPS level.

5.1 Dudley Knox Library (DKL)



5.1.1 Mission:

Dudley Knox Library contributes to learning, research and teaching—anytime, anywhere—through relevant and evolving collections, tools, services, and spaces designed for NPS patrons of today and tomorrow.

5.1.2 Vision:

The Dudley Knox Library is a dynamic and collaborative partner with members of the NPS community that is dedicated to advancing knowledge through integrated resources, responsive services, library instruction, and research assistance. We work together to promote NPS's position as a top-tier graduate-level teaching and research institution that fosters lifelong learning. DKL is a flexible, agile organization that measures and continually assesses our quality, relevance and effectiveness as we support the NPS strategic plan.

5.1.3 Leadership:

Edward M. Corrado is the chief administrative officer and Director of the Dudley Knox Library. His responsibilities include providing vision and leadership for the Library and campus in accordance with and in support of the NPS mission and strategic plan, managing a budget of approximately $5.5 million. Mr. Corrado joined NPS in 2017. Prior to joining the Naval Postgraduate School he was the Associate Dean of Library Technology Planning and Policy and Interim Dean of Special Collections at the University of Alabama. He was also the Director of Library Technology at Binghamton University. His research interests include digital preservation, data management, cloud computing, and reproducibility of library and information science research. He is the co-author of Digital Preservation for Libraries, Archives, and Museums, which is now in its second edition. He has a

Masters of Library Service from Rutgers University and a Bachelor of Arts in Mathematics from Caldwell University.

5.1.4 Scholarly Content:

The Library provides access to a robust suite of eBooks, eJournals and databases plus a core print collection that supports NPS graduate instruction and research needs. DKL provides access to ~86% of the top-ranked engineering and applied science journals based upon *InCites Journal Citation Reports dataset* (updated September 9, 2017). We also provide access to thousands of additional scientific journals covering many disciplines (search here: https://nps.primo.exlibrisgroup.com).

Like other academic libraries, DKL continues to experience high annual subscription price increases for our scholarly content (11.3% annual price increase over 2015-2017 alone). Such increases, coupled with similar increases in databases, software, and personnel costs, makes it increasingly difficult for us to maintain current levels of subscription spending to as many resources as our faculty and students require. In this environment of escalating costs we regularly engage our stakeholders and monitor usage statistics to best leverage our limited resources to support the NPS mission.

We facilitate discovery of engineering and applied science information through subscriptions to a range of specialized and interdisciplinary databases (with and without full-text) including: *Aerospace Research Central (AIAA), American Society of Mechanical Engineers (ASME), IEEE Explore*, INSPEC, *Janes', JSTOR, Meteorological and Geoastrophysical Abstracts, ProQuest, Web of Knowledge*, and many more.

Because no library is an island we routinely provide "just in time" document delivery and interlibrary loan services that rapidly obtain materials for our students and faculty from other academic and federal libraries.

5.1.5 Seamless Access:

The library website (https://library.nps.edu) provides the portal to our information resources as well as a wide range of student- and faculty-academic support services. Over recent years library staff reviewed web analytics, conducted usability studies, and created "personas" of our three key users – resident students, distributed learning (DL) students, and faculty to help us understand our patrons. Armed with this information we comprehensively redesigned our website with a focus on making it "user-centric." The resulting site emphasizes patrons' top activities to simplify their access to information and associated services. We continue to gather feedback and make continuous improvements to the site. Other libraries as well as the team behind the redesign of the NPS institutional website have adapted many of our process and best practices.

In 2017 we launched a cutting-edge, cloud-based, access and discovery system that gives our patrons a more "Google/Google Scholar-like" search experience. A single search box on the library homepage enables users to quickly search across both resources and disciplines to retrieve results from print, online and data sources at the journal or book title level down to the journal article or book chapter level. Putting more resources into the hands of our patrons through this consolidated search helps users rapidly locate appropriate resources and know which sources are available for more advanced search protocols.

A team of four reference librarians provide the primary reference assistance and instruction services to campus. An additional four librarians also support individual departments and disciplines. We offer drop-in research-related workshops: ***Research Quick Start I & II*** and ***Thesis Quick Start***, as well as visits to classrooms to provide discipline-specific information modules.

5.1.6 Institutional Memory:

Named for NPS's first faculty member, Calhoun, the NPS institutional archive (https://calhoun.nps.edu) is a highly searched and centralized archive of NPS-authored works. Built on open-source software, Calhoun provides worldwide access to more than 55K items including theses and dissertations (dating from the early 1920's); faculty-authored journal articles, book chapters, and technical reports; and institutional publications. Resources have permanent handle-style URLs that are discoverable from Google, Google Scholar and other locations and used for many purposes at and beyond NPS.

In a parallel effort to promote and provide access to NPS-authored works that are "restricted through classified," we created an internal online portal to provide access to NPS restricted theses, dissertations and technical reports from 2001 to present. We also created and continue to curate NPS' presence on classified networks to raise awareness of NPS research efforts.

FY17 Library Quick Facts

Number	Description
25.5	Library staff FTE
78	Average weekly hours (Sun-Sat); extended hours during finals weeks
695,144	Titles in Library catalog
32,438	Titles in Restricted catalog
589,387	eResources available in Library catalog (books, journals, reports & more)
55,158	NPS-authored eResources in NPS Archive: Calhoun
1,701	NPS-authored eResources in Restricted Collection
12,885	Physical volumes circulated
1,491	Physical course reserves circulated
4,300	Interlibrary loans borrowed from other libraries for NPS users
984	Document delivery from physical collection to NPS users
1,082	Daily visits average to the library building
1,466	Daily visits average for the website
1,642	Daily visits average for NPS Archive: Calhoun
606	Daily visits average for our research guides
22	Daily visits average for Ask a Librarian
807	Daily visits average for our library search*
24,052	Hours students used collaborative study rooms (includes 10,900 hours in technology-equipped rooms)
1,297	Students taking advantage of extended hours during finals
138	Library instruction sessions offered (face-to-face and virtual)
2,881	Students receiving library instruction
176	Hours of library instruction
2,545	Reference questions (from all service points)
23	New resident student library web orientation and tours
960	Students receiving web orientation and tours
260	Student technology help requests
356	Staff technology help requests

Both Calhoun and our restricted resources have proven to be extremely well utilized centralized repositories for public access to NPS-authored and institutional content. Ongoing collaborations with the Defense Technical Information Center (DTIC) (http://www.dtic.mil) enriches their databases and provides broader access to NPS-authored scholarly works and associated data.

5.1.7 Peer Comparisons:

Dudley Knox Library provides annual statistical inputs to the Integrated Postsecondary Data System (IPEDS) and the Association of College and Research Libraries (ACRL). This enables us to benchmark our staffing and spending against two groups of peer academic libraries (peer groups defined by NPS: NPS Research Peer Institutions and NPS Peer Institutions). While our library is currently understaffed as compared to peer libraries, our total spending (labor, content and operations) is comparable. Despite our staff vacancies (exacerbated by hiring freezes, recent retirements, and the climbing cost of serials pressuring our relatively level budget), DKL has excellent service to our community as demonstrated through faculty feedback and graduating student surveys.

5.2 Graduate Writing Center (GWC)

5.2.1 Mission:

To develop the writing and critical thinking skills of NPS students for success in graduate school and as military and civilian leaders.

5.2.2 Leadership:

Dr. Sandra Leavitt has been the Director of the Graduate Writing Center and Thesis Processing Office at the Naval Postgraduate School since 2012. With a budget of approximately $1.5 million, she supervises writing coaches and language instructors while providing tutorials and hands-on workshops for resident and distance learning masters and doctoral degree thesis students. She holds the title of research assistant professor with a 2007 doctorate in Comparative Politics and International Relations from Georgetown University.

The GWC provides all new students with an overview of expectations for graduate-level research and writing through its *Foundations of Academic Writing* seminar.

The Graduate Writing Center offers individualized, one-to-one coaching to help NPS students develop the critical thinking, writing, and communication skills necessary for success at NPS and in their future assignments.

Additional GWC services include a rich variety of hands-on workshops, tutorials, online resources, and learning tools to help students advance their critical thinking and develop their academic communication, research, and writing skills.

Workshops are offered in person and many are recorded to provide just-in-time refreshers.

5.3 Thesis Processing Office (TPO)

5.3.1 Mission:

Publish high-quality theses, dissertations, and capstone reports that reflect NPS's commitment to quality, service, academic integrity, and expansion of knowledge.

Thesis processors provide tutorials for using NPS-specific Word and LaTeX templates for the preparation and publication of theses and dissertations. TPO staff work closely with students and their advisors on applying DoD distribution markings, proper attribution, and copy editing to their capstone reports. International students have free editing available to them. Thesis processors prepare for publication public release as well as restricted through Top Secret theses and dissertations. Thesis Processing also produces *Compilations of Abstracts (COAs)* covering all of NPS and specific academic groups, such as undersea warfare, cybersecurity, and energy. Public release theses and COAs are accessible via the Library's Calhoun repository as well as the Defense Technical Information Center (DTIC), while

access to restricted through classified publications is provided through other avenues (including DTIC) for access by authorized individuals.

5.4 Information Technology and Communications Services (ITACS)

5.4.1 Mission:

The Information Technology and Communications Services (ITACS) department provides technological and communications support for the entire voice, video and data infrastructure of NPS. This support encompasses national and international students enrolled in both residential and Distance Learning (DL) programs, all requiring robust and flexible educational delivery systems and research capabilities.

5.4.2 Leadership and organization:

The ITACS department is led by Mr. Joe LoPiccolo, Director, Information Technology and Communications Services and Chief Information Officer, and is comprised of 52 civilian staff, organized as below.

5.4.3 Operations:

5.4.3.1 Client Services: Client Services is made up of Educational Technologies, the Technology Assistance Center, and Classified Computing Programs.

a. The ***Educational Technologies*** team provides campus-wide support of the technology in all NPS' shared learning spaces and audio-visual (AV) systems used in teaching both resident and non-resident students. This includes oversight of 12 computer labs, 8 VTC/Video Tele-Education (VTE) systems, 86 smart classrooms, 21 technology smart conference facilities, 135 software packages and several virtual environments with over 300 virtual machines. Educational Technologies also maintains the Sakai Collaborative Learning Environment (CLE), web-based collaboration, streaming and on-demand video systems, on-campus podcasting, and the robust video tele-education infrastructure including a 60-port Video Bridge.
b. The ***Technology Assistance Center (TAC)*** is the primary means of IT support for students and faculty. The TAC handles the level one, two and three support calls, including hardware support for faculty, staff, resident students, and DL students. In a typical month the TAC will respond to approximately 1,400 phone calls, 300 walk-ins, and 1,000 emails.
c. The ***Classified Computing Program (CCP)*** provides staff and infrastructure to support the operations of the University's three classified networks. Leveraging the expertise found in ITACS' other functional areas, CCP supports classrooms, computer labs, secure video teleconferencing, distance learning, conferences, and seminars in the Sensitive Compartmented Information Facility (SCIF), Systems Technology Battle Lab (STBL), the Dudley Knox Library, Watkins Hall, and in various auditoria and lecture halls around campus, as needed.

5.4.3.2 Research Computing: Research Computing provides support for High Performance Computing (or HPC, also known as Supercomputing), Linux computing,

Machine Learning/Artificial Intelligence, and Big Data/Data Analytics (Hadoop). The HPC Data Center was established in 2009, and currently hosts approximately 400 users (students, faculty, staff, and their collaborators) that are using the computers for teaching and research. As of May 2018, the systems in the HPC datacenter have approximately 5,570 CPU "cores" across 124 servers, and over 3 Petabytes of disk storage. The users of the systems typically are running models and codes that require immense amounts of computing power and storage that would otherwise require them to obtain resources on systems outside of NPS. Several new faculty members have come to NPS in part because of the availability of the NPS Research Computing resources.

***5.4.3.3 Resources Management*:** This includes IT Asset Management; Contract Administration; Financial Management; Facilities Management; and Human Resources.

The Development Operations (DevOps) team consists of three primary groups including Application Development, Cyberinfrastructure and Unified Communications:

a. The ***Application Development*** team provides integrated, comprehensive technology solutions that enable NPS to streamline and improve its business processes and practices. This includes the technical implementation of the NPS public web site (www.nps.edu), the NPS Intranet web site, maintenance and administration of over 50 locally developed and commercial web applications, development of new web applications, administration of approximately 310 relational databases on more than 30 instances of database servers (Microsoft SQL Server, Oracle, and MySQL), implementation and maintenance of an academic information data warehouse, implementation and maintenance of a web-based issue tracking and project management system, and implementation and maintenance of web-based collaboration tools, such as an Enterprise Wiki and SharePoint. Examples of major applications that the team supports include the NPS student management system (known as “Python”) and an open source financial management system, Kuali Financial System (KFS). Additionally, the team provides assistance to researchers in the areas of database administration, application administration, and application development.
b. ***Cyberinfrastructure (CI)*** operates five distinct physical networks connecting more than 7,500 wired and wireless edge devices. The largest is the EDU network with a 100 Gigabit per second (Gb/s) connection to the Corporation for Education Network Initiative in California’s (CENIC) Digital California (DC) network backbone for commercial Internet and the High-Performance Research (HPR) networks for Internet2, U.S. Department of Energy’s Energy Sciences Network (ESnet), National Lambdarail (NLR) and other research capabilities. The datacenter houses 335 physical and virtual servers. CI manages the enterprise backup system and is also responsible for the infrastructure for telephone and network cabling and the physical plant, including construction/remodeling projects across campus.
c. The ***Unified Communications*** team supports all of the e-mail, telephone, VoIP, cell phone, Blackberry and video tele-conferencing communications at NPS.

5.4.3.4 Cybersecurity: The Cybersecurity (CS) team is responsible for securing the networks and data on campus including computer network defense and monitoring, anti-virus and vulnerability management, operating system and application patch management, certification and accreditation of networks and applications, and provides the tools and technologies to find, protect, and react to the unauthorized disclosure of sensitive privacy data on NPS networks. CS provides measures that protect and defend information and information systems by ensuring their confidentiality, integrity, availability, non-repudiation and authentication. This includes Computer Network Defense for intrusion detection, network monitoring, and restoration of information systems.

The team liaises with third parties throughout DoD, DON, the greater academic community, as well as state and local government organizations to maintain currency with the latest cybersecurity and privacy policies, guidelines, threats, and vulnerabilities. Additionally, the team delivers relevant and timely Cybersecurity and Privacy training to the campus user population as well as collaborates with faculty and students on Cybersecurity-relevant Research topics. Recently, the team established an EDU Cybersecurity Operations Center (CSOC) that provides around the clock CS support to the campus and other DoD educational partners including the US Naval Academy, the US Naval War College, and the Defense Language Institute-Foreign Language Center.

5.4.4 Communications Services, Partnerships and Outreach

The IT Strategic Plan, *Enabling the Mission*, informs planning and policy decisions for the department. The Information Technology Council, comprised of representatives from every major academic area as well as a number of administrative departments, acts as the advisory group for planning and implementation of initiatives while under the strategic direction of the IT Executive Council led by the NPS Provost.

Information Technology and Communications Services provides the following campus-wide services, which also support all areas of engineering at NPS:

1. Accounts: 6,054
2. Active Phone Lines: 989 digital; 728 VoIP; 2,059 analog
3. Audio-Conferencing Ports: 24
4. ISDN Video-Conferencing Circuits: 60
5. Video-Conferencing Facilities: 49
6. Video Tele-Education Systems: 8
7. Sixty Port Multipoint Control Unit (MCU)/Video Bridge: 1
8. Multimedia Presentation Systems: 130
9. Backup Data combined: 442.8 terabytes
10. E-Mail Stored: 29.6 terabytes
11. Client E-Mail Quotas—unlimited
12. Client Storage Quotas--unlimited
13. External E-Mail Received: 29,503,038 per year
14. Internet Traffic: 3.1 terabytes per day
15. Network Attached Systems: 5,451
16. Campus Wireless bandwidth—1gigabytes

17 Campus Wireless traffic—2.6 terabytes per day
18 Campus Wired Network—Software Defined Network (1st in DoD)
19 Campus Internet Connection—100 Gigabits—(1st in DoD)
20 Networks: 5
21 User Data: 595.2 terabytes
22 Web Services:

Extranet: page views: 6,850,655 per year

Intranet: page views 1,641,144 per year

Additionally, the Monterey Peninsula Department of Defense Net (DoDNet) provides fiber-optic connectivity from NPS to local DoD assets including the Defense Language Institute-Foreign Language Center and Presidio of Monterey, the Defense Manpower Data Center, Fleet Numerical Meteorology and Oceanography Center, the Naval Research Laboratory Monterey detachment, and the National Weather Service, enabling these properties to abandon commercial leased services and save resultant costs.

5.4.5 Facilities

The following facilities offer support to engineering programs:

- Twenty-nine classrooms, equipped with multimedia projection systems and instructor computers
- Eight video-tele-education classrooms augmented with videoconferencing technology, specialized video display systems, instructor computer, document camera, live streaming and capture technology, microphones, speakers and digital audio-visual routing consoles.
- Fifteen Learning Resource Centers (some specifically used by engineering), which includes secure labs that maintain circuit layout and design software, programming and simulation software; and some with thirty-four computer workstations, a multi-function device, and multi-media system used for classroom-level instruction.

5.4.6 High-Performance computing (HPC)

HPC includes supercomputer systems, storage and archiving systems, Linux-based scientific workstations, visualization systems, high-speed networks, special purpose and experimental systems, and application and systems software needed to make these systems useful. The HPC resources at NPS include the following:

5.4.6.1 HAMMING

Hamming is a general-purpose heterogeneous supercomputer. First installed in 2009 and refreshed several times since, the cluster's name commemorates the internationally renowned mathematician Richard Hamming, who was a Professor of Mathematics at NPS from 1976 until his passing in 1998. With 4270 cores and over 18 Terabytes of available memory, the Hamming supercomputer is a formidable resource for research needs and classroom use alike. Ten of Hamming's 81 compute nodes also feature GPUs for appropriate applications, and a large curated collection of proprietary and open-source software is available.

5.4.6.2 GRACE

Grace is a cluster for "big data" research using the Hadoop distributed filesystem and Spark in-memory processing system. First installed in 2015, this subsystem is named after RDML Grace Hopper, a pioneer in computer science and information theory whose significance to the US Navy and her field will be remembered for generations. Whereas Hamming is suited for simulations, where code on multiple machines can "pull in" data as needed, Grace's model is the opposite: the code is deployed to the data, which is stored across multiple compute nodes, for processing "in place." These intermediate results can then be combined incrementally to give research insights. This model makes Grace suited for real-world data sets that are too large for processing directly.

5.4.6.3 MASERATI

Maserati is a fast data transfer point, connected directly to the CENIC research network. Maserati is a data transfer node (DTN) connected via a 100Gb/s link, and participates in the Pacific Research Platform. This network is especially useful for researchers who want to share data with colleagues at other institutions along the west coast, including California universities, Department of Defense research laboratories, and Department of Energy computing facilities.

5.4.6.4 BOWDITCH

Bowditch is a platform for "cloud-native" computing applications. The system is named after the mathematician Nathaniel Bowditch, whose work in navigation is still important to navies and sailors today over 200 years after his death. Bowditch is a generic "container" platform, using some of the same tools that power the likes of Google and Amazon. Resources already developed on Hamming or Grace can be accessed from Bowditch using the unified high-speed cluster network or deployed to cloud services such as Amazon Web Services (AWS) when more scalability is needed. Still under development, Bowditch will be used for applications such as neural network training, artificial intelligence, and machine learning.

5.4.6.5 EXISTING USE

The current user base consists of over 400 users from over a dozen departments, institutes and academic groups, and includes NPS faculty, students, distance learning students, and partner institutions (e.g. Naval Academy, NRL, AFRL). Workloads include weather forecasting, arctic ice prediction, turbo-propulsion modeling, digital forensics, image recognition, and many other topics related to the DoD mission.

5.4.6.6 Classified HPC

Although this is currently outside the scope of the current use of HPC resources, our users have expressed a strong desire to have similar HPC resources available on the classified side. This is an important area for further investigation and consideration.

6. Credit Unit

NPS courses are listed with two numbers in parentheses separated by a hyphen, which indicate the hours of instruction per week in the classroom and in the laboratory respectively. When calculating quarter-hours for the credit value of the course, laboratory hours are assigned half the value shown. Thus, a (3-2) course, having three hours of lecture and two hours of laboratory, will be assigned a credit of four quarter hours.

NPS operates year round, with four twelve-week quarters. Included in each quarter are final examinations and an enrichment week.

6.1 Course Credit for Master's Thesis Work

Credit hours of 0 lectures, 8 laboratories (0-8) will be granted for each thesis slot registered for provided it is on the student's course matrix. Thesis credit shall be graded pass/fail, thus it is not used in computation of the student's QPRs.

6.2 Credit Hour Policy

A credit hour is an amount of work represented in intended learning outcomes and verified by evidence of student achievement that reasonably approximates not less than:

6.2.1 One hour of classroom or direct faculty instruction and a minimum of two hours of out-of-class student work each week for approximately ten to twelve weeks for one quarter hour of credit, or the equivalent amount of work over a different amount of time; or

6.2.2 At least an equivalent amount of work as required in paragraph (1) of this definition for other academic activities as established by NPS, including laboratory work, internships, practica, and other academic work leading to the award of credit hours.

7. Tables

Table D-1 (Part 1). Program Enrollment and Degree Data

Engineering Education Unit as a Whole (GSEAS- w/ SEA 308 program)

	Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
			1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
2019		FT							425		0		
		PT							392		0		
2018		FT							369		0	177	8
		PT							430		0	228	1
2017		FT							403		0	167	12
		PT							529		0	237	0
2016		FT							441		0	174	11
		PT							563		0	247	0
2015		FT							402		0	187	7
		PT							517		0	200	0
2014		FT							457		0	202	13
		PT							530		0	244	2

Note:

Shaded areas are not applicable.

All enrollment data is from the fall term of each academic year.

Table D-1 (Part 2). Program Enrollment and Degree Data

Astronautical Engineering

	Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
			1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
2019		FT							17		0		
		PT							2		0		
2018		FT							0		0	2	0
		PT							8		0	6	0
2017		FT							0		0	0	0
		PT							0		0	0	0
2016		FT							0		0	0	0
		PT							10		0	10	0
2015		FT							0		0	0	0
		PT							17		0	11	0
2014		FT							0		0	0	0
		PT							17		0	12	0

Shaded areas are not applicable.
All enrollment data is from the fall term of each academic year.

Table D-1 (Part 3). Program Enrollment and Degree Data

Electrical Engineering

	Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
			1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
2019		FT							71		0		
		PT							78		0		
2018		FT							60		0	28	0
		PT							63		0	30	0
2017		FT							56		0	28	0
		PT							100		0	48	0
2016		FT							57		0	25	0
		PT							123		0	42	0
2015		FT							66		0	28	2
		PT							74		0	20	0
2014		FT							79		0	39	4
		PT							61		0	27	0

Note:

Shaded areas are not applicable.
All enrollment data is from the fall term of each academic year.

Table D-1 (Part 4). Program Enrollment and Degree Data

Mechanical Engineering

Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
		1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
2019	FT							50		0		
	PT							55		0		
2018	FT							55		0	28	1
	PT							65		0	9	0
2017	FT							63		0	34	1
	PT							67		0	8	0
2016	FT							64		0	27	1
	PT							65		0	13	0
2015	FT							50		0	29	0
	PT							70		0	12	0
2014	FT							68		0	35	2
	PT							101		0	10	0

Note:

Shaded areas are not applicable.
All enrollment data is from the fall term of each academic year.

Table D-1 (Part 5). Program Enrollment and Degree Data

Systems Engineering (Resident)

	Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
			1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
2019		FT							87		0		
		PT											
2018		FT							75		0	37	2
		PT											
2017		FT							85		0	36	0
		PT											
2016		FT							91		0	35	4
		PT											
2015		FT							93		0	43	0
		PT											
2014		FT							108		0	43	0
		PT											

Note:

Shaded areas are not applicable.
All enrollment data is from the fall term of each academic year.

Table D-1 (Part 6). Program Enrollment and Degree Data

Systems Engineering (DL)

	Academic Year		Enrollment Year					Total Undergrad	Total Grad	Degrees Awarded			
			1st	2nd	3rd	4th	5th			Associates	Bachelors	Masters	Doctorates
2019		FT											
		PT							254		0		
2018		FT											
		PT							271		0	164	0
2017		FT											
		PT							335		0	163	0
2016		FT											
		PT							353		0	159	0
2015		FT											
		PT							326		0	138	0
2014		FT											
		PT							323		0	162	0

Shaded areas are not applicable.
All enrollment data is from the fall term of each academic year.

Table D-2 (Part 1). Personnel

Department of Electrical and Computer Engineering

Year: 2019

	HEAD COUNT		FTE
	FT	PT	
Administrative[1]	1	.75	1.75
Faculty (tenure-track)[2]	18	2.25	20.25
Research Assistant/Associate/Full Professors	2	0	2
Lecturers, Sr. Lecturers, & Prof. of Practice	2	0	2
Technicians/Specialists	5	0	5
Office/Clerical Employees	2	0	2
Faculty Associates – Research	4	0	4

[1]Department Chair, 0.25 FTE for Associate Chair Fargues, 0.25 FTE for Associate Chair Kragh, and 0.25 for Associate Chair (Fouts)
[2]Excludes Department Chair and 0.75 FTE each for tenured Professor Fargues, Kragh, and Fouts

Table D-2 (Part 2). Personnel

Department of Mechanical and Aerospace Engineering

Year: 2019

	HEAD COUNT		FTE
	FT	PT	
Administrative[1]	1	0	1
Faculty (tenure-track)[2]	13	0	13
Research Assistant/Associate/Full Professors	12	0	12
Lecturers, Sr. Lecturers, & Prof. of Practice	4	1	5
Technicians/Specialists	5	0	5
Office/Clerical Employees	2	0	2
Faculty Associates – Research or LSS[3]	4	0	4

[1]Department Chair
[2]Excludes Department Chair
[3]Learning Support Systems

Table D-2 (Part 3). Personnel

Department of Systems Engineering

Year: 2019

	HEAD COUNT		FTE
	FT	PT	
Administrative[1]	2	0	2
Faculty (tenure-track)[2]	13	0	13
Research Assistant/Associate/Full Professors	0	0	0
Lecturers, Sr. Lecturers, & Prof. of Practice[3]	17	0	17
Technicians/Specialists	2	0	2
Office/Clerical Employees	3	0	3
Faculty Associates – Research or Education	6	0	6

[1]Includes Department Chair & Associate Chair for Distributed Programs & Outreach - Owen.
[2]Excludes Department Chair
[3]Excludes Associate Chair for Distributed Programs & Outreach - Owen.

Appendix E – BSAE Course Reviews 1 – 7 Student Outcomes

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Seivwright, D.L.

Course Title: AE2820 Introduction to Spacecraft Structures (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii Homework iii Term Projects Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Term Projects iii [select factor 3] Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Handouts/Slides ii [select factor 2] iii [select factor 3] Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Handouts/Slides iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Term Projects ii [select factor 2] iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Seivwright, D.L. Date: 10/09/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Brij Agrawal

Course Title: AE3804 Thermal Control of Spacecraft (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Homework ii Group/Team Work iii Laboratory Exercises Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Group/Team Work ii Laboratory Exercises iii Prior Knowledge Recall Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Group/Team Work ii Term Projects iii Laboratory Exercises Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Reading Assignments ii Homework iii Guest Speakers Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii Laboratory Exercises iii Project Assignments Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Group/Team Work ii Laboratory Exercises iii Project Assignments Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Homework ii Laboratory Exercises iii Case Studies Contribution Strong

Narrative: (Additional Comments)

This course help the student do spacecraft thermal design in capstone design course AE 4871

Submitted by (Course Coordinator): Brij Agrawal Date:

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Brij Agrawal

Course Title: AE3811 Space Systems Laboratory (2-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Handouts/Slides ii Laboratory Exercises iii Laboratory Exercises Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Laboratory Exercises iii Group/Team Work Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Group/Team Work ii Off-site Visits iii Guest Speakers Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Case Studies ii Project Assignments iii Guest Speakers Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii Laboratory Exercises iii Term Projects Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Group/Team Work iii Project Assignments Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Laboratory Exercises ii Term Projects iii Project Assignments Contribution Strong

Narrative: (Additional Comments)

This course help the students to gain knowledge in spacecraft testing for AE 4871 spacecraft design course.

Submitted by (Course Coordinator): Brij Agrawal Date:

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Marcello Romano

Course Title: AE3815 Spacecraft Rotational Mechanics (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii Homework iii Laboratory Exercis Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(3) an ability to communicate effectively with a range of audiences

i Homework ii Term Projects iii Laboratory Exercis Contribution Modera

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Homework ii Term Projects iii Laboratory Exercis Contribution Modera

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercis ii Homework iii Term Projects Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Homework iii Term Projects Contribution Modera

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Date: 10/05/2018

Reviewed by (Tech Committee Chair): Marcello Romano Date: 10/05/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Marcello Romano

Course Title: AE3818 Spacecraft Attitude, Determination, and Control (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii Homework iii Laboratory Exercis Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(3) an ability to communicate effectively with a range of audiences

i Homework ii Term Projects iii Laboratory Exercis Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Homework ii Term Projects iii Laboratory Exercis Contribution Moderate

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercis ii Homework iii Term Projects Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Homework iii Term Projects Contribution Moderate

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Date: 10/05/2018

Reviewed by (Tech Committee Chair): Marcello Romano Date: 10/05/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: ROSS, MIKE

Course Title: AE3830 Spacecraft Guidance and Control (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): ROSS, MIKE Date:

Reviewed by (Tech Committee Chair): Date:

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: BROPHY, CHRIS

Course Title: AE3851 Spacecraft Propulsion (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): BROPHY, CHRIS Date:

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Seivwright, D.L.

Course Title: ME1000 Preparation for Professional Engineers Registration (3-0)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Sample Problems ii Handouts/Slides iii Lecture Materials Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Sample Problems ii Handouts/Slides iii Lecture Materials Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Sample Problems ii In-class Exercises iii [select factor 3] Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Reading Assignments ii Lecture Materials iii Handouts/Slides Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Lecture Materials iii Reading Assignments Contribution Strong

Narrative: (Additional Comments)

Course was reviewed by the Structures/Solids Group for consistency in accordance with the new student outcome guidelines. Changes were made to reflect the consensus of the group based on said guidelines.

Submitted by (Course Coordinator): Seivwright, D.L. Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Anthony J Gannon

Course Title: ME2101 Engineering Thermodynamics (4-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Sample Problems ii Derivations/Proofs iii In-class Exercises Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Case Studies ii In-class Exercises iii Sample Problems Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Group/Team Work ii Off-site Visits iii Project Assignments Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Case Studies ii [select factor 2] iii [select factor 3] Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii In-class Exercises iii Project Assignments Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Derivations/Proofs ii Off-site Visits iii Lecture Materials Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Derivations/Proofs ii Case Studies iii Lecture Materials Contribution Strong

Narrative: (Additional Comments)

Off-site visit coordinated with other class visits, including visits to MAE Energy Laboratories

Submitted by (Course Coordinator): Anthony J Gannon Date: 05/16/2018

Reviewed by (Tech Committee Chair): Date:

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: M.S. Chandrasekhara

Course Title: ME2201 Introduction to Fluid Mechanics (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii In-class Exercises iii Homework Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Handouts/Slides ii [select factor 2] iii [select factor 3] Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Laboratory Exercises ii [select factor 2] iii [select factor 3] Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Handouts/Slides ii [select factor 2] iii [select factor 3] Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii [select factor 2] iii [select factor 3] Contribution Weak

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Handouts/Slides iii Demonstrations Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Homework ii [select factor 2] iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

This is the first course in the sequence and is taught at a near beginner's level

Submitted by (Course Coordinator): M.S. Chandrasekhara Date: 05/16/2018

Reviewed by (Tech Committee Chair): Date:

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Christopher Adams

Course Title: ME2501 Statics (3-0)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Homework ii In-class Exercises iii [select factor 3] Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii In-class Exercises iii [select factor 3] Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i In-class Exercises ii Derivations/Proofs iii [select factor 3] Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii [select factor 2] iii [select factor 3] Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Homework ii Derivations/Proofs iii [select factor 3] Contribution Weak

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Case Studies ii Homework iii In-class Exercises Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Homework iii In-class Exercises Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Christopher Adams Date: 09/24/2018

Reviewed by (Tech Committee Chair): Christopher Adams Date: 09/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Christopher Adams

Course Title: ME2502 Dynamics (4-1)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Homework ii In-class Exercises iii Handouts/Slides Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Homework ii Lecture Materials iii [select factor 3] Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i In-class Exercises ii Demonstrations iii Lecture Materials Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i In-class Exercises ii Lecture Materials iii [select factor 3] Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Homework ii In-class Exercises iii Derivations/Proofs Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Case Studies ii Homework iii In-class Exercises Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Homework iii In-class Exercises Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Christopher Adams Date: 09/24/2018

Reviewed by (Tech Committee Chair): Christopher Adams Date: 09/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Young Kwon

Course Title: ME2601 Mechanics of Solids I (4-1)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii In-class Exercises iii Term Projects Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Term Projects iii [select factor 3] Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Term Projects ii Group/Team Work iii Prior Knowledge Recall Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Term Projects iii In-class Exercises Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Term Projects ii Group/Team Work iii [select factor 3] Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Lecture Materials ii Term Projects iii In-class Exercises Contribution Strong

Narrative: (Additional Comments)

This outcome was reviewed and approved by the Structure/Solid Group Committee

Submitted by (Course Coordinator): Young Kwon Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Brian Bingham

Course Title: ME2801 Introduction to Engineering System Dynamics and Control (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Homework ii Software Training/Use iii Lecture Materials Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Homework ii Case Studies iii Lecture Materials Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Homework ii Laboratory Exercises iii [select factor 3] Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii [select factor 2] iii [select factor 3] Contribution Weak

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii [select factor 2] iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Brian Bingham Date: 09/21/2018

Reviewed by (Tech Committee Chair): Kaminer Date: 09/26/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Anthony J Gannon

Course Title: ME3150 Heat Transfer (4-1)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii In-class Exercises iii Laboratory Exercises Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Homework iii Lecture Materials Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Laboratory Exercises ii Sample Problems iii [select factor 3] Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Case Studies ii Laboratory Exercises iii Lecture Materials Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii Group/Team Work iii Project Assignments Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Demonstrations iii Derivations/Proofs Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Derivations/Proofs ii Case Studies iii Lecture Materials Contribution Strong

Narrative: (Additional Comments)

Introduction to the various modes of heat transfer and their engineering applications. Steady and unsteady conduction using thermal circuit analogs and analytical techniques. External and internal forced convection, fundamentals and correlations. External natural convection. Boiling. Condensation. Heat exchanger, boiler and condensor analysis including design problems. Thermal radiation, spectra, view factors and material properties. PREREQUISITES: ME2101, ME2201

Submitted by (Course Coordinator): Anthony J Gannon Date: 05/16/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: M.S. Chandrasekhara

Course Title: ME3201 Applied Fluid Mechanics (4-1)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii Homework iii Derivations/Proofs Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Homework iii [select factor 3] Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Laboratory Exercises ii [select factor 2] iii [select factor 3] Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Handouts/Slides ii Lecture Materials iii [select factor 3] Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Demonstrations ii Laboratory Exercises iii [select factor 3] Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii [select factor 2] iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Homework ii In-class Exercises iii Laboratory Exercises Contribution Strong

Narrative: (Additional Comments)

The labs in this course require a written report that must be like a professional report and is reviewed and graded like a technical paper.

Submitted by (Course Coordinator): M.S. Chandrasekhara Date: 05/16/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: M.S. Chandrasekhara

Course Title: ME3205 Missile Aerodynamics (4-1)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Case Studies ii Demonstrations iii In-class Exercises Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Case Studies ii In-class Exercises iii [select factor 3] Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i In-class Exercises ii Group/Team Work iii [select factor 3] Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i In-class Exercises ii Group/Team Work iii [select factor 3] Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii [select factor 2] iii [select factor 3] Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii In-class Exercises iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i In-class Exercises ii [select factor 2] iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): M.S. Chandrasekhara Date:

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Garth Hobson

Course Title: ME3240 Marine Power and Propulsion (4-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i In-class Exercises ii Homework iii Lecture Materials Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i In-class Exercises ii In-class Exercises iii Software Training/Use Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Project Assignments ii [select factor 2] iii [select factor 3] Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii In-class Exercises iii Project Assignments Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii Group/Team Work iii [select factor 3] Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Handouts/Slides iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Software Training/Use ii [select factor 2] iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

The labs in this course require a written report that must be like a professional report and is reviewed and graded like a technical paper.

Submitted by (Course Coordinator): Garth Hobson Date:

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Gordis

Course Title: ME3450 Computational Methods in Mechanical Engineering (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Software Training/Use ii Laboratory Exercises iii Lecture Materials Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Software Training/Use ii Homework iii Lecture Materials Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Project Assignments ii Laboratory Exercises iii Project Assignments Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Laboratory Exercises iii Software Training/Use Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii Project Assignments iii Software Training/Use Contribution Weak

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Software Training/Use iii Project Assignments Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Project Assignments ii Software Training/Use iii Prior Knowledge Recall Contribution Strong

Narrative: (Additional Comments)

Revised 5/30/18 after review by Solid Mechanics committee.

Submitted by (Course Coordinator): Gordis Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Gordis

Course Title: ME3521 Mechanical Vibration (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii Sample Problems iii Homework Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Sample Problems iii Homework Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Lecture Materials ii Sample Problems iii Homework Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Sample Problems iii Homework Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii Group/Team Work iii Homework Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Homework iii Lecture Materials Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Lecture Materials ii Homework iii Laboratory Exercises Contribution Strong

Narrative: (Additional Comments)

Revised 5/30/18 after review by Solid Mechanics committee.

Submitted by (Course Coordinator): Gordis Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Young Kwon

Course Title: ME3611 Mechanics of Solids II (4-0)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii In-class Exercises iii Term Projects Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Term Projects iii Homework Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Term Projects ii Group/Team Work iii Prior Knowledge Recall Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Term Projects iii In-class Exercises Contribution Weak

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Term Projects ii Group/Team Work iii Homework Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i [select factor 1] ii [select factor 2] iii [select factor 3] Contribution None

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Lecture Materials ii Term Projects iii In-class Exercises Contribution Strong

Narrative: (Additional Comments)

This Outcome was reviewed and approved by Solids/Structure Committee

Submitted by (Course Coordinator): Young Kwon Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Gordis

Course Title: ME3711 Design of Machine Elements (4-1)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii Homework iii Project Assignments Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Homework iii Project Assignments Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Lecture Materials ii Homework iii Project Assignments Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Homework iii Project Assignments Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Project Assignments ii Homework iii Lecture Materials Contribution Weak

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Homework ii Project Assignments iii Lecture Materials Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Project Assignments ii Homework iii Lecture Materials Contribution Strong

Narrative: (Additional Comments)

Revised 5/30/18 after review by Solid Mechanics committee.

Submitted by (Course Coordinator): Gordis Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Young Kwon

Course Title: ME3712 Capstone Design (1-6)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Capstone Design ii Group/Team Work iii Project Assignments Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Capstone Design ii Demonstrations iii Project Assignments Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Capstone Design ii Group/Team Work iii Demonstrations Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Capstone Design ii Demonstrations iii Project Assignments Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii Capstone Design iii Demonstrations Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Capstone Design ii Group/Team Work iii Demonstrations Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Capstone Design ii Demonstrations iii Project Assignments Contribution Strong

Narrative: (Additional Comments)

The Outcome was reviewed and approved by Solids/Structure Committee

Submitted by (Course Coordinator): Young Kwon Date: 05/30/2018

Reviewed by (Tech Committee Chair): Date:

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Douglas Horner

Course Title: ME3720 Introduction to Unmanned Systems (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Project Assignments ii Homework iii Group/Team Work Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Reading Assignments iii Software Training/Use Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Project Assignments ii Group/Team Work iii Guest Speakers Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Reading Assignments iii Guest Speakers Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii Laboratory Exercises iii Project Assignments Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Project Assignments ii Demonstrations iii Homework Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Lecture Materials ii Project Assignments iii Demonstrations Contribution Strong

Narrative: (Additional Comments)

ME-3720 Introduction to Unmanned Systems takes a hands-on approach to teaching the core components of robotics. This includes practical aspects of dynamics, control, navigation and sensor integration. The course features lectures that are reinforced by 3 project assignments that permit students software programming and deployment of unmanned systems.

Submitted by (Course Coordinator): Douglas Horner Date: 09/24/2018

Reviewed by (Tech Committee Chair): Kaminer Date: 09/25/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Kaminer

Course Title: ME3801 Dynamics and Control of Marine and Autonomous Vehicles I (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Handouts/Slides ii Homework iii In-class Exercises Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i In-class Exercises ii Handouts/Slides iii Homework Contribution Weak

(3) an ability to communicate effectively with a range of audiences

i Handouts/Slides ii In-class Exercises iii [select factor 3] Contribution Weak

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Handouts/Slides iii Homework Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Lecture Materials ii In-class Exercises iii [select factor 3] Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i In-class Exercises ii Handouts/Slides iii [select factor 3] Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Lecture Materials iii [select factor 3] Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Kaminer Date: 09/25/2018

Reviewed by (Tech Committee Chair): Kaminer Date: 09/25/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Claudia Luhrs

Course Title: MS2201 Introduction to Materials Science and Engineering (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i In-class Exercises ii Laboratory Exercises iii Sample Problems Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Sample Problems ii In-class Exercises iii Homework Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i In-class Exercises ii Demonstrations iii Laboratory Exercises Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Case Studies ii Lecture Materials iii Handouts/Slides Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii Group/Team Work iii Demonstrations Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Derivations/Proofs ii In-class Exercises iii Laboratory Exercises Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Case Studies ii Homework iii Reading Assignments Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Claudia Luhrs Date: 08/20/2018

Reviewed by (Tech Committee Chair): Claudia Luhrs Date: 09/10/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Claudia Luhrs

Course Title: MS3202 Properties, Performance and Failure of Engineering Materials (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Case Studies ii Laboratory Exercises iii Sample Problems Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Project Assignments ii Term Projects iii In-class Exercises Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Case Studies ii Project Assignments iii Term Projects Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Case Studies ii Lecture Materials iii Handouts/Slides Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Term Projects ii Project Assignments iii Laboratory Exercises Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Project Assignments iii Term Projects Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Case Studies ii Homework iii Reading Assignments Contribution Strong

Narrative: (Additional Comments)

Submitted by (Course Coordinator): Claudia Luhrs Date: 08/20/2018

Reviewed by (Tech Committee Chair): Claudia Luhrs Date: 09/10/2018

http://www.nps.edu/mae rev. 04/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 - Student Outcomes

Course Coordinator Name: Andy Nieto

Course Title: MS3304 Corrosion and Marine Environmental Deterioration (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Lecture Materials ii In-class Exercises iii Case Studies Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Lecture Materials ii Case Studies iii Project Assignments Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Group/Team Work ii Project Assignments iii Prior Knowledge Recall Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Lecture Materials ii Reading Assignments iii Project Assignments Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Laboratory Exercises ii Group/Team Work iii [select factor 3] Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Project Assignments iii Handouts/Slides Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Handouts/Slides ii Laboratory Exercises iii Homework Contribution Strong

Narrative: (Additional Comments)

Fall 2018 quarter is being team taught between Prof. Menon and Prof. Nieto. Prof. Nieto will take on the lead role as course coordinator going forward, the current assessment is based on the lecture notes, class activities and laboratories being offered during current quarter.

Submitted by (Course Coordinator): Andy Nieto Date: 08/22/2018

Reviewed by (Tech Committee Chair): Claudia Luhrs Date: 09/24/2018

Department of Mechanical & Aerospace Engineering

NAVAL POSTGRADUATE SCHOOL

ABET CRITERION 3 – Student Outcomes

Course Coordinator Name: Ibrahim Emre Gunduz

Course Title: MS3606 Introduction to Welding and Joining Metallurgy (3-2)

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.

(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

i Case Studies ii Lecture Materials iii Homework Contribution Strong

(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

i Homework ii In-class Exercises iii Lecture Materials Contribution Strong

(3) an ability to communicate effectively with a range of audiences

i Group/Team Work ii Homework iii In-class Exercises Contribution Strong

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

i Reading Assignments ii Lecture Materials iii [select factor 3] Contribution Strong

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

i Group/Team Work ii In-class Exercises iii Sample Problems Contribution Strong

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

i Laboratory Exercises ii Homework iii In-class Exercises Contribution Strong

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

i Case Studies ii Reading Assignments iii Homework Contribution Strong

Narrative: (Additional Comments)

Prof. Gunduz just took the role as course coordinator, the current assessment is based on the lecture notes, class activities and laboratories he is preparing for the new installment of the class.

Submitted by (Course Coordinator): Ibrahim Emre Gunduz Date: 09/21/2018

Reviewed by (Tech Committee Chair): Claudia Luhrs Date: 09/24/2018

Appendix F – BSAE Equivalency Form

A blank copy of the BSAE Equivalency Form is attached here.

Department of Mechanical and Aerospace Engineering
ABET Accredited BS-AE Degree Equivalence

The Department of Mechanical and Aerospace Engineering at the Naval Postgraduate School is accredited at the advanced level through the Accreditation Board for Engineering and Technology. Students earning a Master of Science in Astronautical Engineering or the Degree of Astronautical Engineer at NPS must either have earned an ABET accredited undergraduate Astronautical Engineering degree, or earned the equivalency of a Bachelor of Science Degree in Astronautical Engineering. Some courses from the student's undergraduate institution may count toward that equivalency, even though his/her final undergraduate degree may not have been in Astronautical Engineering. Some courses taken at NPS may also be applied to meet this undergraduate equivalency. This checklist is provided to document the completion of that equivalency.

First and Last Name:
Quarter enrolled at NPS: **Quarter** **Year**
Exp. Graduation: **Quarter** **Year**

Undergraduate Institution Attended:
Degree Earned:
Dates [From and To]:
Is this School ABET Accredited? **Yes**
If unsure check ABET web site here

I certify that the information is correct.

Student Signature **Date:**

Department of Mechanical and Aerospace Engineering

I certify that this student has MET the minimum requirements for the equivalency of the BS-AE degree.

Academic Associate **Date**

Program Officer **Date**

Department Chair **Date**

Modified Aug 2016

ABET BS-AE

Department of Mechanical and Aerospace Engineering
Checklist for BS-AE Degree Equivalence

The Department of Mechanical and Aerospace Engineering at the Naval Postgraduate School is accredited at the advanced level through the Accreditation Board for Engineering and Technology. Students earning a Master of Science in Astronautical Engineering or the Degree of Astronautical Engineer at NPS must either have earned an ABET accredited undergraduate Astronautical Engineering degree, or earned the equivalency of a Bachelor of Science Degree in Astronautical Engineering. Some courses from the student's undergraduate institution may count toward that equivalency, even though his/her final undergraduate degree may not have been in Astronautical Engineering. Some courses taken at NPS may also be applied to meet this undergraduate equivalency. This checklist is provided to document the completion of that equivalency.

First and Last Name:

Quarter enrolled at NPS: **Quarter Year**

Exp. Graduation: **Quarter Year**

Do you have an ABET accredited BS-AE Degree? if **YES**, use **"Tab" ABET BS-AE**, if **NO**, complete the rest of this checklist.

If unsure check ABET web site here

Undergraduate Institutions Attended	Degree Earned (attach transcript(s))	Type in Dates [From and To]

BS-AE Equivalency Summary			
I. A. Mathematics	12 required	NOT MET	0.0
B. [Multivariable Calculus, Differential Equations and Linear Algebra]	required	NOT MET	
C. Basic Sciences	12 required	NOT MET	0.0
Total Math and Basic Science Credits	32 required	NOT MET	0.0
II. A. Engineering Sciences	Total Non-Service Related Engineering Science SCH		0.0
B. Engineering Design	Total Engineering Science & Design Credit Hours minimum 48 required	NOT MET	0.0
III. General Education	32 required	NOT MET	0.0
All categories above must be **MET** for the minimum requirements for the equivalency of the BS-AE degree.		NOT MET	

I certify that the information on this checklist is correct at the time of my graduation, and accurately documents courses I have completed to satisfy BS-AE equivalence. I also certify that no courses that appear on this form also appear on my MS-AE checklist.

Student Signature: _____ **Date:** _____

Department of Mechanical and Aerospace Engineering

I certify that this student --Has NOT MET-- the minimum requirements for the equivalency of the BS-AE degree.

_____

Academic Associate **Date**

_____

Program Officer **Date**

_____

Department Chair **Date**

Modified Aug 2016

I. MATHEMATICS AND BASIC SCIENCES

A minimum of 48 quarter credit hours or 32 semester credit hours of a combination of college-level mathematics and basic sciences is required with a minimum of 12 semester credit hours in each area. List all college-level mathematics courses passed with a grade of C or better. For each course, indicate the college or university where the course was taken, the course number, the course title, and the number of credit hours. Note that credits for NPS courses used for undergraduate ABET equivalency cannot be applied to satisfaction of MS-AE requirements.

A. Mathematics

1. A minimum of 12 Semester Credit Hours (SCH) or 18 Quarter Credit Hours (QCH) of college-level mathematics is required. The NPS courses listed are representative of the types of mathematics courses considered appropriate to meet BSAE Mathematics requirements.

University	Course Number	Title	Quarter Credit Hrs.	Quarter Lab Hrs.	Semester Credit Hrs.
		Total Quarter Lecture/Lab Credit Hours	**0.0**	**0**	
		Total Quarter Credit Hours		**0.0**	
		Total Semester Credit Hours			**0.0**
		Total Semester Math Credits **(12 Semester Credit Hours Required)**			**0.0**

B. For each of the **following mathematics subjects** that has been studied, indicate the college or university where the subject was studied, the course title, and course number. All courses must have been passed with a grade of **C** or better.

Subject	Course No.	Title	University
Multivariable Calculus			
Differential Equations			
Linear Algebra			

C. BASIC SCIENCES

A minimum of 12 SCH (Semester Credit Hours) or 18 QCH (Quarter Credit Hours) of college-level basic science is required; must include a General Physics or Chemistry sequence at the College level with a complete year of study in one or the other.

University	Course Number	Title	Quarter Credit Hrs.	Quarter Lab Hrs.	Semester Credit Hrs.
		Total Quarter Lecture/Lab Credit Hours	**0.0**	**0**	
			Total Quarter Credit Hours	**0.0**	
				Total Semester Credit Hours	**0.0**
				Total Semester Basic Science Credits (12 Semester Credits Hours Required)	**0.0**
				Total Math and Basic Science Credits (32 Semester Credits Hours Required)	**0.0**

II. ENGINEERING SCIENCES AND ENGINEERING DESIGN

A minimum of 72 quarter credit hours or 48 semester credit hours of engineering sciences and design are required. **Astronautical engineering topics covered must include orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion.**

A. Engineering Sciences

1. List all non-service related Engineering Sciences courses passed with a grade of C or better. For each course, indicate the college or university where the course was taken, the course number, the course title, and the number of credit hours (weekly lecture hours plus one half of the lab hours). Course content must include orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion.

University	Course Number	Title	Quarter Credit Hrs.	Quarter Lab Hrs.	Semester Credit Hrs.
Total Quarter Lecture/Lab Credit Hours			**0.0**	**0**	
Total Quarter Credit Hours				**0.0**	
Total Semester Credit Hours					**0.0**
Total Non-Service Related Engineering Science Semester Credit Hours					**0.0**

2. DoD officers are entitled to certain college credit based on service schools attended (Naval Nuclear Power School, DCA School, MPA School, etc.) If you have attended any technical DoD schools, including in a prior enlisted status, list those service schools by title. See your Academic Associate for evaluation of those courses based on publications by the American Council on Education. If applicable, the Engineering Science credit hours may be added to the total as identified below.

Service School Title	Course Number and Description	Service Related QCH	Service Related SCH
	Total Quarter Credit Hours	0	
		Total Semester Credit Hours	0.0
		Total Service Related Engineering Science Semester Credit Hours	0.0
		Total Engineering Science Semester Credit Hours	0.0

B. Engineering Design

Engineering Design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. This requirement can be satisfied either through engineering design courses taken at the undergraduate level, or by taking credit for the design content in NPS engineering courses taken. **Note that credits for NPS courses used for undergraduate ABET equivalency cannot be applied to satisfaction of MS-AE requirements.**

Engineering Design Instructions:

a. Enter the equivalent design semester credit hours (SCH) for NPS courses for which design credit will be taken.

b. Add any design course credit from courses taken at other institutions in the "other" lines.

c. Add number of Design SCH in the last column to arrive at total.

University	Course Number	Title	Allowed Design QCH	Allowed Design SCH	Design SCH for Course
NPS	AE2440	Introduction to Digital Computation	1.2	0.8	
NPS	AE2820	Introduction to Spacecraft Structures	2.0	1.3	
NPS	AE3804	Thermal Control of Spacecraft	0.3	0.2	
NPS	AE3811	Space Systems Laboratory	1.0	0.7	
NPS	AE3815	Introduction to Spacecraft Dynamics	2.0	1.3	
NPS	AE3818	Spacecraft Attitude Dynamics & Control	2.0	1.3	
NPS	AE3851	Spacecraft Propulsion	0.5	0.3	
NPS	AE3852	Propulsion for Launch Vehicles	1.0	0.7	
NPS	AE3870	Comp. Tools for Spacecraft Design	2.0	1.3	
NPS	AE4452	Advanced Missile Propulsion	0.6	0.4	
NPS	AE4502	Supersonic and Hypersonic Flows	0.5	0.3	
NPS	AE4506	Rarefied Gas Dynamics	0.5	0.3	
NPS	AE4850	Astrodynamic Optimization	1.0	0.7	
NPS	AE4870	Spacecraft Design & Integration I	4.0	2.7	
NPS	AE4871	Spacecraft Design & Integration II	4.0	2.7	
NPS	EC2300	Control Systems	2.0	1.3	
NPS	EC2820	Digital Logic Circuits	2.0	1.3	
NPS	PH3052	Physics of Space & Airborne Sensor Systems	1.0	0.7	
NPS	SS3001	Military Applications of Space	1.0	0.7	
NPS	SS3035	Microprocessors for Space Applications	1.0	0.7	
		Other			
		Other			
				Total Engineering Design Semester Credit Hours	**0.0**
				Total Engineering Science and Design Credit Hours (Minimum 48 SCH Required)	**0.0**

III. GENERAL EDUCATION

A minimum of 48 quarter credit hours (QCH) or 32 semester credit hours (SCH) is required in subjects other than mathematics, basic science, computer science, and engineering. These general education courses should complement the technical content of the curriculum. Examples of traditional subjects in these areas are philosophy, religions, history, literature, fine arts, sociology, psychology, political science, anthropology, economics, and foreign language.

University	Course Number	Title	Quarter Credit Hrs.	Quarter Lab Hrs.	Semester Credit Hrs.
		Total Quarter Lecture/Lab Credit Hours	0.0	0	
		Total Quarter Credit Hours		0.0	
		Total Semester Credit Hours			0.0
		Total Semester General Education Credits (32 SCH Required)			0.0

Appendix G – Naval/Mechanical Curriculum (570) Engineering ESRs

The most recent copy of the Naval/Mechanical Curriculum (570) Engineering Skill Requirements is attached here.

591 Space Systems Engineering

Core Skill Requirements:

CSR 1: Space Acquisition and Development. Formulate the following for the development and employment of national security space systems within the construct of end-to-end, system-of-systems integration of products and services supporting operational missions: operational and derived technical requirements, system-level architectures, operational concepts, conceptual spacecraft designs, system integration and test plans, and incremental capabilities of cyber and platform resiliency.

CSR 2: Spacecraft Design. To support operational missions: demonstrate technical knowledge in orbital mechanics and the design of spacecraft and their payloads to include the harsh space environment, resiliency, and serviceability. This knowledge will encompass spacecraft subsystems and their ground support segment subsystems to include: communications, command and data handling, attitude determination, guidance, navigation and control, structures, propulsion, thermal control and electrical power.

CSR 3: Space Systems Engineering. Demonstrate leadership of end-to-end, system-of-systems, engineering efforts to direct design, development, acquisition, integration and testing of spacecraft and associated ground support systems throughout their life-cycles including launch and on-orbit operations.

CSR 4: Space Liaison. Develop in collaboration with other services, agencies, and industry the policy and procedures necessary for requirements development and analysis of the: design, acquisition and operational employment of space systems, ground support segments, and end-to-end, system-of-systems integration of products and services to support operational missions.

CSR 5: Decision Analysis. Perform technical evaluation of space systems design and performance with the purpose of providing recommendations to senior decision-makers regarding space systems engineering, performance and mission assurance. These evaluations and recommendations shall include system of systems and end-to-end considerations to ensure cost and schedule efficiencies while maximizing performance.

Educational Skill Requirements:

ESR-1 Orbital Mechanics and Space Environment:

a. Graduates will examine the basic physics of orbital motion, and calculate and distinguish the parameters used in the description of orbits and their ground tracks.
b. Graduates will examine the design of orbits and constellations, and analyze how they are achieved, maintained, and controlled; to include space maneuver and orbit transfer calculations.
c. Graduates will examine the fundamentals of spacecraft tracking and command/control from a ground station.
d. Graduates will examine the various orbital perturbations, including those due to non-spherical earth and due to atmospheric drag, and interpret their effects.
e. Graduates will analyze the relationship between various orbital characteristics and the satisfaction of mission requirements, including the advantages and disadvantages of various orbits.
f. Graduates will design and optimize mission orbits through the analysis of common performance measures such as access, coverage, and revisit; and will employ appropriate tools to conduct theses analyses.
g. Graduates will examine the physical behavior of the upper atmosphere, ionosphere and space environment under the influence of both natural and artificial phenomena such as solar activity, geomagnetic and magnetospheric effects, and man-made disturbances.
h. Graduates will apply this understanding of how the space environment impacts spacecraft parts, materials, and operations to spacecraft and mission design.

ESR-2 National Security Space Systems:

a. Graduates will examine the nature of space warfare (theory, history, doctrine, and policy) to distinguish how space operations as discussed in JP 3-14 enable joint force capabilities, and interpret how current and planned space capabilities contribute to the satisfaction of mission objectives.
b. Graduates will examine the roles, responsibilities, and relationships of National and DoD organizations in establishing policies, priorities, and requirements for National Security Space systems; and in the design, acquisition, operation, and exploitation of these systems.
c. Graduates will examine the role of the Services / Agencies in establishing required space system capabilities, and will translate these capabilities into end-to-end, system-of-systems performance requirements.
d. Graduates will examine: current and planned Intelligence, Surveillance, and Reconnaissance (ISR) capabilities; how space systems contribute to these capabilities; the intelligence collection and analysis process; and how war-fighters access information from theses sources.
e. Graduates will develop concepts of employment and assess space tactics and CONOPS. The development and assessment shall consider end-to-end capabilities and system-of-systems architectures that enhance, support, and integrate into military operations to include resiliency concepts in a contested environment.
f. Graduates will identify how proposed space-related capabilities / doctrine transition from concept to real-world implementation through experimentation.
g. Graduates will examine the capabilities of unclassified DoD and commercial space systems, and how those systems relate to National Space Systems to include potential overlaps and leverage opportunities.

ESR-3 Project Management And System Acquisition:

a. Graduates will examine project management and DoD system acquisition methods and procedures to include contract management, financial management and control, and the Planning, Programming, Budgeting and Execution (PPBE).
b. Graduates will recognize the role of the Defense Acquisition University and the acquisition courses and qualifications available.
c. Graduates will examine system acquisition organizational responsibilities and relationships (e.g., Congress, DoD, Services, Resource Sponsor, Systems Commands, Operating Forces) as they pertain to the acquisition of systems for DoD, Naval, and civilian agency users.
d. Graduates will examine the unique nature of space acquisition programs and plan a notional space system acquisition program.

ESR-4. Communications:

a. Graduates will examine the basic principles of communications systems engineering to include both the space and ground segments.
b. Graduates will examine digital and analog communications architecture design, including such topics as frequency reuse, multiple access, link design, repeater architecture, source encoding, waveforms/modulations, and propagation media.
c. Graduates will calculate and analyze link budgets to assess communication system suitability to support mission requirements, and to translate mission requirements into communications system design characteristics.
d. Graduates will differentiate, compare, and contrast the characteristics and capabilities of current and future communications systems in use or planned by Naval operating and Joint forces afloat and ashore.
e. Graduates will examine how current and planned space communications systems should be used to meet Joint communications requirements across the spectrum of operations.
f. Graduates will differentiate signal processing techniques, both digital and analog, as applied to missions such as spacecraft communications, surveillance, and signals intelligence.
g. Graduates will examine spacecraft vulnerabilities in an electronic warfare context.

ESR-5. Computers: Hardware and Software:

a. Graduates will understand the fundamentals of digital logic and digital system design of simple digital computer subsystems.
b. Graduates will examine the design of current and planned computer hardware and software architectures for space-based applications to include their potential to support service life extensions and enable incremental capabilities of cyber and platform resiliency.
c. Graduates will examine the use of computers in complex systems such as guidance, signal processing, communications, and control systems.
d. Graduates will examine the fundamentals of electronic component design, fabrication, reliability, and testing (to include radiation hardening), with an emphasis on parts, materials, and processes.
e. Graduates will examine modern Information Technology capabilities and their applications for space systems ground processing, data storage, information sharing, and network design.

ESR-6. Spacecraft Guidance and Control:

a. Graduates will analyze the field of spacecraft guidance and control, to include topics such as linear control, rotational kinematics, rigid body dynamics, gravity gradient, spin and three-axis stabilization design, active nutation control, sources of and response to disturbance torques, and attitude determination and associated sensors and actuators.
b. Graduates will apply these techniques to the analysis and design of resilient spacecraft guidance and control systems.

ESR-7. Spacecraft Structures, Materials, and Dynamics:

a. Graduates will examine the engineering of space structures and perform simplified sizing calculations and analytical modeling of advanced materials.
b. Graduates will analyze the advanced dynamics and control of these structures.
c. Graduates will analyze the viability of structures and materials for survivability in the space environment.

ESR-8. Propulsion Systems:

a. Graduates will examine the operating principles (fluid mechanics, thermodynamics, electricity and magnetism) and propulsion devices used in current and proposed space applications.
b. Graduates will analyze and choose appropriate propulsion systems for spacecraft applications to include launch, orbit transfers, and spacecraft maneuvering with the potential for on-orbit serviceability.

ESR-9. Spacecraft Thermal Control:

a. Graduates will examine the principles of heat transfer and how surfaces and materials are manipulated in spacecraft thermal control.
b. Graduates will examine the design, analysis, and applications of current active and passive thermal control devices (including heat pipes, louvers, and materials).

c. Graduates will examine the sources of heat in space (solar, terrestrial, reflected solar, internal vehicle generation) and their variation as a function of vehicle orbit, and apply this knowledge to thermal subsystem analysis and design.

ESR-10. Spacecraft Power:

a. Graduates will examine the principles and operating characteristics of major power generating systems for spacecraft, including the performance of photovoltaic sources in the natural and artificial radiation environment.
b. Graduates will examine the principles and operating characteristics of energy storage devices in power systems design to include the potential to support associated service life extensions.

ESR-11. Remote Sensing And Payload Design:

a. Graduates will examine principles of active and passive sensors in current or planned use, to include analysis of electromagnetic wave propagation and design of optics, detectors, and antennae.
b. Graduates will examine the effects of the space, atmospheric, and terrestrial environments (including countermeasures) on sensor performance.
c. Graduates will assess and conduct tradeoffs among various sensors and platforms, evaluating how each satisfies mission requirements such as access area, resolution, timeliness, and capacity.
d. Graduates will examine the design of current and planned space-based mission payloads (e.g., ISR, Communications, PNT, SIGINT).
e. Graduates will analyze mission capabilities and conduct associated trades in order to develop associated payload design requirements.

ESR-12. Spacecraft Design Integration and Systems Engineering:

a. Graduates will develop and assess an overall space system architecture to meet defined mission requirements through the use of systems engineering tools and processes.
b. Graduates will derive system and subsystem performance criteria from stated mission capabilities and conduct trade-offs between payload and other spacecraft subsystems in addressing these capabilities.
c. Graduates will examine a broad spectrum of mission assurance concerns such as reliability, risk management, configuration management, qualification and acceptance testing, proto-flight strategy, spacecraft materials and manufacturing processes, resiliency considerations and cyberspace.
d. Graduates will examine various engineering and mathematical definitions of cost functions (revisit time, dwell time, local coverage, etc.) and apply emerging methods and tools to optimizing these utility measures in support of mission objectives.
e. Graduates will examine the basic principles and operational issues of space access to include launch vehicle performance, launch windows, and their impact on military operations.
f. Graduates will examine the capabilities of the various current and planned launch systems, and characterize the issues associated with integrating a spacecraft with a launch vehicle, to include the effects of launch environment.

g. Graduates will perform a trade-off analysis in the selection of a launch vehicle based on mission requirements, performance and design constraints, and business issues involved (e.g., pricing, insurance, policy).
h. Graduates will demonstrate proficiency in design, analysis, and modeling / simulation tools such as NX, MATLAB / Simulink, and Systems Tool Kit (STK).
i. Graduates will examine the processes and methods of systems engineering including requirements analysis, functional analysis and allocation, system design, and verification.

ESR-13. Ground Systems and Systems Engineering:

a. Graduates will understand the fundamentals of a space-ground system architecture including the system-of-systems that comprise a space-based, end-to-end capability across all mission areas.
b. Graduates will examine Department of Defense Architecture Framework (DoDAF) views of real or notional space network architectures in order to understand necessary internal and external interfaces and domain interactions.
c. Graduates will analyze enterprise and mission-specific frameworks from standard communications infrastructures (C&C, messaging, data, etc.), services, and tools to mission specific T&C, information products and data.
d. Graduates will analyze network and non-network communications within an Information Technology Enterprise Domain context.
e. Graduates will understand application program interface (API) challenges in relation to security requirements, risks and mitigation.
f. Graduates will understand Risk Management Framework integration for cyber security system engineering efforts including information assurance and relevant documentation such as NIST SP800-30, DOD8500.1 and 8500.2.
g. Graduates will analyze command and telemetry requirements and capabilities to support mission execution, vehicle operations and anomaly resolution.
h. Graduates will analyze services for access, sharing, processing and external dissemination of information including data management and storage challenges such as "Big Data", open-source implementation and cloud technology applications for Ground Systems.

ESR-14. Conduct and Report Independent Research:

a. Graduates will conduct independent research on a space systems problem, including resolution of the problem and presentation of the results and analysis in both written and oral form, via a Master’s thesis.

Appendix H – Thesis Proposal Approval Form

A blank copy of the Thesis Proposal Form is attached here.

Department of Mechanical and Aerospace Engineering

THESIS PROPOSAL APPROVAL FORM
Astronautical Engineering Degrees

A. First and Last Name:

B. Curriculum:

C. Exp. Graduation: Quarter Year

D. Primary Degree: **MSAE** Secondary Degree: **N/A**

E. Primary Thesis Advisor:

F. Co-Advisor: Second Reader:

G. List 4000 level courses which support your thesis:

H. Thesis Classification Level: **Unclassified**

I. Tentative Thesis Title:

J. Anticipated Funding Requirements (If any): Funding provided by:

K. Human Subjects Research Involved: **No** If yes a Human Subject Determination Request Form must be filled out, signed by the advisor. For more information and forms click **here**

Answer Research Questions "L" through "Q" on the following page.

By signing and submitting this thesis approval form, I acknowledge that I have read, understood, and agreed to following the online instructions, **NPS Academic Honor Code /NPS Thesis Processing Office** for student theses, and I also acknowledge I am responsible for entering the thesis information into Python within five days of receipt of approved document.

Student signature: _____ Date _____

Approved by:

Thesis Advisor: _____ D ate: _____

Co-Advisor: _____ Date: _____

Second Reader: _____ D ate: _____

Academic Associate: _____ D ate: _____

Chairman: _____ Date: _____

Noted /Date: _____ **Program Officer**: _____

Modified Aug 2016

L. Research Questions/Objectives
Identify the primary research question and subsidiary research questions. The primary research question should be broad enough that it covers the entire spectrum of the research activity. Subsidiary research questions subdivide the primary research question into manageable research segments. This should be a very explicit statement of the questions the research will seek to answer. While the questions may be redefined later as the research progresses, initial objective should be made specific.

M. Discussion of Topic
Describe the main thrust of the study, what areas will be specifically investigated and what areas will be excluded; put boundaries around the study; identify what the study will be (e.g., a computer simulation, an experiment, an electronic design and implementation, a system study); discuss any limitations of the study.

N. Tentative Chapter Outline
Identify tentative chapter headings and provide brief discussion of chapter content (Note: This can change).

O. Benefit of Study
State the contribution expected from your research efforts, what individuals/organizations will use the results of your thesis and what problems/issues you expect to be addressed/resolved.

P. Literature Review and Preliminary Bibliography
Provide a listing of representative materials consulted during preliminary literature search. This should include references to the problem or issue to be studied, prior thesis work, literature references, or other sources of information. The final bibliography will probably be much more extensive. Use a standard and complete citation format.

Q. Milestones
This is a tentative list of target dates for completion of the successive stages of the project. You will not be held strictly to this schedule; it is a means of conveying to others when you expect to complete major milestones of the study. Give the dates during which the following activities will be accomplished.

(1.) Literature Review
(2.) Construct Research Approach
(3.) Conduct Research/Travel
(4.) Analyze Data
(5.) Draft Thesis
(6.) Final Thesis Submission Signature

Appendix I - Thesis Evaluations

AY/AQ	Thesis Title	Student Name	Rater Name	1. Subject Matter Competence	2. Methods and Technical Merit	3. Critical Thinking	4. Written Communication	5. Oral Communication (optional)	6. Defense Relevance	7. Relevance to Curriculum	Publication Type	8. Potential for Publication
18/1	FLEXIBLE MULTI-BODY SPACECRAFT SIMULATOR: DESIGN, CONSTRUCTION, AND EXPERIMENTS	Atwood, Adam L.	Karpenko, Mark	3	4	4	4	5	5	5	Academic publication	4
18/1	DESIGN, INTEGRATION, AND TESTING OF AN AUTONOMOUS MULTI-BODY SPACECRAFT SIMULATOR FOR LOW GRAVITY HOPPING AND GRASPING	Bradstreet, Andrew	Marcello Romano	5	5	5	4	5	5	5	Academic and Practitioner publications	5
18/1	IMPACT OF ACTUATOR ARRANGEMENT AND DENSITY OF OPTICAL PERFORMANCE OF AN ACTUATED HYBRID MIRROR (AHM) USING ZERNIKE POLYNOMIALS	Eddy, Janet	Kim, Jae Jun	4	3	4	5	4	5	5		
18/1	ENHANCING THE SCIENCE COLLECTION CAPABILITY OF NASA'S LUNAR RECONNAISSANCE ORBITER (LRO)	Lippman, Travis	Karpenko, Mark	5	5	5	4	4	5	5	Academic publication	5

18/1	OPTIMIZING ENGINEERING TOOLS USING MODERN GROUND ARCHITECTURES	McArdle, Ryan	Ross, Isaac	3	3	3	3	3	3	4		
18/1	CONVEX OPTIMIZATION AND CONTROL OF AGGREGATING AND DISAGGREGATING SPACECRAFT	Pandya, Neehar	Romano, Marcello	3	3	3	2	3	5	5	Academic publication	3
18/1	IMPROVING MID-COURSE FLIGHT THROUGH THE APPLICATION OF REAL-TIME OPTIMAL CONTROL	Roncoroni, Mark	Ross, Isaac	5	5	5	3		5	4	Academic and Practitioner publications	5
18/1	LOW-COST, SOFTWARE-ONLY MODIFICATIONS FOR IMPROVED GUIDANCE AND CONTROL OF TACTICAL MISSILES	Roush, Angela	Karpenko, Mark	4	4	4	4	5	5	4	Academic publication	4
18/1	DESIGN AND IMPLEMENTATION OF AN OPTICAL SPARSE APERTURE TESTBED FOR SMALL SATELLITE FORMATION SPACE-BASED REMOTE SENSING	Sundey, Sean	Kim, Jae Jun	5	4	4	5		5	5	Academic publication	5
			Total Averages	**4.11**	**4.00**	**4.11**	**3.78**	**4.14**	**4.78**	**4.67**		**4.43**

19/1	DESIGN, CONSTRUCTION, AND TESTING OF A SOLAR-POWERED, MULTIROTOR, UNMANNED AERIAL VEHICLE	Gleason, Brian P.	Michael, Sherif N.	4	4	4	4	4	5	4	Practitioner publications	3
19/1	FABRICATION OF SHAPE MEMORY ALLOYS USING AFFORDABLE ADDITIVE MANUFACTURING ROUTES	Anantachaisilp, Farsai	Luhrs, Claudia C.	4	4	4	4	5	4	4	Academic publication	5
19/1	MECHATRONICS: THE DEVELOPMENT, ANALYSIS, AND GROUND-BASED DEMONSTRATIONS OF ROBOTIC SPACECRAFT HOPPING WITH A MANIPULATOR	Komma, Justin L.	Romano, Marcello	5	5	4	4		5	5	Academic and Practitioner publications	5
19/1	ROBOTIC SPACECRAFT HOPPING: APPLICATION AND ANALYSIS	Alsup, Katrina P.	Romano, Marcello	5	5	5	4	4	5	5	Academic and Practitioner publications	5
19/1	SOFTWARE-DEFINED RADIO PAYLOAD DESIGN FOR CUBESAT AND X-BAND COMMUNICATIONS	Lovdahl, Bianca L.	Newman, James H.	4	5	4	5	5	5	5	Academic publication	3
19/1	SUBMUNITION DESIGN FOR A LOW-COST SMALL UAS COUNTER-SWARM MISSILE	Lobo, Keith	Brophy, Christopher M.	4	4	4	5	4	4	4		4
			Total Averages	**4.33**	**4.50**	**4.17**	**4.33**	**4.40**	**4.67**	**4.50**		**4.17**

Sample Comments with names redacted;

- This thesis satisfies the depth requirement as the work takes the development of an advanced control system concept from theory, through hardware instantiation, and then to practical implementation. This thesis satisfies the breadth requirement in that concepts from space-systems, multi-body dynamics, control and optimization as well as practical laboratory experimentation are used as part of the thesis work.

- The thesis research included techniques from various subjects including structures, finite element, optics, and controls. Several different software was utilized in the thesis such as Nastran, Sigfit, and Matlab to provide analysis and simulation. This provided students to expose an real-world engineering problem that is relevant to DoD space.

- This thesis covers depth and breadth criteria as the work spans both space engineering and operations and employee techniques from mathematics, engineering and computer science.

- We plan to publish his thesis next year.

- This thesis covers depth and breadth criteria. The breath criteria is met as the work spans abstracts concepts form space systems engineering and applies these ideas to advancing tactical missile guidance. The depth requirement is met by a thorough understanding of the operation of missile guanaco and control systems.

- The student thesis addresses the efforts made on the design and implementation of sparse aperture testbed as well as some simulation and laboratory testing results using the developed testbed. The thesis provided hands-on experience to work on the complex multidisciplinary system. Student was required to learn some subjects such as optics and optical systems, which are not included in the regular 591 curriculum. However, this should be encouraged as optical system is a very important subject for the relevant government space platform.

- This is a breadth thesis.

Appendix J – MSAE Checklist

A blank copy of the MSME Checklist is attached here.

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

CHECKLIST FOR MS-AE/MS-ES(AE) DEGREE

This checklist documents the completion of the requirements for the degrees of:

- *Master of Science in Astronautical Engineering (MS-AE)*
- *Master of Science in Engineering Science, Astronautical Engineering (MS-ES(AE))*
- *Astronautical Engineer (AE)*

The degree of Master of Science in Astronautical Engineering (MS-AE) is accredited by the Accreditation Board of Engineering and Technology (ABET), and hence eligibility for this degree is contingent upon satisfying one of the following two conditions:

1. Having earned an ABET-accredited Bachelor of Science in Astronautical Engineering (BS-AE),
2. Establishing ABET BS-AE "equivalency" (satisfying requirements documented by the BS-AE equivalency checklist).

ALL students must complete both the BS-AE equivalency checklist and this MS checklist.

First and Last Name: Enrolled (MM/Yr.) at NPS: Select Quarter Year

Exp. Graduation: Select Quarter Year

Mechanical and Aerospace Engineering Degree Summary

Total 4000 Level MAE courses.	[12] required	NOT MET	0.0
Total 3000 and 4000 Level MAE courses.	[24] required	NOT MET	0.0
Total 3000 and 4000 non-Level MAE courses.	[8] required	NOT MET	0.0
Master of Science Total Quarter Credit Hours:	[48] required	NOT MET	16.0
	Master of Science Total Quarter Hours	NOT MET	

BS-AE Degree Equivalence

Requirements satisfied? Yes

Degree Sought: Select Degree No. of Thesis Credits: 16

Thesis Advisor:

Thesis Title:

Specialization Area:

Course Number	Course Title	Lecture	Lab

Approved by:

Academic Associate: _____

Department Chair: _____

I certify that the information contained within this form is correct at the time of my graduation and accurately documents the courses I completed to satisfy the degree requirements for the M.S. in Astronautical Engineering. I also certify that no courses that appear on this form also appear on my BS-AE checklist.

_____

Student Signature **Date**

Department of Mechanical and Aerospace Engineering

I certify that this student has met the minimum degree requirements. _____ **Academic Associate** **Date**

_____

Program Officer **Date**

_____

Department Chair **Date**

Modified Aug 2016

1. Competency / Specialization Area Requirement:

In order to complete the requirements for the degree of Master of Science (MS-AE or MS-ES), a specific specialization area within the discipline of Astronautical Engineering must be declared.

The course matrix must include a minimum of two 4000 level courses in the specialization area approved by both the Department Chairman and Academic Associate. List applicable courses below:

Course Number	Course Title	Lecture	Lab

2. Course Credit Requirements:

The degree of Master of Science (MS-AE or MS-ES) requires at least 32-quarter hours of graduate level credits. At least 12-quarter hours must be at the 4000 level and at least 24 quarter hours must be in courses offered by the Mechanical and Aerospace Engineering Department.

A. List 4000 level Mechanical or Astronautical Engineering courses applied toward MS-AE / MS-ES degree.

Course Number	Course Title	Credit Hours	
		Lecture	Lab
	Total Lecture/Lab Hours	0	0
	Total 4000 Level MAE Course Quarter Credit Hours.		0.0
	[12] required		0.0

C. List 3000 level Mechanical or Astronautical Engineering courses applied toward MS-AE / MS-ES degree.

Course Number	Course Title	Credits Hours	
		Lecture	Lab

	Total Lecture/Lab Hours	0	0
	Total 3000 Level MAE Course Quarter Credit Hours		0.0
	Total of 3000 and 4000 Level Credit Hours in MAE. [24] required		0.0

D. List 3000 and 4000 level non-Mechanical or Astronautical Engineering courses applied toward MS-AE / MS-ES degree.

Course Number	Course Title	Credits Hours	
		Lecture	Lab
	Total Lecture/Lab Hours	0	0
	Total 3000 and 4000 Level non-MAE Course Quarter Credit Hours		0.0
	Total 3000 and 4000 non-MAE Level Credit Hours [8] required		0.0
	Total 3000 and 4000 Level Credit Hours [32] required		0.0
	Thesis credits [16] required		16
	Total Quarter Hours [48] required		16.0

Appendix K - MAE ABET YEARLY REPORT - 2015

The MAE Department has been divided into six Technical Committees (TC) in Structures/Solids, Fluids/Thermo, Controls/UAV's, Materials, Weaponeering/Survivability/TSSE and Astronautical Engineering. Each TC has under its charge the list of courses in Attachment A. On a quarterly basis each TC will reviews its courses for correctness of course description, prerequisites and ABET outcomes (currently a though k) and report back to the Department on their findings and corrective actions. The list of Faculty assigned to each TC is appended in Attachment B and the reporting order of sequence is as listed above. This quarter the Structures/Solids TC reported (Attachment C) on all the courses that they reviewed and has drawn up a list of 9 out of a total 14 courses that will need Academic Council approval for either a course description or prerequisites change. A new online course review form was developed to assist in this process. Each course coordinator was responsible for the review of their course(s), which in turn was reviewed by the whole TC before reposting back to the Department.

Attachment A – Technical Committees and Courses Under Their Purview.

Structures/Solids

AE2820
ME1000
ME2601
ME3611
ME3450
ME3521
ME3711
ME3712
ME4522
ME4525
ME4612
ME4613
ME4731

Fluids/Thermo

AE4452
AE4502
ME2101
ME2201
ME3150
ME3201
ME3205
ME3240
ME4101
ME4161
ME4162
ME4202
ME4220
ME4225
ME4420
ME4424
ME4704

Controls/UAVs

AE2440
ME2801
ME3720
ME3801
ME4703
ME4801
ME4811
ME4821
ME4823

Materials

MS2201
MS3202
MS3304
MS3606
MS4312
MS4410
MS4811

Weaponeering/Survivability/TSSE

ME2501
ME2502
ME4700
ME4702
ME4751
ME4753
TS3000
TS3001
TS3002
TS3003
TS4000
TS4001
TS4002
TS4003

Astronautical Engineering

AE3804
AE3811
AE3815
AE3818
AE3820
AE3830
AE3851
AE4818
AE4820
AE4830
AE4831
AE4850
AE4860
AE4870
AE4871

Attachment B – Memorandum and List of Professors per TC

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CA 93943-5146

NPS(MAE)
7 Oct 2015

MEMORANDUM

From: Professor and Chairman, Mechanical and Aerospace Engineering Department

To: MAE Faculty

Subj: RECONSTITUTION OF TECHNICAL COMMITTEES

1. This reconstitutes the existence and make-up of the six Technical Committees (TC) within the Department as shown in attachment 1.
2. The list of courses under the responsibility of each TC is shown in attachment 2.
3. Each TC will meet on a semi-annual basis to review the course descriptions of each course under their purview, the course pre-requisites as well as the ABET criteria.
4. On a quarterly basis each TC will report back to Department on their assessments.

GARTH V. HOBSON

MAE Technical Committees – 10/06/2015

Structures/Solids
Kwon (Chair)
Gordis
Hooper
Didoszak
Seivwright
Alley (NSWC)

Fluids/Thermo
Hobson (Chair)
Brophy
Gannon
Chandra
Sathe
Jones
Dausen
Rhatigan

Controls/UAVs
Kaminer (Chair)
Bingham
Yakimenko
Horner
Dobrokhodov
Du Toit

Materials
Luhrs (Chair)
Menon
Phillips (PH)
Alley (NSWC)
Tran (NSWC)

Weaponeering/Survivability/TSSE
Driels (Chair)
Adams
Didoszak
Rhoades (SE)
Smithtro (GSEAS)
Ashton (ECE)
Romero (ECE)
Harkins (PH)

Astronautical Engineering
Romano (Chair)
Agrawal
Ross
Brophy
Kim
Rhatigan
Racoosin (SSAG)
Tackett (SSAG)

Attachment C - MAE Department ABET Technical Committee Summary Report

Committee Chairman:		Young Kwon

Date	11/26/18

Committee Members:		Structures/Solids

	Present?
Kwon	Yes
Gordis	Yes
Hooper	Yes
Didoszak	Yes
Seivwright	Yes
Alley	No

Course Review

	Reviewed ?	Recommended Actions
AE2820	Yes	None
ME1000	Yes	None
ME2601	Yes	Change of Course Description and Prerequisities
ME3611	Yes	Change of Course Description - Substantive
ME3450	Yes	Change of Course Prerequisites
ME3521	Yes	None
ME3711	Yes	Change of Course Prerequisites
ME3712	Yes	Change of Course Prerequisites
ME4522	Yes	None
ME4525	Yes	Change of Course Description - Minor
ME4550	Yes	Change of Course Description - Substantive
ME4612	Yes	None
ME4613	Yes	Change of Course Prerequisites
ME4731	Yes	Change of Course Prerequisites
	-	-

Narrative

1. Alley did not attend the meeting but he sent his comments by e-mail before the meeting. 2. All courses were reviewed for their BSME Equivalent Course Outcomes (a-k) as well as for the MSME Program Outcomes, and those were revised as necessary based on the committee members' unanimous votes. 3. Necessary changes for the course descriptions and prerequisites were identified by the committee, and will be proposed for necessary approvals for the requested change. 4. The review will be repeated approximately every 18 months.

Appendix L - MAE ABET YEARLY REPORT - 2016

The MAE Department has been divided into six Technical Committees (TC) namely;

Structures/Solids,
Fluids/Thermo,
Controls/UAV's,
Weaponeering/Survivability/TSSE,
Materials and
Astronautical Engineering.

Each TC has under its charge the list of courses in Attachment A. On a quarterly basis each TC will reviews its courses for correctness of course description, prerequisites, program objectives and ABET outcomes (currently a though k) and report back to the Department on their findings and corrective actions that need to take place. The list of Faculty assigned to each TC is appended in Attachment B and the reporting order of sequence is as listed above. Thus far the first four TCs have reported (Attachment C) on all the courses that they reviewed and have drawn up lists of courses that were submitted (**Attachment D**) to the Academic Council for approval for either a course description or prerequisites change.

The summary of changes requested by each TC thus far are;

Structures/Solids TC - 9 out of a total 14,
Fluids/Thermo TC - 7 out of a total 19 ,
Controls/UAVs TC - 5 out of a total 9,
Weaponeering/Survivability/TSSE – 5 out of a total 14,

courses that needed Academic Council approval for either a course description or prerequisites change

A new addition to the course review template was the inclusion of the curriculum outline per ABET and Academic Council outlines (the Solids and Fluids TCs will need to add these during the next cycle)

Criterion IV has also been updated (**Attachment E**) in draft form.

The Department underwent a Mechanical Engineering (570/563) Curricula Review (CR) on December 13th, 2016 with Rear Admiral Selby, NAVSEA 05, the Chief Engineering Duty Officer in the Navy and Mr Robert Klocek, NAVSEA 00T1. The final signed CR letter with the signatures of all the Major Area Sponsors; Director, Total Force Manpower, Training and Educations Requirements Division (N12), President, Naval Postgraduate School, Director, Chief of Naval Operations, Energy and Environmental

Readiness Division (OPNAV N45) and the Chief Engineer (SEA05) was obtained on April 25, 2017. A copy of which is included as **Attachment F**.

Attachment A – Technical Committees and Courses Under Their Purview.

Structures/Solids
AE2820
ME1000
ME2601
ME3611
ME3450
ME3521
ME3711
ME3712
ME4522
ME4525
ME4612
ME4613
ME4731

Fluids/Thermo
AE4452
AE4502
ME2101
ME2201
ME3150
ME3201
ME3205
ME3240
ME4101
ME4161
ME4162
ME4202
ME4220
ME4225
ME4420
ME4424
ME4704

Controls/UAVs
AE2440
ME2801
ME3720
ME3801
ME4703
ME4801
ME4811
ME4821
ME4823

Materials
MS2201
MS3202
MS3304
MS3606
MS4312
MS4410
MS4811

Weaponeering/Survivability/TSSE
ME2501
ME2502
ME4700
ME4702
ME4751
ME4753
TS3000
TS3001
TS3002
TS3003
TS4000
TS4001
TS4002
TS4003

Astronautical Engineering
AE3804
AE3811
AE3815
AE3818
AE3820
AE3830
AE3851
AE4818
AE4820
AE4830
AE4831
AE4850
AE4860
AE4870
AE4871

Attachment B – ABET Committee Members

MAE Technical Committees – 11/06/2016

Structures/Solids
Kwon (Chair)
Gordis
Hooper
Didoszak
Seivwright
Alley (NSWC)

Fluids/Thermo
Hobson (Chair)
Brophy
Gannon
Chandra
Jones
Dausen
Rhatigan

Controls/UAVs
Kaminer (Chair)
Bingham
Yakimenko
Horner
Dobrokhodov
Du Toit

Materials
Luhrs (Chair)
Menon
Phillips (PH)
Alley (NSWC)
Tran (NSWC)

Weaponeering/Survivability/TSSE
Driels (Chair)
Adams
Didoszak
Rhoades (SE)
Smithtro (GSEAS)
Ashton (ECE)
Romero (ECE)
Harkins (PH)

Astronautical Engineering
Romano (Chair)
Agrawal
Ross
Brophy
Kim
Rhatigan
Racoosin (SSAG)
Tackett (SSAG)

Attachment C – MAE Department ABET Technical Committee Summary Report

Committee Chairman:		Isaac Kaminer

Date	11/26/18

Committee Members:		Controls/UAV

	Present?
Kaminer	Yes
Bingham	Yes
Yakimenko	Yes
Horner	Yes
Dobrokhodov	Yes
Bingham	Yes

Course Review

	Reviewed ?	Recommended Actions
AE2440	Yes	Change of Course Description - Minor
ME2801	Yes	None
ME3720	Yes	None
ME3801	Yes	Change of Course Description and Prerequisites
ME4703	Yes	Change of Course Description - Minor
ME4801	Yes	None
ME4811	Yes	Change of Course Description - Substantive
ME4821	Yes	None
ME4823	Yes	Change of Course Description - Substantive
	-	-

Narrative

2440 - Change the title of the course in the catalogue (not Python); 3801 - add EC2300 as a prereq; 4703 - change of title and minor change of course description; 4822 - needs to be added to the list of courses in this file. It was reviewed and minor changes to course description; 4811 and 4823 - major changes. The same instructor should teach both.

Verified by Isaac Kaminer commite chair Controls/UAVs

Committee Chairman:		Garth Hobson

Date	11/26/18

Committee Members:		Fluids/Thermodynamics

	Present?
Hobson	Yes
Brophy	Yes
Gannon	Yes
Chandra	Yes
Jones	Yes
Dausen	Yes
Rhatigan	Yes

Course Review

	Reviewed ?	Recommended Actions
AE3804	Yes	Change of Course Description - Substantive
AE3851	Yes	None
AE4452	Yes	Change of Course Description - Substantive
AE4502	Yes	None
ME2101	Yes	Change of Course Description - Substantive
ME2201	Yes	Change of Course Description - Substantive
ME3150	Yes	Change of Course Description - Substantive
ME3201	Yes	-
ME3205	Yes	-
ME3240	Yes	Change of Course Description - Minor
ME4101	Yes	Change of Course Description - Substantive
ME4161	No	-
ME4162	Yes	-
ME4202	No	-
ME4220	Yes	-
ME4225	Yes	None
ME4420	No	-
ME4424	Yes	None
ME4704	Yes	None

Narrative

The main decision during the general discussion was to move Fluids ME3201 and Heat Transfer ME3150 to separate quarters.

Verified by Garth Hobson committee chairman for Fluids/Thermodynamics

Committee Chairman:		Morris Driels

Date	11/26/18

-

Committee Members:		Weaponeering/Survivability/TSSE

	Present?
Driels	Yes
Adams	Yes
Didoszak	Yes
Rhoades	Yes
Smithro	Yes
Ashton	Yes
Romero	Yes
Harkins	Yes
Papoulias	Yes
Greene	Yes

Course Review			
		Reviewed ?	Recommended Actions
ME2501		Yes	Change of Course Description (substantive) and Prerequisites
ME2502		Yes	None
ME4700		Yes	None
ME4702		Yes	None
ME4751		Yes	None
ME4753		Yes	None
TS3000		Yes	None
TS3001		Yes	Change of Course Description - Substantive
TS3002		Yes	Change of Course Description (substantive) and Prerequisites
TS3003		Yes	Change of Course Description - Substantive
TS4000		Yes	None
TS4001		Yes	Change of Course Prerequisites
TS4002		Yes	None
TS4003		Yes	None

Narrative

Verified by	Morris Driels	committee chairman for	Weaponeering/Survivability/TSSE

Attachment D – List of Courses that needed Academic Council Approval for changes

Thermo/Fluids

AE3804
AE4452
ME2101
ME2201
ME3150
ME3240
ME4101

Controls

AE2440
ME3801
ME4703
ME4811
ME4823

Weaponeering/Survivability/TSSE

ME2501
TS3001
TS3002
TS3003
TS4001

Attachment E - CRITERION 4. CONTINUOUS IMPROVEMENT

The MAE Department uses "Annual Reports," as a primary means to assist in the evaluation of assessment data collected throughout the year from various sources. As part of the continuous improvement process, these reports, prepared by the Mechanical Engineering "ABET Standing Committee", are used as a key assessment tool in the identification of how well the program is meeting its stated Program Educational Objectives and student outcomes. This report contains direct and indirect measures of program objectives and student outcomes, process reviews and other assessments to aid in continually improving the program leading to the awarding of a MSME degree at NPS.

A series of primary Assessment Criteria (AC) are used to evaluate the Student Outcomes throughout this cycle. The following eight AC measure the effectiveness of the five (5) stated Student Outcomes, based on the three (3) Program Educational Objectives.

1. Graduating students will meet ABET-accredited BSME equivalence. All students will complete the BSME equivalency checklist form submitting it for review and approval by the Academic Associate, Program Officer and the MAE Department Chairman. (The BSME Checklist was updated and replaced online in Feb 2017)

2. Graduating students will complete one year of study beyond the basic level of graduate level study and follow a specialization track in one of the available disciplines of Mechanical Engineering.

3. All MSME degree recipients will complete and present a thesis. Thesis evaluation consists of reviewing the thesis signature page, thesis distribution statement, and completion of the thesis evaluation and rating forms by the thesis advisors.

4. Tracking and review of PE and FE examinations participants and success rates.

5. Survey results from the Engineering Duty School Senior Course.

6. Survey results from the graduating student exit surveys and interviews.

7. Survey results from recent graduates, alumnus and their supervisors.

8. Sponsor program review and evaluation, i.e. Curricula Reviews.

The results of the Student Outcomes assessments were obtained by a combination of student record, coursework and academic performance reviews while the Program Educational Objective assessment was mainly through surveys responses, interviews and other direct and indirect assessments by department faculty members

Table 4-1 displays the relationships of ACs to Student Outcomes. The ACs are listed here against the Student Outcomes that they serve. However the AC 1-4 primarily functions as a direct measure of the Student Outcomes, while AC 5-8 relate to the corresponding

Student Outcomes indirectly through evaluation of the Program Educational Objectives under which they fall.

Table 4-1 Assessment Criteria (AC) to Measure Student Outcomes

	AC-1. BSME Equivalency Checklist	**AC-2.** MSME Checklist	**AC- 3.** Thesis Evaluation	**AC -4.** PE Exams	**AC-5.** ED School Presentation and Report	**AC- 6.** Exit Survey	**AC -7.** Alumni & Supervisor Survey	**AC- 8.** Program Sponsor Evaluation
Outcome #1: ABET-BSME Equivalency	**X**					**X**		
Outcome #2: Advanced Study		**X**				**X**	**X**	**X**
Outcomes #3: Communication Skills			**X**		**X**	**X**	**X**	**X**
Outcomes #4: Identify, Formulate, and Solve Technical & Engineering Problems			**X**	**X**		**X**	**X**	**X**
Outcomes #5: Apply technical Knowledge in Leadership & National Security					**X**	**X**	**X**	**X**

The MSME Degree Program does not currently have a stated goal set for our expected level of attainment for each of the Program Educational Objectives and Student Outcomes. Rather, the results of the continuing assessments are compared with the prior year results and trends over the ABET accreditation cycle. Historical data are establish, reviewed and corrective actions implemented where necessary as deemed by review of the ABET committee and MAE Department Chairman. Priority is given to those areas that are failing to maintain or improve based on the aforementioned AC.

The MAE Department has a standing ABET committee, which meets regularly throughout the cycle. The committee is comprised of faculty members that head the six technical committees within the department and the curriculum program officer. During CY2016, the faculty members on the committee were: Distinguished Professor Young

Kwon Solids and Structures Technical Committee (TC) Chair, Professor Isaac Kaminer Contols and Unmanned Systems TC Chair, Professor Claudia Luhrs Materials TC Chair, Professor Morris Driels Design TC Chair, Associate Professor Marcello Romano Astronautics TC Chair and Professor Garth Hobson Thermo Fluids TC Chair and Chair of Department. The Program Officer was CDR Todd Greene.

A. Program Educational Objectives

The assessment processes used to gather data, evaluation procedures, data collection examples and summaries for the Program Educational Objectives are presented jointly with the Student Outcomes in the following section.

B. Student Outcomes

The assessment processes used to gather data and methods implemented to evaluate the attainment of Student Outcomes is described as follows for each of the AC that were previously defined. As noted before, a number of these AC also serve in the role of inherently providing assessment and evaluation of the underlying Program Educational Objectives in addition to the stated Student Outcomes.

1. AC-1: BSME Equivalency

In order for the MAE Department to confer to a student an ABET-accredited Master's degree, the student must either possess an ABET-accredited BSME degree, or establish that the equivalent knowledge has been obtained from undergraduate courses taken elsewhere and/or from undergraduate-level classes taken in the MAE Department at NPS.

The BSME equivalency form, which every student is required to complete prior to graduation, documents the courses taken which comprise the equivalent of an ABET-accredited BSME degree. No courses used to populate the BSME equivalency form may be used towards the MSME Degree Requirements. The latest revision of the BSME checklist issued by the program is from Aug 2016. The BSME checklist had only minor updates and no substantive changes.

2. AC-2: MSME Checklist

After completing the BSME equivalency, every student also completes the MSME checklist to meet the requirements for the degree. These forms are completed based on students' course matrices, and are reviewed by the Academic Associate and Program Officer. As the course matrices are updated for students, the forms are also revised to reflect the changes. Eventually, when students complete all course requirements, these forms are approved by the Academic Associate, Program Officer, and the Department Chairman.

In Aug 2016, the MSME checklist underwent some formatting.

3. AC-3: Thesis Evaluation

Completing a thesis is one of the requirements for the MSME degree. When students complete their theses, they submit the written theses as well as make oral presentations to department faculty, students and guests during scheduled seminar sessions. The thesis advisors, co-advisors, second readers, and/or the MAE Department Chairman evaluate the theses and presentations in terms of technical quality, writing skills, and oral presentation skills. Their evaluation of the student's overall thesis (oral presentation and written submission) is reported in the Thesis Evaluation form. This is used as a primary assessment of Student Outcome 3, which supports Program Educational Objective 3, "The ability to communicate advanced technical information effectively in both oral and written form." The scale used in the evaluations is as follows: 5 - Outstanding, 4 - Excellent, 3 - Satisfactory, 2 - Fair and 1- Poor.

Written communication of technical material continues to be an area that students struggle with year in and year out. The MAE Department Chairman, who reviews each graduate thesis submitted as part of the MSME Degree Program, has consistently reported back to the faculty and specifically thesis advisors, co-advisors and second readers, who are charged with guiding and reviewing student graduate theses, his concerns over the quality of work being submitted.

A Graduate Writing Center has been established at NPS and currently is under the guidance of Dr. Sandra Leavitt. Its expressed mission is "to help students develop their academic writing skills, enhance their learning experience and clearly communicate their ideas and knowledge while at NPS and beyond." This provides another resource for students in additional to ongoing departmental improvement efforts and the currently required thesis preparation seminar offered by the NPS Research Office.

4. AC-4: PE Exams

The MAE Department encourages students to pursue Professional Engineers (PE) registration even though the exam is not a requirement for graduation. Students are made aware of the opportunity to do this through several methods. Seminars are offered each year in which the basics of the registration process are outlined. During the quarterly new student brief for mechanical engineering students, a short presentation is given in which the incoming students are made aware of the registration process and the support that the MAE Department offers through courses such as ME1000.

The ME1000 course, "Preparation for Professional Engineering Registration" is offered at a minimum of once a year. This course is open to students who are pursuing professional engineering licensure, through the FE and PE examinations. Taking the PE is not a requirement of the course, which is graded as a pass/fail. The enrollment in ME1000 has fluctuated from 2013-2016 with 4, 15, and 3 students respectively. So roughly a quarter of our ME students take this course.

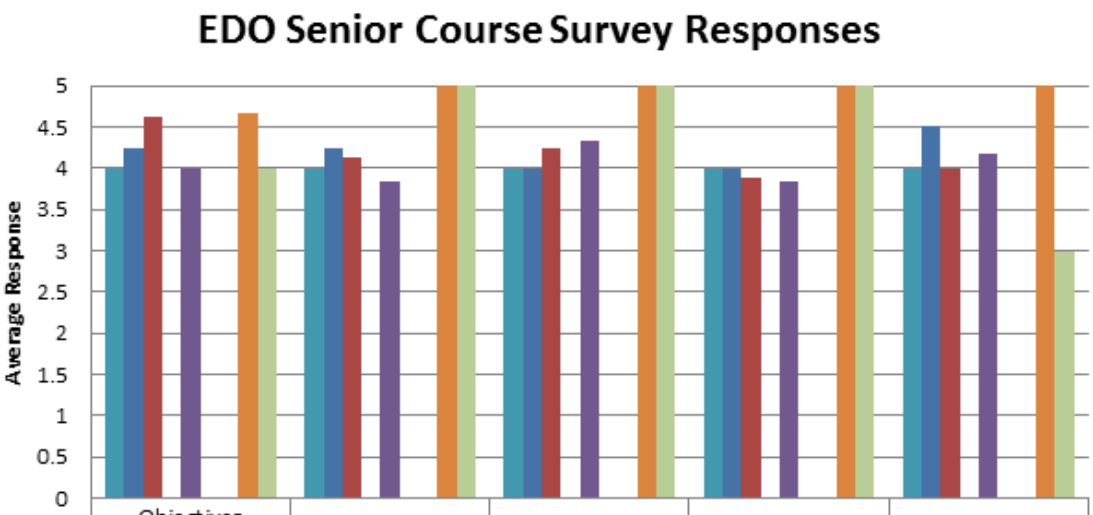
Tracking the completion of the PE Exam and the pass rate is one of the measures used to assess the students' ability to "Identify, Formulate, and Solve Technical & Engineering Problems" as defined in Student Outcome 4. It is of concern that more students are not willing to engage in the preparations and licensure program initiated with the FE and PE Examinations. About 10 percent of the ME students take the PE Exam in Mechanical Engineering and they have above an 80% pass rate compared to less than 50% pass rate in the State of California.

5. AC-5: Engineering Duty Officer (EDO) School Surveys and Interviews

The MAE Department conducts surveys and interviews of graduates to assess how they perceive their MSME education has served them so far in their careers. Additionally their views on the skills and abilities of more recent program graduates working in the field are collected as a means of gauging how well prepared their successors are in serving the Engineering Duty Officer community.

Figure 1 shows the historic trends for Engineering Duty Officer Alumni responses. As is evident from the plot of results dating back to 2008, the average responses have stayed relatively flat over time, with some local fluctuations, but all are generally favorable. Though a visit was made each year between 2008 and 2016, unfortunately, no reports were received from the Curriculum Officer for 2011, 2013 and 2014.

Figure 2, is the Supervisor Survey Responses over the period 2010 till 2016 for the same 5 Student Outcomes. Unfortunately no reponses were uptained for 2011 thru 2014.



	Objectives Support Navy Needs	Technical Competence	Communication Skills	Problem Solving Skills	Technical Leadership
2008	4	4	4	4	4
2009	4.25	4.25	4	4	4.5
2010	4.625	4.13	4.25	3.88	4.00
2011	0				
2012	4	3.83	4.33	3.83	4.17
2013	0				
2014	0				
2015	4.67	5.00	5.00	5.00	5.00
2016	4.00	5.00	5.00	5.00	3.00

Figure 1. EDO Senior Course Survey Reponses of MAE Department Alumnus

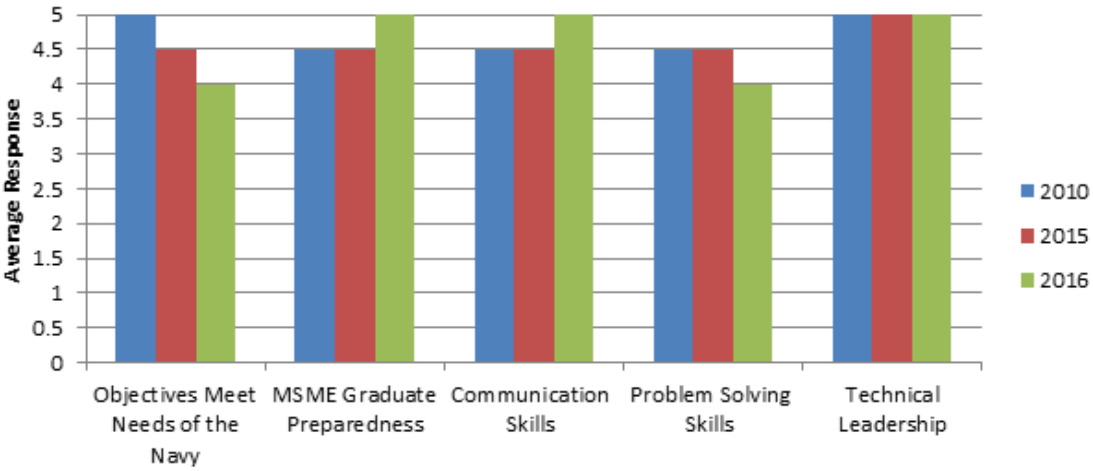


Figure 2. Supervisor Survey Reponses of MAE Department Alumnus

6. AC-6: Graduating Student Exit Surveys

The graduating student exit survey form focuses on three sections 1) Program Objectives 2) Program Outcomes and 3) Suggestions for Improvement. Additionally the students are surveyed as to whether or not they completed their Professional Engineering Licensure Examination while at NPS.

The initial part of the form asks that students rate the Program Objectives on a numerical scale of 0 to 5 (5 being the most favorable response) with respect to each of the three stated Program Objectives. The MSME Program Objectives are:

Objective 1) The ability to identify, formulate, and solve technical and engineering problems in Mechanical and Aerospace 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.

Objective 2) 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.

Objective 3) The ability to communicate advanced technical information effectively in both oral and written form.

The CY 2014 Student Outcomes are surveyed and are also summarized over the period covering the years 2012, since the last ABET reaccreditation visit. Again graduating students from the Program were asked to rate the MSME Program on the same scale of 0 to 5 with respect to each of the program outcomes as was the case with the Program Objectives. The first three outcomes are broken down even further into more specific questions.

Outcome 1, "Graduating students will have knowledge and skills equivalent to an ABET-accredited BSME"

Outcome 1.1 (Have a solid grasp on statistics)

Outcome 1.2 (Understand the process of design) and

Outcome 1.3 (Have an adequate foundation for advanced level study)

Outcome 1.4 (Apply knowledge of mathematics, science and engineering)

Outcome 2, "Graduating students will have advanced knowledge in Mechanical Engineering and competence in one of the available specialized disciplines of Mechanical

Engineering." This is further broken into three detailed questions regarding the obtainment of knowledge and skills in the use of analytic/numerical tools and software, laboratory techniques/facilities and an area of specialization within their field of study.

Outcome 2.1 (Achieve advanced competence in my specialization field)

Outcomes 2.2 (Advanced knowledge of analytical/numerical tool)

Outcome 2.3 (Achieve advanced knowledge of modern laboratory techniques)

Outcome 3, "Graduating students will have high level of communication skills including technical writing and oral presentation,"

Outcome 3.1 (Make a contribution to the scientific or technical literature)

Outcome 3.2 (Perform thesis research of benefit to the military)

Outcome 3.3 (Do an effective and clear technical presentation)

Outcome 3.4 (Have the ability to carry out further original research)

Outcome 4 "Graduating students will have the ability to independently identify, formulate and solve technical and engineering problems in Mechanical Engineering"

Outcome 5, "Graduating students will have the ability to apply technical knowledge in a leadership role related to national security,"

7. AC-7: Alumni and Supervisor Survey

The Alumni and Supervisor Survey reports are used as an indirect measure of how effective the MSME program is in providing engineers into the Department of the Navy workforce. NPS alumni are defined as those persons who graduated from NPS, but not necessarily from the MSME program themselves. Engineering Duty Officers interact and are supervised by senior officers and government civilians that may have had completed their education in fields related to mechanical engineering such as: naval architecture, systems engineering, electrical engineering, aeronautical engineering, physic or similar.

In the case of many supervisors that are asked to provide input, they will have attended another institution but may have had competed a MSME program as well. They are requested to provide feedback on the performance and impressions of the MSME program graduates from NPS as they perform in the Navy workforce. The survey itself is similar in format to the EDO Senior Course surveys but is taken from the stance of an outsider looking in.

AC-8: Program Sponsor Evaluation (2014-2016)

The MSME Degree Program sponsor, Naval Sea Systems Command (NAVSEA), conducts biennial reviews. During this ABET cycle curriculum sponsor reviews were held in 2014 and a second one is scheduled for December 2016.

C. Continuous Improvement

Annually, MAE Department ABET Committee report records program improvements, corrective actions, or other items of interest that have been identified by the Committee through the aforementioned assessments and subsequent evaluations as well as through faculty and sponsor direct input. In 2014 the MAE Department was been divided into six Technical Committees (TC) in Structures/Solids, Fluids/Thermo, Controls/UAV's, Materials, Weaponeering/Survivability/TSSE and Astronautical Engineering. Each TC has under its charge a list of courses. On a quarterly basis each TC reviews its courses for correctness of course description, prerequisites and ABET outcomes (currently a though k) and reports back to the Department on their findings and corrective actions. In quarter 1 AY 2016 the Structures/Solids TC reported on all the courses that they reviewed and drew up a list of 9 out of a total 14 courses that needed Academic Council approval for either a course description or prerequisites change. In quarter 2 the Fluids/Thermo TC met and reported on their findings and drew up a list of 7 out of a total 19 courses that needed Academic Council approval for either a course description or prerequisites change. In quarter 3 the Controls/UAVs TC met and reported on their findings and drew up a list of 5 out of a total 9 courses that needed Academic Council approval for either a course description or prerequisites change. A new online course review form was developed to assist in this process. Each course coordinator was responsible for the review of their course(s), which in turn was reviewed by the whole TC before reposting back to the Department.

Appendix M - MAE ABET YEARLY REPORT - 2017

A. Continuous Improvement

Annually, the MAE Department ABET Committee Report records program improvements, corrective actions, or other items of interest that have been identified by the Committee through the aforementioned assessments and subsequent evaluations as well as through faculty and sponsor direct input. In 2014 the MAE Department was divided into six Technical Committees (TC) in Structures/Solids, Fluids/Thermo, Controls/UAV's, Materials, Astronautical Engineering and Weaponeering/Survivability/Total Ship Systems Engineering (TSSE). On a quarterly basis each TC reviews its courses for correctness of course description, prerequisites and ABET outcomes (currently a though k) and reports back to the Department on their findings and corrective actions. In 2017, the added requirement of a complete course syllabus has been added and will be subsequently added to each of the courses within each TC's purview. The Materials TC met and reported on their findings and drew up a list of 4 out of a total 8 courses that needed Academic Council approval for either a course description or prerequisites change. In quarter 4 the Astronautical TC met and reported on their findings and drew up a list of 10 out of a total 12 courses that needed Academic Council approval for either a course description or prerequisites change.

3. AC-3: Thesis Evaluation

Completing a thesis is one of the requirements for the MSME degree. When students complete their theses, they submit the written theses as well as make oral presentations to department faculty, students and guests during scheduled seminar sessions. The thesis advisors, co-advisors, second readers, and/or the MAE Department Chairman evaluate the theses and presentations in terms of technical quality, writing skills, and oral presentation skills. Their evaluation of the student's overall thesis (oral presentation and written submission) is reported in the Thesis Evaluation form. This is used as a primary assessment of Student Outcome 3, which supports Program Educational Objective 3, "The ability to communicate advanced technical information effectively in both oral and written form." The scale used in the evaluations is as follows: 5 - Outstanding, 4 - Excellent, 3 - Satisfactory, 2 - Fair and 1- Poor.

A summary of these evaluations for the past year is tabulated in Table 4-2 and plotted in Figure 1. In general the overall quality of the theses has, on average remained constant over the year. The current year also saw a decrease in the defense relevance of the thesis topics. (Note: Because of the small sample size these trends will likely change over the coming years)

Table 4-2 Summary of Student Theses Evaluation

Grad. Date	Subject Matter Competence	Methods & Tech Merit	Crtitical Thinking	Written Comm.	Oral Comm.	Defence Relevance	# Students
Dec-16	4.5	4	4.5	4.25	3.5	5	4
Jun-17	3.67	4.33	4	4.25	4.25	4.67	3
Sep-17	3.8	3.2	3.6	4.4	4.2	4.2	5
Dec-17	4.2	4.2	4.2	4.2	4.4	4.6	5

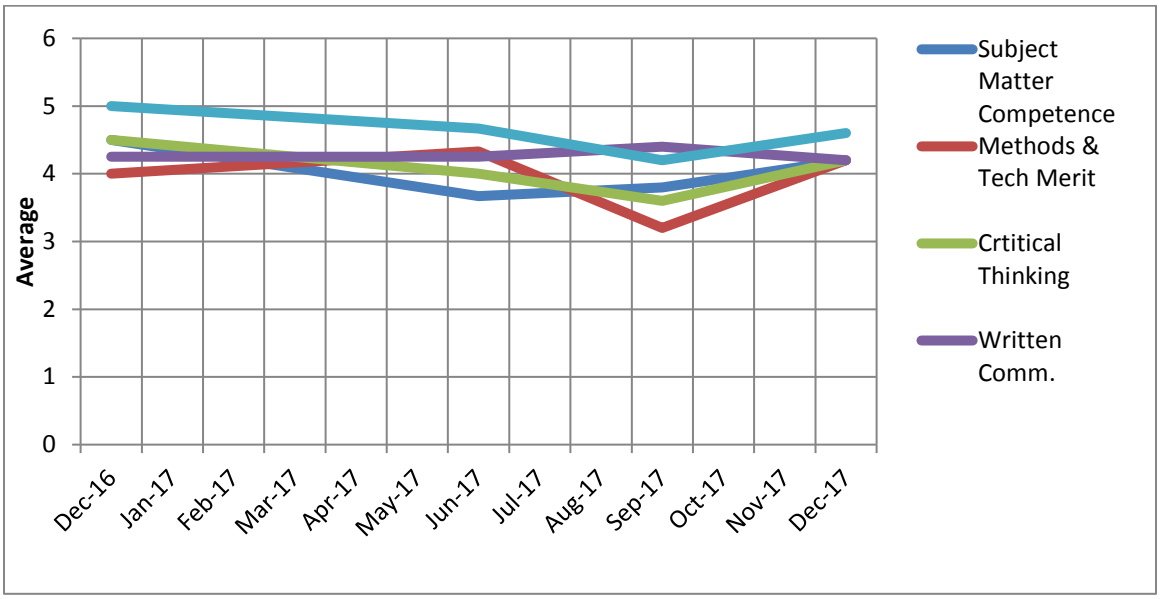


Figure 1. Plot of Student Theses Evaluation

Written communication of technical material continues to be an area that students struggle with year in and year out. The MAE Department Chairman, who reviews each graduate thesis submitted as part of the MSME Degree Program, has consistently reported back to the faculty and specifically thesis advisors, co-advisors and second readers, who are charged with guiding and reviewing student graduate theses, his concerns over the quality of work being submitted.

A Graduate Writing Center has been established at NPS and currently is under the guidance of Dr. Sandra Leavitt. Its expressed mission is "to help students develop their academic writing skills, enhance their learning experience and clearly communicate their ideas and knowledge while at NPS and beyond." This provides another resource for students in additional to ongoing departmental improvement efforts and the currently required thesis preparation seminar offered by the NPS Research Office.

4. AC-4: PE Exams

The MAE Department encourages students to pursue Professional Engineers (PE) registration even though the exam is not a requirement for graduation. Students are made aware of the opportunity to do this through several methods. Seminars are offered each year in which the basics of the registration process are outlined. During the quarterly new student brief for mechanical engineering students, a short presentation is given in which the incoming students are made aware of the registration process and the support that the MAE Department offers through courses such as ME1000.

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Tracking the completion of the PE Exam and the pass rate is one of the measures used to assess the students' ability to "Identify, Formulate, and Solve Technical & Engineering Problems" as defined in Student Outcome 4. It is of concern that more students are not willing to engage in the preparations and licensure program initiated with the FE and PE Examinations. About 10 percent of the ME students take the PE Exam in Mechanical Engineering and they have above an 80% pass rate compared to less than 50% pass rate in the State of California.

Appendix N - MAE ABET YEARLY REPORT - 2018

A. Continuous Improvement

Annually, the MAE Department ABET Committee Report records program improvements, corrective actions, or other items of interest that have been identified by the Committee through the aforementioned assessments and subsequent evaluations as well as through faculty and sponsor direct input. In 2014 the MAE Department was divided into six Technical Committees (TC) in Structures/Solids, Fluids/Thermo, Controls/UAV's, Materials, Astronautical Engineering and Weaponeering/Survivability/Total Ship Systems Engineering (TSSE).

During AY2018 all six TC's met to map the old ABET outcomes a thru k to the new 1 thru 7 . Since Criterion III supports that attainment of student outcomes as defined in the general criteria for **baccalaureate programs**, it was deemed necessary to only evaluate the 2000 and 3000 level courses within the department as those make up the undergraduate BSME requirements. The table below is the summary of all courses as evaluated by the six TC's

MECHANICAL ENGINEERING

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Outcome 6	Outcome 7
AE2440	S	W	N	W	M	S	M
ME1000	S	M	W	M	N	N	S
ME2101	S	M	M	W	M	S	S
ME2201	M	W	W	W	W	M	M
ME2501	S	W	M	W	W	S	S
ME2502	S	W	M	W	M	S	S
ME2601	S	M	W	M	N	N	S
ME2801	S	W	N	W	M	S	M
ME3150	S	M	M	M	M	S	S
ME3201	S	S	M	M	M	S	M
ME3205	S	M	M	M	S	M	M
ME3240	S	M	M	S	M	S	M
ME3450	S	W	M	W	W	M	M
ME3521	S	W	W	M	S	S	M
ME3611	S	W	M	W	M	N	S
ME3711	S	W	M	M	W	M	M
ME3712	S	M	S	M	S	M	S
ME3801	S	W	W	M	S	S	M
MS2201	S	M	S	M	S	S	S
MS3202	S	S	S	S	S	S	S
MS3304	S	S	M	M	S	M	S
MS3606	M	S	W	W	M	M	S
TS3000	W	W	W	W	M	N/A	M
TS3001	S	S	M	M	M	S	S
TS3002	S	S	M	M	M	W	S
TS3003	S	S	M	W	M	M	M

ASTRONAUTICAL ENGINEERING

	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Outcome 5	Outcome 6	Outcome 7
AE2440	S	W	N	W	M	S	M
AE2820	S	S	W	M	N	M	S
AE3804	S	M	S	M	S	S	S
AE3811	M	M	S	S	S	S	S
AE3815	S	N	M	N	M	S	M
AE3818	S	N	S	N	M	S	M
AE3830	M	W	M	W	W	W	S
AE3851	M	W	W	M	N	S	M

Appendix O – 591 Curriculum Review 2018

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
2000 NAVY PENTAGON
WASHINGTON DC 20350-2000

1500
Ser N12/ 008
31 Jan 19

From: Director, Total Force Manpower, Training, and Education Requirements Division (N12)
To: Commander, Space and Naval Warfare Systems Command

Subj: REPORT OF CURRICULUM REVIEW OF RESIDENT CURRICULUM SPACE SYSTEMS ENGINEERING (591) AND SYSTEMS ENGINEERING PHD (597)

Ref: (a) SECNAVINST 1524.2C
(b) OPNAVINST 1520.23C w/CH-1

Encl: (1) SPAWAR ltr 1524 Ser 5.0/743 of 7 Nov 18

1. Per references (a) and (b), enclosure (1) is approved.

DAVID R. MENZEN

Copy to:
NPS Monterey CA

DEPARTMENT OF THE NAVY
NAVAL POSTGRADUATE SCHOOL
1 UNIVERSITY CIR
MONTEREY, CA 93943-5000

IN REPLY REFER TO:
1524
Ser 00/876
DEC 14 2018

SECOND ENDORSEMENT on Commander, Space and Naval Warfare Systems Command ltr 1524 Ser 5.0/743 of 7 Nov 2018

From: President, Naval Postgraduate School
To: Director, Total Force Manpower, Training and Education Requirements Division (OPNAV N12)

Subj: REPORT OF CURRICULUM REVIEW OF RESIDENT CURRICULUM SPACE SYSTEMS ENGINEERING (591) AND SPACE SYSTEMS ENGINEERING PHD (597)

1. Forwarded, recommending approval.

RONALD A. ROUTE
Vice Admiral, U.S. Navy (Ret.)

Copy to:
SPAWAR
NAVSEA 00T1
OPNAV N131E
OPNAV N153
OPNAV N2N6C
PEO SPACE SYSTEMS

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
1333 ISAAC HULL AVE SE
WASHINGTON NAVY YARD DC 20376-0001

IN REPLY REFER TO
9703
SEA 00T1/055
26 Nov 18

FIRST ENDORSEMENT OF COMMANDER, SPACE AND NAVAL WARFARE SYSTEMS COMMAND REPORT OF CURRICULUM REVIEW OF RESIDENT CURRICULUM SPACE SYSTEMS ENGINEERING (591) AND SPACE SYSTEMS ENGINEEREING PhD (597)

From: Commander, Naval Sea Systems Command (SEA 00T1)
To: Director, Total Force Manpower, Training and Education Requirements (N12)
Via: President, Naval Postgraduate School

Subj: REPORT OF CURRICULUM REVIEW OF RESIDENT CURRICULUM SPACE SYSTEMS ENGINEERING (591) AND SPACE SYSTEMS ENGINEEREING PhD (597)

1. Forwarded, recommending approval. NAVSEA concurs with the results of the review conducted by Commander, Space and Naval Warfare Systems Command.

R. A. KLOCEK
By direction

Copy to:
OPNAV N1
OPNAV N127
NAVSEA 00T1

DEPARTMENT OF THE NAVY
SPACE AND NAVAL WARFARE SYSTEMS COMMAND
4301 PACIFIC HIGHWAY
SAN DIEGO, CA 92110-3127

1524
Ser 5.0/ 743
7 Nov 18

From: Commander, Space and Naval Warfare Systems Command
To: Chief of Naval Operations (Director, Total Force Manpower, Training and Education Requirements Division, OPNAV N12)
Via: (1) Commander, Naval Sea Systems Command
(2) President, Naval Postgraduate School

Subj: REPORT OF CURRICULUM REVIEW FOR RESIDENT CURRICULUM SPACE SYSTEMS ENGINEERING (591) AND SPACE SYSTEMS ENGINEERING PhD (597)

Ref: (a) SECNAVINST 1524.2C
(b) OPNAVINST 1520.23C
(c) NAVMILPERSINST 15839 Volume 1 Part B
(d) NAVPGSCOLINST 1550.1G

Encl: (1) Curriculum Review Participants
(2) Current Core Skill Requirements for Curriculum 591
(3) 2018-2020 Core Skill Requirements for Curriculum 591
(4) Current Educational Skill Requirements for Curriculum 591
(5) 2018-2020 Educational Skill Requirements for Curriculum 591
(6) 2018-2020 Curriculum Matrix for Curriculum 591
(7) Educational Skill Requirements to Course Crosswalk
(8) Cost Analysis
(9) Subspecialty Fit-Fill and Utilization Data
(10) Action Items

1. Per references (a) through (d), a detailed review of Space Systems Engineering curriculum (591) was conducted from 31 May - 1 June 2018 and enclosures (1) through (10) are offered. Senior participants conducting the review were RDML Ronald Fritzemeier, Space and Naval Warfare Systems Command (SPAWAR) Chief Engineer and CAPT James Mills, Chief of Staff, Fleet Cyber Command/10th Fleet (FLTCYBERCOM/C10F).

2. The following issues were discussed during the review:

a. Core Skill Requirements (CSR) updates.

b. Educational Skill Requirements (ESR) updates.

3. This review validates the Space Systems Engineering curriculum and updates associated CSRs and ESRs addressing space as a warfighting domain. These updates address space-based systems resiliency, survivability, and serviceability across multi-domain operations along the continuous spectrum from competition, to confrontation, all the way to conflict. Space-based

systems are to be addressed with an end-to-end, system-of-systems context considering mission assurance concerns to include resiliency and cybersecurity. Spacecraft design concepts are to include improved survivability of on-orbit assets, cyber capabilities, platform resiliency, and enabling service life extensions.

4. The Space Systems Engineering PhD Curriculum (597) presumes foundational skills from the 591 curriculum have been met. The 597 curriculum is tailored by the PhD board based on the chosen dissertation. This allows the faculty and PhD board the flexibility to meet the needs of each PhD candidate.

C. D. BECKER

Copy to:
CNO (OPNAV N131E, N153, N2N6C)
PEO Space Systems
SPAWAR SPAFLDACT CHANTILLY VA

Curriculum Review Participants

Major Area Sponsor Representatives

- RDML Ronald Fritzemeier, Chief Engineer, SPAWAR
- CAPT Joseph Kan, Systems of Systems/Space Military Advisor, SPAWAR

Curriculum Review Stakeholders and Subject Matter Experts

- VADM Michael Gilday, Commander, Fleet Cyber Command/10th Fleet
- Dr. Clifton Phillips, Assistant Program Executive Officer for Engineering, PEO Space Systems
- Mr. William Lovejoy, Deputy Director of Education and Training, Fleet Cyber Command/10th Fleet
- CAPT James Mills, Chief of Staff, Fleet Cyber Command/10th Fleet
- CAPT Rick Larson, Naval Information Forces Chief Information Officer & Navy Space Cadre Advisor
- CAPT Henry Vegter, Head, Navy Space Branch OPNAV (N2/N6FX3)
- Mr. Curtis Bogetto, Navy Space Branch OPNAV (N2/N6C)
- CAPT Andy Berner, Commanding Officer, SPAWAR Space Field Activity
- CAPT Vince Chernesky, SPAWAR Space Field Activity, Survivability Assurance Office
- CDR Michael A. Porter, SPAWAR Space Field Activity, Geospace Intelligence/Research and Sponsored Programs Office
- CDR Richard Borden, FCC N39, Fleet Cyber Command/10th Fleet
- CDR Christina Hicks, Commanding Officer, Naval Computer and Telecommunications Station Guam
- CDR Adam DeJesus, Eastern Air Defense Sector
- CDR Sarah Michael, SPAWAR, Mobile User Objective System Contracting Officer's Representative/Principal Assistant Program Manager
- Mr. Mike Connolly, Director, Army Space Personnel Development Office
- Mr. Jerry Pepin, Deputy Director, Army Space Personnel Development Office
- LTC Gary Thomason, USA, Army Space Personnel Development Office
- Mr. Daryl Breitbach, Director, U.S. Army Space and Missile Defense Command School and Doctrine Center
- Maj Erika Teichert, USMC, Marine Air Ground Task Force Space Plans

Naval Postgraduate School

- VADM Ronald Route, USN (Ret.), Naval Postgraduate School President
- Dr. Steve Lerman, NPS Provost
- Dr. Doug Moses, NPS Vice Provost for Academic Affairs
- Dr. Clyde Scandrett, Dean, Graduate School of Engineering and Applied Sciences
- Col Tim Sands, USAF, Military Associate Dean, Graduate School of Engineering and Applied Sciences
- Dr. James Newman, Chair, Space Systems Academic Group
- Dr. Garth Hobson, Chair, Department of Mechanical and Aerospace Engineering
- Dr. Rudy Panholzer, Professor Emeritus, Space Systems Academic Group
- CDR Yolanda Kern, USN, Director of Programs, Naval Postgraduate School
- CDR William Crane, USN, Space Systems Program Officer
- Mr. Steve Tackett, Academic Associate, 366 & 273 Curricula
- Distinguished Professor Mike Ross, Academic Associate, 591 Curriculum
- Mr. Charlie Racoosin, Lecturer, Space Systems Academic Group

Enclosure (1)

Current Core Skill Requirement for Curriculum 591

2016-2018 CORE SKILL REQUIREMENTS
Space Systems Engineering
Subspecialty 5500
Curriculum 591

Billet subspecialty coding is to be based on the minimum education/training/experience level required for optimum performance. 5500 subspecialty coding is justified when, in addition to the general criteria stated in NAVPERS 15839 series (Manual of Navy Officer Manpower and Personnel Classification) Part B, the following specific criteria are satisfied:

1. Description of CSR Competencies. The listed CSRs are a set of quantifiable skills, traits and experiences that a subspecialist must possess to perform acceptably in a coded billet for the 5500.

a. CSR 1: Space Acquisition and Development. Formulate operational and derived technical requirements, system-level architectures, operational concepts, conceptual spacecraft designs and integration and test plans for the development and employment of national security space systems, ground support segments and the distribution, correlation and analysis of their information products.

b. CSR 2: Spacecraft Design. Demonstrate technical knowledge of orbital mechanics and the space environment, design of selected space force enhancement payloads and spacecraft and ground support segment subsystems including: communications, command and data handling, attitude determination, guidance, navigation and control, structures, propulsion, thermal control and electrical power.

c. CSR 3: Space Systems Engineering. Demonstrate leadership of system of systems engineering efforts and direct design, development, acquisition, integration and testing of spacecraft and associated ground support systems throughout their life-cycles including launch and on-orbit operations.

d. CSR 4: Space Liaison. Develop in collaboration with other services, agencies, and industry the policy and procedures necessary for requirements development and analysis of the: design, acquisition and operational employment of space systems, ground support segments and their information products.

Enclosure (2)

e. CSR 5: Decision Superiority. Perform technical evaluation of space systems design and performance and provide recommendations to senior decision-makers regarding space systems engineering, performance and mission assurance issues.

2. Applicable Officer Designator(s):

a. 1000 - 1000 / 1001 - 1019 / 1021 - 1049 / 1050 - 1050 / 1051 - 1099 / 1100 - 1109 / 1110 - 1119 / 1120 - 1129 / 1130 - 1139 / 1140 - 1159 / 1160 - 1169 / 1170 - 1179 / 1180 - 1189 / 1190 - 1199 / 1200 - 1209 / 1200 - 1299 / 1300 - 1399 / 1400 - 1499 / 1510 - 1519 / 1600 - 1609 / 1610 - 1629 / 1630 - 1649 / 1800 - 1899

3. Applicable Billet Designator:

a. 1000 - 1000 / 1001 - 1019 / 1021 - 1049 / 1050 - 1050 / 1051 - 1099 / 1100 - 1109 / 1110 - 1119 / 1120 - 1129 / 1130 - 1139 / 1140 - 1159 / 1160 - 1169 / 1170 - 1179 / 1180 - 1189 / 1190 - 1199 / 1200 - 1209 / 1200 - 1299 / 1300 - 1399 / 1400 - 1499 / 1510 - 1519 / 1600 - 1609 / 1610 - 1629 / 1630 - 1649 / 1800 - 1899

4. Educational and Significant Experience Criteria. Coded billets are authorized when the functions of the billet include the CSR competencies listed above (in paragraph 1). For additional clarification regarding definition of suffixes, refer to the NAVPERS 15839I, Vol 1.

Note: 'Proven' requires at least 18-month experience tour in subspecialty coded billet or billet using the CSR of a related subspecialty.

a. Subspecialty Code Suffixes Authorized.

Current Core Skill Requirement for Curriculum 591

Subspecialty Code Suffixes Authorized				
Billet	Officer	Suffix	Definition	Notes
		C	Proven Doctor of Philosophy	
X	X	D	Doctor of Philosophy	
		F	Proven Master's Degree that does not meet all ESRs	
		G	Master's Degree that does not meet all ESRs	
		H	Master's Degree desired, not required	
		L	Certificate degree at the Master's level	
		M	Proven Post Master's Degree graduate education	
		N	Post Master's Degree graduate education	
X	X	P	Master's Degree in approved Navy subspecialty	
X	X	Q	Proven Master's Degree	
	X	R	Proven Significant Experience	
		S	Significant Experience obtained through OJT	

12. Sponsor and Subject Matter Experts:

Sponsor: VADM William H. Hilarides, Naval Sea Systems Command

Subject Matter Expert: RDML Christian Becker, PEO Space Systems

Action Officer SME: CDR Jason Pratt, PMW 146 (jason.w.pratt@navy.mil)

APPROVED: for 10/3/16
Major Area Sponsor [DATE]

APPROVED: 12/12/16
Director, TFMPE (CPNAV N12) [DATE]

Enclosure (2)

2018-2020 Current Core Skill Requirement for Curriculum 591

2018-2020 CORE SKILL REQUIREMENTS
Space Systems Engineering
Subspecialty 5500
Curriculum 591

1. Billet subspecialty coding is to be based on the minimum education/training/experience level required for optimum performance. 5500 subspecialty coding is justified when, in addition to the general criteria stated in NAVPERS 15839 series (Manual of Navy Officer Manpower and Personnel Classification) Part B, the following specific criteria are satisfied:

2. Description of CSR Competencies. The listed CSRs are a set of quantifiable skills, traits and experiences that a subspecialist must possess to perform acceptably in a coded billet for the 5500.

a. CSR 1: Space Acquisition and Development. Formulate the following for the development and employment of national security space systems within the construct of end-to-end, system-of-systems integration of products and services supporting operational missions: operational and derived technical requirements, system-level architectures, operational concepts, conceptual spacecraft designs, system integration and test plans, and incremental capabilities of cyber and platform resiliency.

b. CSR 2: Spacecraft Design. To support operational missions: demonstrate technical knowledge in orbital mechanics and the design of spacecraft and their payloads to include the harsh space environment, resiliency, and serviceability. This knowledge will encompass spacecraft subsystems and their ground support segment subsystems to include: communications, command and data handling, attitude determination, guidance, navigation and control, structures, propulsion, thermal control and electrical power.

c. CSR 3: Space Systems Engineering. Demonstrate leadership of end-to-end, system-of-systems, engineering efforts to direct design, development, acquisition, integration and testing of spacecraft and associated ground support systems throughout their life-cycles including launch and on-orbit operations.

d. CSR 4: Space Liaison. Develop in collaboration with other services, agencies, and industry the policy and procedures necessary for requirements development and analysis of the: design, acquisition and operational employment of space systems, ground support segments, and end-to-end, system-of-systems integration of products and services to support operational missions.

e. CSR 5: Decision Analysis. Perform technical evaluation of space systems design and performance with the purpose of providing recommendations to senior decision-makers regarding space systems engineering, performance and mission assurance. These evaluations and recommendations shall include system of systems and end-to-end considerations to ensure cost and schedule efficiencies while maximizing performance.

2018-2020 Current Core Skill Requirement for Curriculum 591

2. Applicable Officer Designator(s):

a. 1000 - 1000 / 1001 - 1019 / 1021 - 1049 / 1050 - 1050 / 1051 - 1099 / 1100 - 1109 / 1110 - 1119 / 1120 - 1129 / 1130 - 1139 / 1140 - 1159 / 1160 - 1169 / 1170 - 1179 / 1180 - 1189 / 1190 - 1199 / 1200 - 1209 / 1200 - 1299 / 1300 - 1399 / 1400 - 1499 / 1510 - 1519 / 1600 - 1609 / 1610 - 1629 / 1630 - 1649 / 1800 – 1899

3. Applicable Billet Designator:

a. 1000 - 1000 / 1001 - 1019 / 1021 - 1049 / 1050 - 1050 / 1051 - 1099 / 1100 - 1109 / 1110 - 1119 / 1120 - 1129 / 1130 - 1139 / 1140 - 1159 / 1160 - 1169 / 1170 - 1179 / 1180 - 1189 / 1190 - 1199 / 1200 - 1209 / 1200 - 1299 / 1300 - 1399 / 1400 - 1499 / 1510 - 1519 / 1600 - 1609 / 1610 - 1629 / 1630 - 1649 / 1800 – 1899

4. Educational and Significant Experience Criteria. Coded billets are authorized when the functions of the billet include the CSR competencies listed above (in paragraph 1). For additional clarification regarding definition of suffixes, refer to the NAVPERS 15839I, Vol 1.

Note: 'Proven' requires at least 18-month experience tour in subspecialty coded billet or billet using the CSR of a related subspecialty.

a. Subspecialty Code Suffixes Authorized.

Subspecialty Code Suffixes Authorized				
Billet	**Officer**	**Suffix**	**Definition**	**Notes**
		C	Proven Doctor of Philosophy	
X	X	D	Doctor of Philosophy	
		F	Proven Master's Degree that does not meet all ESRs	
		G	Master's Degree that does not meet all ESRs	
		H	Master's Degree desired, not required	
		L	Certificate degree at the Master's level	
		M	Proven Post Master's Degree graduate education	
		N	Post Master's Degree graduate education	
X	X	P	Master's Degree in approved Navy subspecialty	
X	X	Q	Proven Master's Degree	
	X	R	Proven Significant Experience	
		S	Significant Experience obtained through OJT	

5. Major Area Sponsor and Subject Matter Experts:

2018-2020 Current Core Skill Requirement for Curriculum 591

a. Major Area Sponsor: RADM Christian Becker, Commander, Space and Naval Warfare Systems Command.

b. Subject Matter Expert: RDML Ronald Fritzemeier, Chief Engineer, SPAWAR.

c. Action Officer SME: CAPT Joseph Kan, SoS/Space Military Advisor, SPAWAR.

APPROVED: C. D. Becker — Major Area Sponsor — 29OCT18 [DATE]

APPROVED: Director, OPNAV N12 — 31 JAN 2019 [DATE]

Current Educational Core Skill Requirement for Curriculum 591

2016-2018 EDUCATIONAL SKILL REQUIREMENTS
Space Systems Engineering
Subspecialty 5500
Curriculum 591

1. Curriculum Number: 591

2. Curriculum taught at Naval Postgraduate School

3. Curriculum Length in Months: 27

4. APC Required: 323

5. The officer must understand the fundamental concepts and be familiar with the basic functional areas of Space Systems Engineering within the Department of the Navy (DON) and the Department of Defense (DOD) including the following numbered ESRs:

ESR-1. ORBITAL MECHANICS AND SPACE ENVIRONMENT:
a. Graduates will examine the basic physics of orbital motion, and calculate and distinguish the parameters used in the description of orbits and their ground tracks.
b. Graduates will examine the design of orbits and constellations, and analyze how they are achieved, maintained, and controlled; to include spacecraft maneuver and orbit transfer calculations.
c. Graduates will examine the fundamentals of spacecraft tracking and command/control from a ground station.
d. Graduates will examine the various orbital perturbations, including those due to non-spherical earth and due to atmospheric drag, and interpret their effects.
e. Graduates will analyze the relationship between various orbital characteristics and the satisfaction of mission requirements, including the advantages and disadvantages of various orbits.
f. Graduates will design and optimize mission orbits through the analysis of common performance measures such as access, coverage, and revisit; and will employ appropriate tools to conduct these analyses.
g. Graduates will examine the physical behavior of the upper atmosphere, ionosphere and space environment under the influence of both natural and artificial phenomena such as solar activity, geomagnetic and magnetospheric effects, and man-made disturbances.
h. Graduates will apply this understanding of how the space environment impacts spacecraft parts, materials, and operations to spacecraft and mission design.

d. Graduates will examine the unique nature of space acquisition programs and plan a notional space system acquisition program.

ESR-4. COMMUNICATIONS:
a. Graduates will examine the basic principles of communications systems engineering to include both the space and ground segments.
b. Graduates will examine digital and analog communications architecture design, including such topics as frequency reuse, multiple access, link design, repeater architecture, source encoding, waveforms/modulations, and propagation media.
c. Graduates will calculate and analyze link budgets to assess communication system suitability to support mission requirements, and to translate mission requirements into communications system design characteristics.
d. Graduates will differentiate, compare, and contrast the characteristics and capabilities of current and future communications systems in use or planned by Naval operating and Joint forces afloat and ashore.
e. Graduates will examine how current and planned space communications systems are used to meet Joint communications requirements.
f. Graduates will differentiate signal processing techniques, both digital and analog, as applied to missions such as spacecraft communications, surveillance, and signals intelligence.
g. Graduates will examine spacecraft vulnerabilities in an electronic warfare context.

ESR-5. COMPUTERS: HARDWARE AND SOFTWARE
a. Graduates will understand the fundamentals of digital logic and digital system design of simple digital computer subsystems.
b. Graduates will examine the design of current and planned computer hardware and software architectures for space-based applications.
c. Graduates will examine the use of computers in complex systems such as guidance, signal processing, communications, and control systems.
d. Graduates will examine the fundamentals of electronic component design, fabrication, reliability, and testing (to include radiation hardening), with an emphasis on parts, materials, and processes.
e. Graduates will examine modern Information Technology capabilities and their applications for space systems

d. Graduates will examine the unique nature of space acquisition programs and plan a notional space system acquisition program.

ESR-4. COMMUNICATIONS:
a. Graduates will examine the basic principles of communications systems engineering to include both the space and ground segments.
b. Graduates will examine digital and analog communications architecture design, including such topics as frequency reuse, multiple access, link design, repeater architecture, source encoding, waveforms/modulations, and propagation media.
c. Graduates will calculate and analyze link budgets to assess communication system suitability to support mission requirements, and to translate mission requirements into communications system design characteristics.
d. Graduates will differentiate, compare, and contrast the characteristics and capabilities of current and future communications systems in use or planned by Naval operating and Joint forces afloat and ashore.
e. Graduates will examine how current and planned space communications systems are used to meet Joint communications requirements.
f. Graduates will differentiate signal processing techniques, both digital and analog, as applied to missions such as spacecraft communications, surveillance, and signals intelligence.
g. Graduates will examine spacecraft vulnerabilities in an electronic warfare context.

ESR-5. COMPUTERS: HARDWARE AND SOFTWARE
a. Graduates will understand the fundamentals of digital logic and digital system design of simple digital computer subsystems.
b. Graduates will examine the design of current and planned computer hardware and software architectures for space-based applications.
c. Graduates will examine the use of computers in complex systems such as guidance, signal processing, communications, and control systems.
d. Graduates will examine the fundamentals of electronic component design, fabrication, reliability, and testing (to include radiation hardening), with an emphasis on parts, materials, and processes.
e. Graduates will examine modern Information Technology capabilities and their applications for space systems

ground processing, data storage, information sharing, and network design.

ESR-6. SPACECRAFT GUIDANCE AND CONTROL
a. Graduates will analyze the field of spacecraft guidance and control, to include topics such as linear control, rotational kinematics, rigid body dynamics, gravity gradient, spin and three-axis stabilization design, active nutation control, sources of and response to disturbance torques, and attitude determination and associated sensors and actuators.
b. Graduates will apply these techniques to the analysis and design of spacecraft guidance and control systems.

ESR-7. SPACECRAFT STRUCTURES, MATERIALS AND DYNAMICS
a. Graduates will examine the engineering of space structures and perform simplified sizing calculations and analytical modeling of advanced materials.
b. Graduates will analyze the advanced dynamics and control of these structures.

ESR-8. PROPULSION SYSTEMS
a. Graduates will examine the operating principles (fluid mechanics, thermodynamics, electricity and magnetism) and propulsion devices used in current and proposed space applications.
b. Graduates will analyze and choose appropriate propulsion systems for spacecraft applications to include launch, orbit transfers, and spacecraft maneuvering.

ESR-9. SPACECRAFT THERMAL CONTROL
a. Graduates will examine the principles of heat transfer and how surfaces and materials are manipulated in spacecraft thermal control.
b. Graduates will examine the design, analysis, and applications of current active and passive thermal control devices (including heat pipes, louvers, and materials).
c. Graduates will examine the sources of heat in space (solar, terrestrial, reflected solar, internal vehicle generation) and their variation as a function of vehicle orbit, and apply this knowledge to thermal subsystem analysis and design.

ESR-10. SPACECRAFT POWER
a. Graduates will examine the principles and operating characteristics of major power generating systems for spacecraft, including the performance of photovoltaic

sources in the natural and artificial radiation environment.
b. Graduates will examine the principles and operating characteristics of energy storage devices in power systems design.

ESR-11. REMOTE SENSING AND PAYLOAD DESIGN
a. Graduates will examine principles of active and passive sensors in current or planned use, to include analysis of electromagnetic wave propagation and design of optics, detectors, and antennae.
b. Graduates will examine the effects of the space, atmospheric, and terrestrial environments (including countermeasures) on sensor performance.
c. Graduates will assess and conduct tradeoffs among various sensors and platforms, evaluating how each satisfies mission requirements such as access area, resolution, timeliness, and capacity.
d. Graduates will examine the design of current and planned space-based mission payloads (e.g., ISR, Communications, PNT, SIGINT).
e. Graduates will analyze mission capabilities and conduct associated trades in order to develop associated payload design requirements.

ESR-12. SPACECRAFT DESIGN, INTEGRATION, AND SYSTEMS ENGINEERING
a. Graduates will develop and assess an overall space system architecture to meet defined mission requirements through the use of systems engineering tools and processes.
b. Graduates will derive system and subsystem performance criteria from stated mission capabilities and conduct trade-offs between payload and other spacecraft subsystems in addressing these capabilities.
c. Graduates will examine a broad spectrum of mission assurance concerns such as reliability, risk management, configuration management, qualification and acceptance testing, and parts materials and processes.
d. Graduates will examine various engineering and mathematical definitions of cost functions (revisit time, dwell time, local coverage, etc.) and apply emerging methods and tools to optimizing these utility measures in support of mission objectives.
e. Graduates will examine the basic principles and operational issues of space access to include launch vehicle performance, launch windows, and their impact on military operations.

f. Graduates will examine the capabilities of the various current and planned launch systems, and characterize the issues associated with integrating a spacecraft with a launch vehicle, to include the effects of launch environment.
g. Graduates will perform a trade-off analysis in the selection of a launch vehicle based on mission requirements, performance and design constraints, and business issues involved (e.g., pricing, insurance, policy).
h. Graduates will demonstrate proficiency in design, analysis, and modeling / simulation tools such as IDEAS, MATLAB / Simulink, and Satellite Tool Kit (STK).
i. Graduates will examine the processes and methods of systems engineering including requirements analysis, functional analysis and allocation, system design, and verification.

ESR-13. GROUND SYSTEMS AND SYSTEMS ENGINEERING
a. Graduates will understand the fundamentals of a space ground system architecture including the system-of-systems that comprise a space network across all mission areas.
b. Graduates will examine Department of Defense Architecture Framework (DoDAF) views of real or notional space network architectures in order to understand necessary internal and external interfaces and domain interactions.
d. Graduates will analyze enterprise and mission-specific frameworks from standard communications infrastructures (C&C, messaging, data, etc.), services, and tools to mission specific T&C, information products and data.
e. Graduates will analyze network and non-network communications within an Information Technology Enterprise Domain context.
f. Graduates will understand application program interface (API) challenges in relation to security requirements, risks and mitigation.
g. Graduates will understand Risk Management Framework integration for cyber security system engineering efforts including information assurance and relevant documentation such as NIST SP800-30, DOD8500.1 and 8500.2.
h. Graduates will analyze command and telemetry requirements and capabilities to support mission execution, vehicle operations and anomaly resolution.
i. Graduates will analyze services for access, sharing, processing and external dissemination of information including data management and storage challenges such as

Current Educational Core Skill Requirement for Curriculum 591

"Big Data", open-source implementation and cloud technology applications for Ground Systems.

ESR-14. CONDUCT AND REPORT INDEPENDENT RESEARCH
a. Graduates will conduct independent research on a space systems problem, including resolution of the problem and presentation of the results and analysis in both written and oral form.

APPROVED:	Major Area Sponsor	10/3/16 [DATE]
APPROVED:	President, NPS	OCT 28 2016 [DATE]
APPROVED:	Director, TFMTB (OPNAV N12)	12/12/16 [DATE]

2018-2020 EDUCATIONAL SKILL REQUIREMENTS
Space Systems Engineering
Subspecialty 5500
Curriculum 591

1. Curriculum Number: 591.

2. Curriculum taught at Naval Postgraduate School.

3. Curriculum Length in Months: 27.

4. APC Required: 323.

5. The officer must understand the fundamental concepts and be familiar with the basic functional areas of Space Systems Engineering within the Department of the Navy (DON) and the Department of Defense (DoD) including the following numbered ESRs:

6. ESR-1. ORBITAL MECHANICS AND SPACE ENVIRONMENT:

a. Graduates will examine the basic physics of orbital motion, and calculate and distinguish the parameters used in the description of orbits and their ground tracks.

b. Graduates will examine the design of orbits and constellations, and analyze how they are achieved, maintained, and controlled; to include spacecraft maneuver and orbit transfer calculations.

c. Graduates will examine the fundamentals of spacecraft tracking and command/control from a ground station.

d. Graduates will examine the various orbital perturbations, including those due to non-spherical earth and due to atmospheric drag, and interpret their effects.

e. Graduates will analyze the relationship between various orbital characteristics and the satisfaction of mission requirements, including the advantages and disadvantages of various orbits.

f. Graduates will design and optimize mission orbits through the analysis of common performance measures such as access, coverage, and revisit; and will employ appropriate tools to conduct these analyses.

g. Graduates will examine the physical behavior of the upper atmosphere, ionosphere and space environment under the influence of both natural and artificial phenomena such as solar activity, geomagnetic and magnetospheric effects, and man-made disturbances.

h. Graduates will apply this understanding of how the space environment impacts spacecraft parts, materials, and operations to spacecraft and mission design.

7. ESR-2. NATIONAL SECURITY SPACE SYSTEMS:

a. Graduates will examine the nature of space warfare (theory, history, doctrine, and policy) to distinguish how space operations as discussed in JP 3-14 enable joint force capabilities, and interpret how current and planned space capabilities contribute to the satisfaction of mission objectives.

b. Graduates will examine the roles, responsibilities, and relationships of National and DoD organizations in establishing policies, priorities, and requirements for National Security Space systems; and in the design, acquisition, operation, and exploitation of these systems.
c. Graduates will examine the role of the Services / Agencies in establishing required space system capabilities, and will translate these capabilities into end-to-end, system-of-systems performance requirements.

d. Graduates will examine: current and planned Intelligence, Surveillance, and Reconnaissance (ISR) capabilities; how space systems contribute to these capabilities; the intelligence collection and analysis process; and how war-fighters access information from these sources.

e. Graduates will develop concepts of employment and assess space tactics and CONOPS. The development and assessment shall consider end-to-end capabilities and system-of-systems architectures that enhance, support, and integrate into military operations to include resiliency concepts in a contested environment.

f. Graduates will identify how proposed space-related capabilities / doctrine transition from concept to real-world implementation through experimentation.

g. Graduates will examine the capabilities of unclassified DoD and commercial space systems, and how those systems relate to National Space Systems to include potential overlaps and leverage opportunities.

8. ESR-3. PROJECT MANAGEMENT AND SYSTEM ACQUISITION:

a. Graduates will examine project management and DoD system acquisition methods and procedures to include contract management, financial management and control, and the Planning, Programming, Budgeting and Execution (PPBE).

b. Graduates will recognize the role of the Defense Acquisition University and the acquisition courses and qualifications available.

c. Graduates will examine system acquisition organizational responsibilities and relationships (e.g., Congress, DoD, Services, Resource Sponsor, Systems Commands, Operating Forces) as they pertain to the acquisition of systems for DoD, Naval, and civilian agency users.

d. Graduates will examine the unique nature of space acquisition programs and plan a notional space system acquisition program.

9. ESR-4. COMMUNICATIONS:

a. Graduates will examine the basic principles of communications systems engineering to include both the space and ground segments.

b. Graduates will examine digital and analog communications architecture design, including such topics as frequency reuse, multiple access, link design, repeater architecture, source encoding, waveforms/modulations, and propagation media.

c. Graduates will calculate and analyze link budgets to assess communication system suitability to support mission requirements, and to translate mission requirements into communications system design characteristics.

d. Graduates will differentiate, compare, and contrast the characteristics and capabilities of current and future communications systems in use or planned by Naval operating and Joint forces afloat and ashore.

e. Graduates will examine how current and planned space communications systems should be used to meet Joint communications requirements across the spectrum of operations.

f. Graduates will differentiate signal processing techniques, both digital and analog, as applied to missions such as spacecraft communications, surveillance, and signals intelligence.

g. Graduates will examine spacecraft vulnerabilities in an electronic warfare context.

10. ESR-5. COMPUTERS: HARDWARE AND SOFTWARE

a. Graduates will understand the fundamentals of digital logic and digital system design of simple digital computer subsystems.

b. Graduates will examine the design of current and planned computer hardware and software architectures for space-based applications to include their potential to support service life extensions and enable incremental capabilities of cyber and platform resiliency.

c. Graduates will examine the use of computers in complex systems such as guidance, signal processing, communications, and control systems.

d. Graduates will examine the fundamentals of electronic component design, fabrication, reliability, and testing (to include radiation hardening), with an emphasis on parts, materials, and processes.

e. Graduates will examine modern Information Technology capabilities and their applications for space systems ground processing, data storage, information sharing, and network design.

11. ESR-6. SPACECRAFT GUIDANCE AND CONTROL

a. Graduates will analyze the field of spacecraft guidance and control, to include topics such as linear control, rotational kinematics, rigid body dynamics, gravity gradient, spin and three-axis

stabilization design, active nutation control, sources of and response to disturbance torques, and attitude determination and associated sensors and actuators.

b. Graduates will apply these techniques to the analysis and design of resilient spacecraft guidance and control systems.

12. ESR-7. SPACECRAFT STRUCTURES, MATERIALS AND DYNAMICS

a. Graduates will examine the engineering of space structures and perform simplified sizing calculations and analytical modeling of advanced materials.

b. Graduates will analyze the advanced dynamics and control of these structures.

c. Graduates will analyze the viability of structures and materials for survivability in the space environment.

13. ESR-8. PROPULSION SYSTEMS

a. Graduates will examine the operating principles (fluid mechanics, thermodynamics, electricity and magnetism) and propulsion devices used in current and proposed space applications.

b. Graduates will analyze and choose appropriate propulsion systems for spacecraft applications to include launch, orbit transfers, and spacecraft maneuvering with the potential for on-orbit serviceability.

14. ESR-9. SPACECRAFT THERMAL CONTROL

a. Graduates will examine the principles of heat transfer and how surfaces and materials are manipulated in spacecraft thermal control.

b. Graduates will examine the design, analysis, and applications of current active and passive thermal control devices (including heat pipes, louvers, and materials).

c. Graduates will examine the sources of heat in space (solar, terrestrial, reflected solar, internal vehicle generation) and their variation as a function of vehicle orbit, and apply this knowledge to thermal subsystem analysis and design.

15. ESR-10. SPACECRAFT POWER

a. Graduates will examine the principles and operating characteristics of major power generating systems for spacecraft, including the performance of photovoltaic sources in the natural and artificial radiation environment.

b. Graduates will examine the principles and operating characteristics of energy storage devices in power systems design to include the potential to support associated service life extensions.

16. ESR-11. REMOTE SENSING AND PAYLOAD DESIGN

a. Graduates will examine principles of active and passive sensors in current or planned use, to include analysis of electromagnetic wave propagation and design of optics, detectors, and antennae.

b. Graduates will examine the effects of the space, atmospheric, and terrestrial environments (including countermeasures) on sensor performance.

c. Graduates will assess and conduct tradeoffs among various sensors and platforms, evaluating how each satisfies mission requirements such as access area, resolution, timeliness, and capacity.

d. Graduates will examine the design of current and planned space-based mission payloads (e.g., ISR, Communications, PNT, SIGINT).

e. Graduates will analyze mission capabilities and conduct associated trades in order to develop associated payload design requirements.

17. ESR-12. SPACECRAFT DESIGN, INTEGRATION, AND SYSTEMS ENGINEERING

a. Graduates will develop and assess an overall space system architecture to meet defined mission requirements through the use of systems engineering tools and processes.

b. Graduates will derive system and subsystem performance criteria from stated mission capabilities and conduct trade-offs between payload and other spacecraft subsystems in addressing these capabilities.

c. Graduates will examine a broad spectrum of mission assurance concerns such as reliability, risk management, configuration management, qualification and acceptance testing, proto-flight strategy, spacecraft materials and manufacturing processes, resiliency considerations and cyberspace.

d. Graduates will examine various engineering and mathematical definitions of cost functions (revisit time, dwell time, local coverage, etc.) and apply emerging methods and tools to optimizing these utility measures in support of mission objectives.

e. Graduates will examine the basic principles and operational issues of space access to include launch vehicle performance, launch windows, and their impact on military operations.

f. Graduates will examine the capabilities of the various current and planned launch systems, and characterize the issues associated with integrating a spacecraft with a launch vehicle, to include the effects of launch environment.

g. Graduates will perform a trade-off analysis in the selection of a launch vehicle based on mission requirements, performance and design constraints, and business issues involved (e.g., pricing, insurance, policy).

h. Graduates will demonstrate proficiency in design, analysis, and modeling / simulation tools such as NX, MATLAB / Simulink, and Systems Tool Kit (STK).

i. Graduates will examine the processes and methods of systems engineering including requirements analysis, functional analysis and allocation, system design, and verification.

18. ESR-13. GROUND SYSTEMS AND SYSTEMS ENGINEERING

a. Graduates will understand the fundamentals of a space-ground system architecture including the system-of-systems that comprise a space-based, end-to-end capability across all mission areas.

b. Graduates will examine Department of Defense Architecture Framework (DoDAF) views of real or notional space network architectures in order to understand necessary internal and external interfaces and domain interactions.

c. Graduates will analyze enterprise and mission-specific frameworks from standard communications infrastructures (C&C, messaging, data, etc.), services, and tools to mission specific T&C, information products and data.

d. Graduates will analyze network and non-network communications within an Information Technology Enterprise Domain context.

e. Graduates will understand application program interface (API) challenges in relation to security requirements, risks and mitigation.

f. Graduates will understand Risk Management Framework integration for cyber security system engineering efforts including information assurance and relevant documentation such as NIST SP800-30, DoDI 8500.1 and 8500.2.

h. Graduates will analyze command and telemetry requirements and capabilities to support mission execution, vehicle operations and anomaly resolution.

i. Graduates will analyze services for access, sharing, processing and external dissemination of information including data management and storage challenges such as "Big Data", open-source implementation and cloud technology applications for Ground Systems.

19. ESR-14. CONDUCT AND REPORT INDEPENDENT RESEARCH

a. Graduates will conduct independent research on a space systems problem, including resolution of the problem and presentation of the results and analysis in both written and oral form, via a Master's thesis.

20. Major Area Sponsor and Subject Matter Experts:

a. Major Area Sponsor: RADM Christian Becker, Commander, Space and Naval Warfare Systems Command.

2018-2020 Educational Skill Requirement for Curriculum 591

b. Subject Matter Expert: RDML Ronald Fritzemeier, Chief Engineer, SPAWAR.

APPROVED: _____ 29 OCT 18
Major Area Sponsor [DATE]

APPROVED: _____ DEC 14 2018
President, NPS [DATE]

APPROVED: _____ 31 JAN 2019
Director, OPNAV N12 [DATE]

2018-2020 Curriculum Matrix for Curriculum 591

2018-20 Curriculum Matrix for Curriculum 591
(with refresher quarter zero)

0S	AE2440 Scientific Programming	MA1115/6 Multi-Variable Calculus	PH1121 Mechanics	NW3230 Strategy & Policy
1F	PH1322 Electromagnetism	MA2121 Differential Equations	AE2820 Introduction to Spacecraft Structures	ME2801 Introduction to Control Systems
2W	SS3500 Orbital Mechanics & Launch Systems	PH2514 Space Environment	MA3046 Matrix Analysis	NW3285 NSDM
3S	AE3815 Spacecraft Rotational Mechanics	EO2525 Analysis of Signals & Communication Systems	PH3052 Physics of Space and Airborne Sensor Systems	Degree Track Course
4S	AE3851 Spacecraft Propulsion	EO3525 Communications Engineering	SS3051 Military, DoD & Commercial Space	Degree Track Course
5F	SS3861 Spacecraft Payload Design I	AE3818 Spacecraft ADC	EC3230 Space Power & Radiation Effects	Degree Track Course
6W	SS4861 Spacecraft Payload Design II	AE3804 Thermal Control of Spacecraft	SS3001 Military Applications of National Space Systems	Degree Track Course
7S	AE4870 Spacecraft Design & Integration I	SS3101 Space Ground Systems & Mission Operations	SS0810 Thesis Research	Degree Track Course
8S	AE4871 Spacecraft Design & Integration II	EO2701 Introduction to Cyber Systems	SS0810 Thesis Research	NW3275 JMO Part 1
9F	SS0810 Thesis Research	SS0810 Thesis Research	MN3331 Acq. & Program Management	NW3276 JMO Part 2

Refresher
P - Code
Elective
JPME

Educational Skill Requirements (ESR) to Course Crosswalk

Curriculum Number: 591
Subspecialty Code: 5500P
Title: Masters of Science in Space Systems Engineering

591 EDUCATIONAL SKILL REQUIREMENTS MAP		Blooms Taxonomy Level			Satisfied By:			
		Knowledge / Comprehension	Application / Analysis	Synthesis / Evaluation	Course	Course	Course	Course
1	**ORBITAL MECHANICS AND SPACE ENVIRONMENT:**							
a	Graduates will examine the basic physics of orbital motion, and calculate and distinguish the parameters used in the description of orbits and their ground tracks.				SS3500	SS3001	PH3052	
b	Graduates will examine the design of orbits and constellations, and analyze how they are achieved, maintained, and controlled; to include spacecraft maneuver and orbit transfer calculations.				SS3500	EC3230	SS3001	
c	Graduates will examine the fundamentals of spacecraft tracking and command/control from a ground station.				SS3101	SS3500	SS3051	SS3001
d	Graduates will examine the various orbital perturbations, including those due to non-spherical earth and due to atmospheric drag, and interpret their effects.				SS3500			
e	Graduates will analyze the relationship between various orbital characteristics and the satisfaction of mission requirements, including the advantages and disadvantages of various orbits.				SS3500	SS3001	PH3052	SS3001
f	Graduates will design and optimize mission orbits through the analysis of common performance measures such as access, coverage, and revisit; and will employ appropriate tools to conduct these analyses.				PH3052	SS3500	EC3230	
g	Graduates will examine the physical behavior of the upper atmosphere, ionosphere and space environment under the influence of both natural and artificial phenomena such as solar activity, geomagnetic and magnetospheric effects, and man-made disturbances.				PH2514	EO2525	EC3230	SS3001
h	Graduates will apply this understanding of how the space environment impacts spacecraft parts, materials, and operations to spacecraft and mission design.				SS3861, SS4861	EC3230	SS3001	
2	**NATIONAL SECURITY SPACE SYSTEMS:**							
a	Graduates will examine the nature of space warfare (theory, history, doctrine, and policy) to distinguish how space operations as discussed in JP 3-14 enable joint force capabilities, and interpret how current and planned space capabilities contribute to the satisfaction of mission objectives.				SS3051	SS3001		
b	Graduates will examine the roles, responsibilities, and relationships of National and DoD organizations in establishing policies, priorities, and requirements for National Security Space systems; and in the design, acquisition, operation, and exploitation of these systems.				SS3051	SS3001		
c	Graduates will examine the role of the Services / Agencies in establishing required space system capabilities, and will translate these capabilities into end-to-end, system-of-systems performance requirements.				SS3001	SS3001	SS3051	
d	Graduates will examine: current and planned Intelligence, Surveillance, and Reconnaissance (ISR) capabilities; how space systems contribute to these capabilities; the intelligence collection and analysis process; and how war-fighters access information from these sources.				SS3001	PH3052		
e	Graduates will develop concepts of employment and assess space tactics and CONOPS. The development and assessment shall consider end-to-end capabilities and system-of-systems architectures that enhance, support, and integrate into military operations to include resiliency concepts in a contested environment.				SS3051	SS3001		
f	Graduates will identify how proposed space-related capabilities / doctrine transition from concept to real-world implementation through experimentation.				SS3001	SS3051		
g	Graduates will examine the capabilities of unclassified DoD and commercial space systems, and how those systems relate to National Space Systems to include potential overlaps and leverage opportunities.				SS3051			

Educational Skill Requirements (ESR) to Course Crosswalk

3	**PROJECT MANAGEMENT AND SYSTEM ACQUISITION:**							
a	Graduates will examine project management and DoD system acquisition methods and procedures to include contract management, financial management and control, and the Planning, Programming, Budgeting and Execution (PPBE).				MN3331			
b	Graduates will recognize the role of the Defense Acquisition University and the acquisition courses and qualifications available.				MN3331			
c	Graduates will examine system acquisition organizational responsibilities and relationships (e.g., Congress, DoD, Services, Resource Sponsor, Systems Commands, Operating Forces) as they pertain to the acquisition of systems for DoD, Naval, and civilian agency users.				MN3331			
d	Graduates will examine the unique nature of space acquisition programs and plan a notional space system acquisition program.				AE4871	SS4861		
4	**COMMUNICATIONS:**							
a	Graduates will examine the basic principles of communications systems engineering to include both the space and ground segments.				EO2525	SS3001	SS3001	
b	Graduates will examine digital and analog communications architecture design, including such topics as frequency reuse, multiple access, link design, repeater architecture, source encoding, waveforms/modulations, and propagation media.				EO3525	SS3001		
c	Graduates will calculate and analyze link budgets to assess communication system suitability to support mission requirements, and to translate mission requirements into communications system design characteristics.				EO3525	SS3001		
d	Graduates will differentiate, compare, and contrast the characteristics and capabilities of current and future communications systems in use or planned by Naval operating and Joint forces afloat and ashore.				EO3525	SS3051		
e	Graduates will examine how current and planned space communications systems should be used to meet Joint communications requirements across the spectrum of operations.				SS3051			
f	Graduates will differentiate signal processing techniques, both digital and analog, as applied to missions such as spacecraft communications, surveillance, and signals intelligence.				EO3525	SS3001		
g	Graduates will examine spacecraft vulnerabilities in an electronic warfare context.				SS3051	EC3230	SS3001	
5	**COMPUTERS: HARDWARE AND SOFTWARE**							
a	Graduates will understand the fundamentals of digital logic and digital system design of simple digital computer subsystems.				EO2701	SS3861, SS4861		
b	Graduates will examine the design of current and planned computer hardware and software architectures for space-based applications to include their potential to support service life extensions and enable incremental capabilities of cyber and platform resiliency.				SS3861, SS4861	EO2701		
c	Graduates will examine the use of computers in complex systems such as guidance, signal processing, communications, and control systems.				AE4871	SS3861, SS4861	SS3001	
d	Graduates will examine the fundamentals of electronic component design, fabrication, reliability, and testing (to include radiation hardening), with an emphasis on parts, materials, and processes.				EC3230	SS3861, SS4861	SS3001	
e	Graduates will examine modern Information Technology capabilities and their applications for space systems ground processing, data storage, information sharing, and network design.				PH3052	SS3861, SS4861		
6	**SPACECRAFT GUIDANCE AND CONTROL**							
a	Graduates will analyze the field of spacecraft guidance and control, to include topics such as linear control, rotational kinematics, rigid body dynamics, gravity gradient, spin and three-axis stabilization design, active nutation control, sources of and response to disturbance torques, and attitude determination and associated sensors and actuators.				AE3815	AE3818		
b	Graduates will apply these techniques to the analysis and design of resilient spacecraft guidance and control systems.				AE3815	AE3818		

Educational Skill Requirements (ESR) to Course Crosswalk

7	**SPACECRAFT STRUCTURES, MATERIALS, AND DYNAMICS**							
a	Graduates will examine the engineering of space structures and perform simplified sizing calculations and analytical modeling of advanced materials.				AE2820	AE4870		
b	Graduates will analyze the advanced dynamics and control of these structures.				AE3818			
c	c. Graduates will analyze the viability of structures and materials for survivability in the space environment.				AE4871	SS4861	AE2820	
8	**PROPULSION SYSTEMS**							
a	Graduates will examine the operating principles (fluid mechanics, thermodynamics, electricity and magnetism) and propulsion devices used in current and proposed space applications.				AE3851	SS3500		
b	Graduates will analyze and choose appropriate propulsion systems for spacecraft applications to include launch, orbit transfers, and spacecraft maneuvering with the potential for on-orbit serviceability.				AE3851	SS3500		
9	**SPACECRAFT THERMAL CONTROL**							
a	Graduates will examine the principles of heat transfer and how surfaces and materials are manipulated in spacecraft thermal control.				AE3804	EC3230		
b	Graduates will examine the design, analysis, and applications of current active and passive thermal control devices (including heat pipes, louvers, and materials).				AE3804	EC3230		
c	Graduates will examine the sources of heat in space (solar, terrestrial, reflected solar, internal vehicle generation) and their variation as a function of vehicle orbit, and apply this knowledge to thermal subsystem analysis and design.				AE3804	EC3230		
10	**SPACECRAFT POWER**							
a	Graduates will examine the principles and operating characteristics of major power generating systems for spacecraft, including the performance of photovoltaic sources in the natural and artificial radiation environment.				EC3230			
b	Graduates will examine the principles and operating characteristics of energy storage devices in power systems design to include the potential to support associated service life extensions.				EC3230	EO2525		
11	**REMOTE SENSING AND PAYLOAD DESIGN**							
a	Graduates will examine principles of active and passive sensors in current or planned use, to include analysis of electromagnetic wave propagation and design of optics, detectors, and antennae.				PH3052	SS3001		
b	Graduates will examine the effects of the space, atmospheric, and terrestrial environments (including countermeasures) on sensor performance.				PH3052	EC3230	SS3861, SS4861	
c	Graduates will assess and conduct tradeoffs among various sensors and platforms, evaluating how each satisfies mission requirements such as access area, resolution, timeliness, and capacity.				SS3861, SS4861	PH3052	SS3001	
d	Graduates will examine the design of current and planned space-based mission payloads (e.g., ISR, Communications, PNT, SIGINT).				SS3861, SS4861	PH3052	SS3001	SS3051
e	Graduates will analyze mission capabilities and conduct associated trades in order to develop associated payload design requirements.				SS3861, SS4861	PH3052	AE4871	

Educational Skill Requirements (ESR) to Course Crosswalk

12	SPACECRAFT DESIGN, INTEGRATION, AND SYSTEMS ENGINEERING							
a	Graduates will develop and assess an overall space system architecture to meet defined mission requirements through the use of systems engineering tools and processes.				AE4871	MN3331	EC3230	
b	Graduates will derive system and subsystem performance criteria from stated mission capabilities and conduct trade-offs between payload and other spacecraft subsystems in addressing these capabilities.				AE4871	SS4861	MN3331	EC3230
c	Graduates will examine a broad spectrum of mission assurance concerns such as reliability, risk management, configuration management, qualification and acceptance testing, proto-flight strategy, spacecraft materials and manufacturing processes, resiliency considerations and cyberspace.				AE4871 / SS4861	MN3331	EO2701	AE2820
d	Graduates will examine various engineering and mathematical definitions of cost functions (revisit time, dwell time, local coverage, etc.) and apply emerging methods and tools to optimizing these utility measures in support of mission objectives.				AE4871			
e	Graduates will examine the basic principles and operational issues of space access to include launch vehicle performance, launch windows, and their impact on military operations.				AE4871	SS4861	SS3500	AE3815
f	Graduates will examine the capabilities of the various current and planned launch systems, and characterize the issues associated with integrating a spacecraft with a launch vehicle, to include the effects of launch environment.				AE4871	SS3500		
g	Graduates will perform a trade-off analysis in the selection of a launch vehicle based on mission requirements, performance and design constraints, and business issues involved (e.g., pricing, insurance, policy).				AE4871			
h	Graduates will demonstrate proficiency in design, analysis, and modeling / simulation tools such as NX, MATLAB / Simulink, and Systems Tool Kit (STK).				AE4871 / SS4861	AE3815	SS3500	EC3230
i	Graduates will examine the processes and methods of systems engineering including requirements analysis, functional analysis and allocation, system design, and verification.				AE4871	MN3331	SS3861, SS4861	

Educational Skill Requirements (ESR) to Course Crosswalk

13	**GROUND SYSTEMS AND SYSTEMS ENGINEERING**							
a	Graduates will understand the fundamentals of a space-ground system architecture including the system-of-systems that comprise a space-based, end-to-end capability across all mission areas.				SS3101			
b	Graduates will examine Department of Defense Architecture Framework (DoDAF) views of real or notional space network architectures in order to understand necessary internal and external interfaces and domain interactions.				SS3101			
c	Graduates will analyze enterprise and mission-specific frameworks from standard communications infrastructures (C&C, messaging, data, etc.), services, and tools to mission specific T&C, information products and data.				SS3101			
d	Graduates will analyze network and non-network communications within an Information Technology Enterprise Domain context.				SS3101			
e	Graduates will understand application program interface (API) challenges in relation to security requirements, risks and mitigation.				SS3101			
f	Graduates will understand Risk Management Framework integration for cyber security system engineering efforts including information assurance and relevant documentation such as NIST SP800-30, DOD8500.1 and 8500.2.				SS3101			
g	Graduates will analyze command and telemetry requirements and capabilities to support mission execution, vehicle operations and anomaly resolution.				SS3101			
h	Graduates will analyze services for access, sharing, processing and external dissemination of information including data management and storage challenges such as "Big Data", open-source implementation and cloud technology applications for Ground Systems.				SS3101			
14	**CONDUCT AND REPORT INDEPENDENT RESEARCH**							
a	Graduates will conduct independent research on a space systems problem, including resolution of the problem and presentation of the results and analysis in both written and oral form, via a Master's thesis.				AE0810			

COLOR CODE	
Satisfies ESR:	Addresses ESR:

Cost Analysis

NPS Cost Analysis Form

CURRICULUM: Space Systems Engineering
CURRICULUM #: 591
SUBSPECIALTY: SS00
DEGREE: Masters

LENGTH: 9 quarters with NO refresher
DESIGN: Resident
COURSES: 26 with thesis & capstone project
JPME: Yes

NOTE: This table presents a standard cost of a curriculum for one cohort of students based principally on the number of courses contained. Implicit assumptions are that all curriculum courses are provided for the individual curriculum and their costs are attributed separately to it. In practice, courses may be shared by curricula, potentially reducing cost attributable per curriculum. Ongoing costs of curriculum administration and maintenance are included. Overhead costs are assigned using standard rates approximating experience. JPME costs are not reflected. Thesis/capstone project courses are not included in the total number of courses, but thesis/capstone project advising costs are implicit in other program costs.

NPS Cost Elements	Explanation	Examples	Type Cost		Calculation	Annual Cost ($K)	Program Cost ($K)	Comment
Refresher Delivery Costs								
Refresher Quarter	Program-level direct course delivery, by student	Faculty cost (faculty cost per student)	Direct	0	Assumes 25K/1 course and 4 refresher courses/quarter and 20 students per course. Calculation is 5K per student.	$0	$0	
Program Delivery Costs								
Program Delivery / Faculty (shared courses)	Direct delivery of program, course sections	Faculty cost	Direct	15	Assumes $25K per course section (SSE has 15 shared courses)	$167	$375	
Program Delivery / Faculty (curriculum specific courses)	Direct delivery of program, course sections	Faculty cost	Direct	11	Assumes $25K per course section (SSE has 11 curriculum specific courses)	$122	$275	Only direct cost recovered with program cancellation.
Program Administration	Program-level direct administration, by faculty	Faculty cost	Direct		Assumes 1/2 quarter FTE at $25K	$25	$56	
Prog. Development Costs								
New Course Development	Course research and preparation for first delivery	Faculty cost	Direct		Varies by circumstance. Stnd assumption of 1/2 quarter FTE ($25K) per course	$0	$0	
Program Support Costs								
Student Support	Special prog. support specific to the curriculum	e.g., TAD for student thesis travel. Experience tour.	Direct			$0	$0	
Thesis/Project Development	Administration & development of student theses in conjunction with Naval stakeholders, for deliverable output to those stakeholders.		Direct			$0	$0	
Technical Support - Lab	Ongoing maintenance of functionality, infrastructure & maintenance support, provided by technicians	e.g., Lab technician	Direct			$0	$0	
Prog. Maint/Recap Costs								
Academic Maintenance /Recapitalization	Recapitalization into faculty, discipline, programs	e.g., RIP, 3rd Q, Program development/ initiatives.	Direct		Assumes 1 quarter (4 courses) at $50K and 50% of courses are staffed by tenure track faculty (Total courses/4/2*50K)	$72	$163	
Research Program	For programs with a directly-associated research program element	e.g., Funding for research seeding.	Direct			$0	$0	
					Direct Costs	**$386**	**$869**	
Overhead Costs								
Academic Organization	Schools/Departments administrative & overhead	Deans, Chairs, Department staff, Academic Labs staff	Overhead		5% on Direct Costs	$19	$43	
Academic Infrastructure	OH related to NPS academic/education mission	Provost, Library, Acad Affairs, Registrar, Ed Technology, Admissions, Research Office, IT	Overhead		20% on Direct Costs	$77	$174	
Command Infrastructure	OH related to NPS as Navy command	President, Comptroller, Com Eval, Legal, IT, PAO	Overhead		15% on Direct Costs	$58	$130	
					OH Costs	**$154**	**$348**	
Total					**Total**	**$541**	**$1,216**	

NPS TUITION (FY18 per student)					Annual ($K)	Program ($K)
Non-Naval Military	Standard Resident				$21	$47
Govt Civilian	Standard Resident				$21	$47
International	Expected Intl average				$40	$89
Contractor	Standard Resident				$21	$47

NAVAL COST (FY18 per student)					Annual ($K)	Program ($K)
IA: Individuals Acct	(Assumes O-4)				$181	$408
Medical						
Other						

Subspecialty Fit-Fill and Utilization Data

Unclassified

Fit / Fill
Space Systems Engineering (5500P)

	Coded Billets		Officer Inventory		% Fill[1]	% Fit (Matrix)[2]
	P	Q	P	Q		
URL	0	0	26	4	NA	NA
RL	32	5	34	27	35/37 96%	19/35 54%
STAFF	0	0	0	0	NA	NA
1000 (Billets)	2	0	0	0	1/2 50%	1/1 100%
1050 (Billets)	0	0	0	0	NA	NA
TOTAL	34	5	60	31	36/39 92%	20/36 56%

[1] "%Fill" any officer in a coded billet
[2] "Matrix Fit" counted when any of an officer's subspecialties match the Matrix code.

Snapshot data "As of" Feb 2018

Unclassified 25

Unclassified

Utilization
Space Systems Engineering (5500P)

	Officer Inventory					Utilization Rates[1]	
	Out of Navy window – Not Utilized	Separating – Not Utilized	Must Use Next Tour to meet Navy window	Utilized inside Navy window	Utilized outside of Navy window	Navy[2]	DoD[3]
URL	5	1	27	8	0	8/14 57%	8/9 89%
RL	13	0	22	43	1	43/58 84%	45/45 100%
STAFF	NA	NA	NA	NA	NA	NA	NA
TOTAL	18	1	49	51	1	51/72 71%	53/54 98%

[1] OPNAVINST 1520.23C requires officers to serve one tour in a validated subspecialty position not later than the second tour following graduation
[2] Navy Compliance = Utilization within 2 shore tours
[3] DOD Compliance = Utilization anytime during a Naval career

Snapshot data "As of" Oct 17 utilization report

Unclassified 26

Action Items

2016 Curricula Review Carry-Over Actions:

1. 591-16-4: Evaluate EO2701 Cyber course as best fit for 591 curriculum.
   Source: 2016 591 curriculum review.
   Intent: Address the spectrum of cybersecurity as it applies to space-based systems.
   Action Officer: NPS Space Systems Program Officer
   Projected Completion: Spring 2019 in conjunction with action 591-18-7

2018 Curricula Review New Actions Levied:

2. 591-18-1: Update Military Applications of Space (SS3001) to incorporate material from the 2018 National Space Strategy and address end-to-end system of systems.
   Source: 591 ESR-2c,e updates
   Intent: Incorporate 2018 National Space Strategy and address resiliency and survivability of space-based systems within the context of end-to-end, system-of-systems architecture construct.
   Action Officer: NPS Space Systems Program Officer
   Projected Completion: Summer 2018

3. 591-18-2: Update Military Applications of DoD & Commercial Space Systems (SS3051) to comply with new JP 3-14 dated 10 April, 2018.
   Source: 591 ESR-2a,e updates
   Intent: Incorporate new JP 3-14 updates. Address removal of space mission areas and incorporate new space as a joint operating area concept.
   Action Officer: NPS Space Systems Program Officer
   Projected Completion: Summer 2018

4. 591-18-3: Continue to refine Spacecraft Payload Design sequence (SS3861 & SS4861) to address service life extensions and enable incremental capabilities of cyber and platform resiliency.
   Source: 591 ESR-5b update
   Intent: Address space-based hardware and software architectures potential to support service life extensions and enable incremental capabilities of cyber and platform resiliency.
   Action Officer: NPS Space Systems Program Officer
   Projected Completion: Spring 2019

5. 591-18-4: Update Spacecraft Attitude Determination and Control course (AE3818) to address analysis and design of resilient spacecraft guidance and control systems.
   Source: 591 ESR-6b update
   Intent: Address spacecraft design concepts to enhance survivability of on-orbit assets.
   Action Officer: NPS Space Systems Program Officer
   Projected Completion: Winter 2019

6. 591-18-5: Update Introduction to Spacecraft Structures course (AE2820) to include specialized materials and manufacturing processes.
   Source: 591 ESR-12c update

Action Items

Intent: Address spacecraft mission assurance considerations and resiliency concerns within the context of spacecraft unique materials and manufacturing processes to include the proto-flight acquisition strategy.
Action Officer: NPS Space Systems Program Officer
Projected Completion: Winter 2018

7. 591-18-6: Update Spacecraft Propulsion course (AE3851) to address the potential for on-orbit serviceability.
Source: 591 ESR-8b update
Intent: Enable students' ability to analyze and choose appropriate spacecraft propulsion systems with the potential for on-orbit serviceability.
Action Officer: NPS Space Systems Program Officer
Projected Completion: Winter 2018

8. 591-18-7: Update Cyber Fundamentals course (EO2701) to address spacecraft and ground systems cyber resiliency across space-based systems from up front design and throughout incremental improvements.
Source: 591 ESR-5b & 12c updates
Intent: Address the spectrum of cybersecurity as it applies to space-based systems.
Action Officer: NPS Space Systems Program Officer
Projected Completion: Spring 2019

Appendix – P MAE Department Retreat – May 16, 2016

08:00 – 08:30 Arrive and Coffee and Donuts

08:80 – 09:00 Introductions and First Ice Breaker

09:00 – State of the Dept (Hobson)

9:30 – Ice Breaker

10:00 – Research, Highlights (Luhrs/Horner(CAVR))

10:20 – Facilities Improvements and Certifications (Seivwright/Kohlgrueber)

10:30 – Curricula Presentations

570/571 (Gordis)
572 (Chandra)
525 (Horner)
563 (Hobson)
591 (Ross)
613 (Adams)
573/597 (Romano)

11:30 – 13:00 Lunch – London Bridge Pub

13:00 – Research Highlights

Agrawal
Kwon
Brophy
Driels
Gannon (ESTEP)
Bingham (Cruser)

14:30 – Strategy Meeting (Facilitated)

To draft a Mission Statement for the Department and draw up a list of Research and Education Thrust Areas

16:00 - Drinks