The Naval Postgraduate School

and

Unrestricted Line Officer Graduate Education

by

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October, 1993

1. Introduction and Purpose

Over the past twenty five years questions of the Naval Postgraduate School's (NPS's) role and existence have risen many times. These are of course both very legitimate concerns, especially as the Navy's size, complexity and mission change in support of changing national defense requirements. The 1975 Secretary of the Navy study [12] is one example of a serious investigation into the complex role of NPS. There have been others, but many supposed comparisons between NPS and civilian institutions (CIVINS) are based on a serious misunderstanding of what takes place at NPS and what can be expected from a civilian university at the graduate level. One recent example seen by the author[1] reduces the comparison to a single page in such a naive and misleading fashion that it is difficult to believe those responsible were seriously interested in a legitimate comparison. The author(s) of that paper would have the reader believe that NPS exists simply to award masters degrees and that this could be done much cheaper and "arguably better" at CIVINS. It concludes that "NPS may be a luxury the Navy can no longer afford." At best this indicates an abysmal knowledge of what the Navy's own institution accomplishes and what can be expected from attendance at a civilian university. To the extent that this is due to a failure on the part of NPS to document its activities and operations this report is intended to address that situation.

Any comparison between NPS and CIVINS has little meaning without a basic understanding of the history that led to the existence of NPS, the connection between NPS and the unrestricted line (URL) officer community, the graduate entry requirements at both NPS and civilian institutions, academic accreditation requirements (especially in engineering fields), year-round operations of NPS versus partial year operations at CIVINS, the focus and ability of NPS to offer graduate level classified and sensitive course material and research, and the lack of institutional and faculty interest at many CIVINS in masters level education and military issues. These and other areas are covered in the following sections.

2. A Brief History of the Naval Postgraduate School

The roots of NPS can be found in the return of the Great White Fleet from its round-the-world cruise from December 1907 to February 1909[2]. Many problems surfaced on that fourteen month cruise in areas that included technology, diplomacy and politics. In the technological area frequent failures occurred in propulsion, ordnance, and the new wireless communications to name a few. Following a review of the cruise on its return the Secretary of the Navy agreed that there was a clear need for Navy line officers to be more aware of and educated in the areas of technology and the underlying science and engineering principles. The result was the formation in 1909 of a graduate division of the Naval Academy that specialized in advanced education in these science and technology areas for line officers.

The present day institution grew out of this graduate division at the Academy when, on 31 July, 1947, the 80th Congress enacted legislation creating NPS as a separate institution[3]. It remained at Annapolis until 22 December, 1951 at which time it was transferred to its current location in Monterey, California[4]. Its mission at that time was:

> *To conduct and direct the instruction of Commissioned Officers by advanced education, to broaden the professional knowledge of General Line Officers and to provide such other indoctrination, technical and professional instruction as may be prescribed to meet the needs of the Naval Service.*

The emphasis at NPS has always been on educating the unrestricted line (URL) officer, and the General Line School was established and collocated with NPS in Monterey on 8 September, 1947[5]. It was disestablished as a separate entity [4] and made part of NPS in December 1951. On 7 April, 1958 it was redesignated as General Line and Naval Science School[6]; its mission was

> *--to raise the educational level, broaden the mental outlook, and increase the professional and scientific knowledge of line officers in order that they may better perform the duties and meet the responsibilities of higher grade.*

The increase in complexity of the Navy and its missions through the period since 1947 resulted in further significant changes to NPS. The areas of tactics and logistics were added in 1953 with the creation of an Operations Research group, and on 6 June, 1956 the Navy Management School was established as an NPS component[7]. These and other additions resulted in a request by the Superintendent to the Chief of Naval Personnel in June 1962 to reorganize and consolidate the various NPS components [8]. After much discussion approval was granted resulting in the disestablishment of the Engineering School, General Line and Naval Science School, and Management School as separate entities, and the creation of NPS as an integrated unit [9].

During this period the role of research in maintaining quality in advanced education was recognized by the Navy. The original mission statement quoted above makes no mention of research, but on 3 August 1960 the NPS mission statement was formally changed to its current form:

> *To conduct and direct the advanced education of commissioned officers, and to provide such other technical and professional instruction as may be prescribed to meet the needs of the Naval Service, and in support of the foregoing, to foster and encourage a program of research in order to sustain academic excellence.*

2.1 Significant Academic Department Changes since 1960

Throughout the period from 1960 to the present numerous reviews, both internal and external, have had significant impact on NPS structure and programs. This section describes some of the most significant changes within the NPS academic structure in the past thirty years.

In the early 1960's the departments of Electrical Engineering and Electronics were merged, and in the mid-80's, in recognition of the tremendous changes occurring in these fields, the department was given its current name of Electrical and Computer Engineering.

In the mid 1960's the interdisciplinary Operations Research Group became a separate academic department. With the consolidation of the Management School into NPS a Department of Business Administration and Economics was created. Two external reviews of this department, one in 1970[10] and one in 1971[11] resulted in consolidation of this department with the Department of Operations Research in 1971. This new department proved to be both unwieldy in size (approximately 90 faculty member) and very broad in scope, and comprised about one third of all NPS faculty. In 1976 this department was split into separate departments of Administrative Sciences and Operations Research which continue to today. One of the recommendations found in [11] called for a management program for engineers to be established in addition to their technical program. This would be aimed at the acquisition side of a URL officer's responsibilities when filling a technical billet in the systems commands. In the mid 1970's NPS acquired faculty and started a Systems Acquisition Management curriculum in response to this recommendation. By the late

1970's following the downsizing of the officer corps after Vietnam withdrawal, the Navy decided that this dual technical/managerial program took an officer out of his or her career area for too long, and the managerial side of the program was abandoned. Partly as a result of the formation of the material specialist designation, a new Systems Acquisition Management curriculum is now being offered.

In the 1960's and early 70's NPS had a Computer Science group consisting of interested and involved faculty from various departments. With the rising importance of this subject it was recognized in the academic community as a separate discipline. With the clear need for this subject throughout the Navy the Department of Computer Science was formed in 1978.

At the direction of the Secretary of the Navy a major review of the Navy Graduate Education Program was undertaken in 1975[12]. This was an in-depth study of the total graduate education program including NPS and the civilian institutions (CIVINS) used by the Navy for fully funded education. NPS was seen as the institution that was uniquely capable of delivering advanced education programs with a specific naval or military focus. Recommendations were made, and subsequently followed, to move curricula that did not require this specific focus from NPS to CIVINS. Chemistry was one of these curricula, and this move resulted in the elimination of Material Science and Chemistry as an academic department. The material science section was retained and merged with Mechanical Engineering. Also at that time NPS offered a sizable undergraduate program to officers who did not possess a Baccalaureate degree. This program, primarily aimed at naval aviators who had become commissioned officers without completing their undergraduate education, was transferred to CIVINS in 1975 and the supporting department of Government and Humanities was eliminated. A nucleus of faculty from that department were retained and new faculty hired to form a new department of National Security Affairs specializing in strategic planning, intelligence and area studies. The academic departments at NPS in 1967 and today are shown in Table 1.

2.2 Warfare Specialties and the Academic Groups

Since faculty receive their advanced degrees in specific academic disciplines it is natural that institutions of advanced education are organized by these disciplines. Although NPS is like all other academic institutions in this respect, its special focus on naval technology, warfare and management has always brought together faculty from various departments to work on interdisciplinary problems. Three academic areas that have long been strong at NPS are underwater acoustics, search and tactics, and physical oceanography. In the mid 1970's faculty in these areas convinced the Navy that NPS could offer a curriculum in anti-submarine warfare (ASW) that was both highly relevant to the operational Navy and of high academic quality. In support of this program the first Academic Group was formally recognized. Members of this group maintained their affiliation with their academic discipline department, but in addition were responsible for developing and teaching the ASW curriculum. This was the first of a number of Academic Groups to be formed over the next fifteen years. Interdisciplinary groups were formed at civilian institutions in the late 1960's and early 1970's to work on specific problems that involved many disciplines, but most have now been abandoned. Although the reasons for their failure are many, faculty at civilian institutions of higher learning are driven to excel in their academic discipline, usually through pursuit of basic research, and have little incentive to become involved in programs of instruction and research that typically are associated with specific applied problems. NPS is unique in that it is an institution of higher education with a clearly defined mission and client. This is a major contributor to the success NPS has achieved with its academic groups.

1967	1992
Departments: Aeronautics Business Administration and Economics Electrical Engineering Government and Humanities Material Science and Chemistry Mathematics Mechanical Engineering Meteorology and Oceanography Operations Research Physics	**Departments:** Aeronautical and Astronautical Engineering Administrative Sciences Computer Science Electrical and Computer Engineering Mathematics Mechanical Engineering Meteorology National Security Affairs Oceanography Operations Research Physics **Groups:** Anti-Submarine Warfare Electronic Warfare Joint Command Control and Communications Space Warfare

Table 1: Academic Departments and Groups at NPS

A few years after the ASW group was formed came the Joint Command, Control and Communications group and the Electronic Warfare group. As its name implies the first of these was responsible for a curriculum that was sponsored by the Joint Chiefs of Staff (JCS) and whose students are drawn from all three services. A fourth group in Space Warfare was formed in the early 1980's and is responsible for two curricula, one in space operations and one in space engineering. The academic programs offered by these four groups are not available at any other institution. Other groups are continually being discussed and a possible reorganization of the current ones is being considered in light of the Navy's changing mission. The current groups are listed in Table 1.

3. The Navy Subspecialty System

In 1909 the Secretary of the Navy recognized the need for scientific and technological expertise by line officers, the men (and today women) who aspire to and are responsible for commanding ships, squadrons and submarines in naval operations. It is this group of officers that is the primary focus of NPS, so the following remarks apply primarily to the URL community.

The Navy of today is vastly more complex and technological than it was in 1909. One way that this is measured in terms of educational requirements of the officer corps is by the sub-specialty system. For those not familiar with the organization of the URL who may wonder why the term "subspecialty" is used and not "specialty" for advanced education, a brief explanation follows.

URL officers are the warrior community of the Navy. Their role is to plan, support, lead, and command naval forces in combat. This community comprises subgroups of warfare specialties, the major ones being aviators, surface officers and submariners (see [13] for complete details). In each group the officers aspire to command aircraft squadrons, surface ships or submarines

in a highly competitive up-or-out system. To prepare them for eventual command each officer must complete operational tours at sea, but because of the hardships involved in sea duty, an officer alternates between assignments at sea and assignments on shore. These shore assignments typically involve working with shore-based staffs, headquarters assignments in the Office of the Chief of Naval Operations (OPNAV), or System Commands (SYSCOMS) where they frequently become involved in activities requiring advanced education. To help match an officer to a position with the most appropriate education a coding system has been devised that applies to both officers and billets; this is called the Subspecialty System[13]. Every two years a Subspecialty Requirements Board (SRB) is convened under the leadership of a flag officer to validate, add, and/or subtract subspecialty coded billets (shortened to SS-coded billets in the remainder of this report). *It is this set of SS-coded billets that justifies the requirement for fully funded advanced education of officers.* Currently there are approximately 4800 of which 31% are URL, 32%RL, and 37% Staff (primarily Civil Engineer Corps, Supply Corps, Chaplain Corps, Medical Service Corps). Table 2 contains a list of those subspecialties that apply to the URL community[1] and that are awarded to officers after successful completion of a curriculum at NPS.

Each subspecialty has associated with it a Primary Consultant (often referred to as the subspecialty Sponsor), usually a flag officer in OPNAV or a SYSCOM, who has responsibility for monitoring the content of the associated curriculum and the appropriate assignment of SS-coded officers in their shore assignments. These are also shown in Table 2. Every two years each NPS curriculum undergoes a formal review, but continuous dialog occurs between the cognizant curricular officer at NPS and the primary consultant's staff. The effects of the formal reviews range from minor variations in areas covered, to major changes in direction, to new curricula being developed and old ones being eliminated. The Primary Consultant's main concern is with maintainingcurriculum relevance to the Navy through educational skill requirements (ESR's), while NPS is charged with filling these requirements in ways consistent with the highest quality of graduate education. This is explained more fully in the next section.

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1. Some of these can be held by restricted line and staff officers also. In addition there are subspecialty codes that apply only to these communities.Since NPS has no programs in these areas and our emphasis is on the URL these are not included. A complete listing can be found in [13].

SUBSPECIALTY		PRIMARY CONSULTANT
NAME	CODE	
Joint Intelligence	16	NAVINTELCOM
Naval Intelligence	17	NAVINTELCOM
MidEast, Africa, Asia	21	N-3/5
Far East, Pacific	22	N-3/5
Western Hemisphere	23	N-3/5
Europe, Russia	24	N-3/5
Strategic Planning	28	N-3/5
Special Operations/Low Intensity	29	NAVSPECWARCOM
Financial Management	31	N-82
Material Logistics Support Management	32	NAVAIRSYSCOM
Manpower, Personnel, Training Analysis	33	N-13
Transportation Management	35	MSC
Education and Training Management	37	CNET
Applied Mathematics	41	USNA
Operations Analysis	42	N-81
Operational Logistics	43	N-4
Anti-Submarine Warfare	44	N-71
Joint C3	45	J-6
Electronic Warfare	46	N-6
Operational Oceanography	49	N-096
Naval/Mechanical Engineering	54	NAVSEA
Total Ship Systems Engineering	54	NAVSEA
Electronics Systems Engineering	55	SPAWAR
Combat Systems Science and Technology	66	NAVSEA
Aeronautical Engineering	71	NAVAIRSYSCOM
Aeronautical Engineering with Avionics	72	NAVAIRSYSCOM
Space Systems Operations	76	N-6
Space Systems Engineering	77	N-6
Information Technology Management	89	NAVCOMPTELCOM
Computer Science	91	NAVCOMPTELCOM

Table 2: Unrestricted Line Officer Subspecialties

4. NPS Program Structure

As was mentioned in the introduction, the major reason for writing this report is to document the educational efforts carried out at NPS as contrasted with CIVINS. The differences become very clear when one looks at the structure of NPS programs. Every NPS curriculum consists of the three components shown in Figure 1 and each of these is explained in the following subsections. The percentage shown in each box shows the approximate average split among the three components. This has been derived from actual student transcripts as is described below.

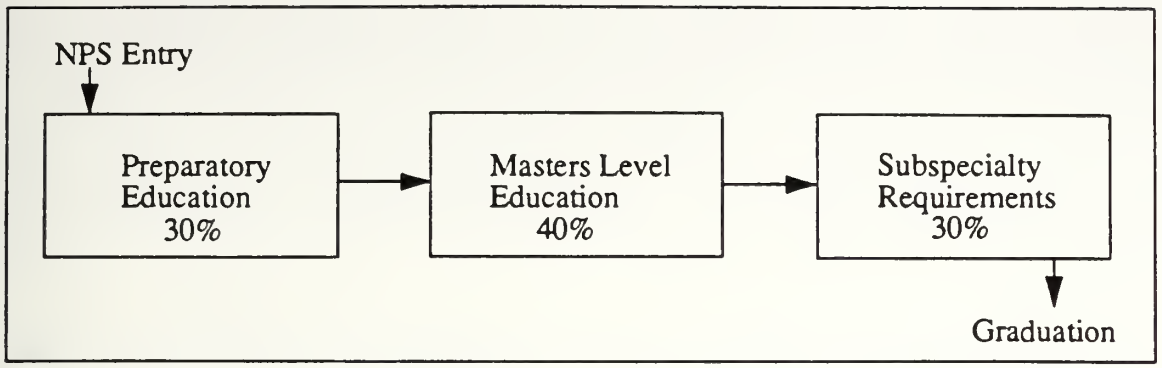

Figure 1:Schematic of NPS Programs

4.1 Preparatory Education

The purpose of the Navy's fully funded graduate education program is to ensure that its officer corps includes sufficient numbers of career-oriented individuals with technical and managerial expertise to man the subspecialty system. Because investment in graduate education is long term, the Navy chooses officers for this program from those who have excelled in their warfare area. The primary screen is their performance as military officers, not how well they did in undergraduate academic programs. Most CIVINS require graduate school applicants to have a minimum undergraduate B average (quality point rating (QPR) of 3.0), and many require a certain performance level on the graduate record exam (GRE). It is a fact that very few URL officers who attend NPS would be eligible for direct entry into CIVINS masters programs. The average QPR of NPS Navy student entrants is approximately 2.2, and while most have not taken the GRE, NPS does not use it as an input screen. To do so would add a significant expense with little if any positive payoff.

At CIVINS most students enter graduate school in the same field as their undergraduate studies. This is especially true in engineering fields due to accreditation requirements. All reputable engineering curricula in the US are accredited by the American Board of Engineering and Technology (ABET). ABET will not accredit an institution if it awards a graduate degree in a specific engineering field to a student *who does not hold an accredited bachelors degree in the same field.* Few officers entering NPS programs meet this requirement as is illustrated in Table 3. Of the

NPS Masters Degree	B.S. in Same Field	B.S. Not in Same Field
Aeronautical Engineering	7	10
Electrical Engineering	7	28
Mechanical Engineering	5	8

Table 3: Undergraduate Backgrounds of a Sample of Recent NPS Engineering Students

65 officers shown, only 19 fill the ABET requirement, and fewer than 10 of these fill the minimum QPR requirement. Thus most URL officers that enter NPS engineering and other technical pro-

grams are not eligible for entry into any accredited engineering or other technical programs at CIVINS. It may be that, if given time (four to five years at most institutions) these students could correct this deficiency. It must be understood that at those institutions, courses are usually offered at the convenience of the faculty, making efficient packaging of a tailored program to reduce residence time extremely difficult if not impossible. At NPS courses are offered whenever there is student demand. *This fundamental difference between NPS and CIVINS is extremely important as it leads to great efficiency at NPS in reducing the time URL officers are away from their warfare specialty.*

Although the ABET requirement accounts for a major portion of the preparatory education it is not the only factor. Often URL officers enter NPS with academic deficiencies in basic subjects such as calculus, linear algebra and physics. Their undergraduate background is often a poor match with their graduate studies, and programs have to be tailored to their specific needs to prepare them for their graduate program. The academic transcripts of twenty seven URL students chosen at random who graduated in 1989 show that an average of 30% of their program was devoted to preparatory work. This varies substantially between students, with a minimum of 7% for three students in 18 month management programs, to 60% for one student in a 30 month mechanical engineering program.

4.2 The Masters Degree Program

It is important to point out that the requirements for the masters degree and requirements for the award of the subspecialty overlap. Some material is required for both. In this report the requirements for the masters degree are considered to be those without which the student would not satisfy degree requirements of both the cognizant academic department or group and the NPS Academic Council. Additional material taken to complete their program is what is referred to in this report as the subspecialty requirements and is discussed in the next subsection.

The academic requirements for the MS and MA degrees at NPS are comparable with those at the highest quality CIVINS. These are measured in a number of ways; (1) the number of graduate equivalent contact hours required at NPS and CIVINS are approximately equal, (2) NPS maintains the highest levels of academic accreditation obtainable, and (3) faculty who visit NPS are consistently impressed with the quality of our programs. Each of these three is further described below.

The standard measure of academic workload and work completion is the equivalent contact hour (ECH). A student in a class that meets for 3 hours each week (the standard in CIVINS) for 16 weeks of a semester will complete 48 contact hours. Laboratory work, project assignments etc. are often counted on an equivalent contact hour basis using norms that are standard across many academic institutions. These are added to actual course contact hours to produce a total ECH. At most CIVINS two or three semesters (one academic year is two semesters) taking 13 hours per week (the approximate average for current navy CIVINS programs) is sufficient to obtain a masters degree *in the same field as the student's baccalaureate*, for a total of 416 to 624ECH. The academic transcripts of the twenty seven URL students at NPS referred to in Section 4.1 show that they averaged 590 ECH excluding thesis and experience tour (these are explained below) for the MS/MA portion of their program.

The Masters Degree is the terminal degree for almost all naval officers; very few are offered a chance to pursue a doctorate since there are very few requirements for uniformed na-

val officers with these degrees. At NPS this fact is recognized and is the major reason this institution requires all our students to complete a thesis as a requirement for graduation. It is felt that it is important for the student to formulate and analyze a problem, to demonstrate an ability to synthesize the diverse areas of advanced study as they apply to the problem, and to report this analysis in a formal way through a structured thesis under faculty supervision. Most civilian universities that offer graduate programs no longer require a thesis for the MS or MA degree. At the large prestigious research institutions such as those listed in [1] the masters degree is often little more than a consolation prize for those students failing passage into a doctorate program, with notable exceptions in professional schools that offer professional degrees such as MBA's. Without a thesis, the student completes a collection of advanced courses in narrow technical areas with little or no opportunity to see how they apply or fit together in solving a real problem.

For purposes of this report discussion of the thesis requirement is included in this subsection since NPS academic policy requires a thesis before award of an MS or MA. However, the thesis requirement is supported by all Primary Consultants since most theses have direct relevance to the subspecialty program being pursued. This is illustrated by the sample of titles of recent theses shown in Table 4. A complete list of all NPS theses with title and abstract is published annually[15] and is available from the Research Office, Code 08 at NPS.

Faculty at civilian institutions are rewarded for, and therefore driven by, publication of basic research results that advance the state of the art of their narrow field. Becoming involved in applied problems, especially in those areas that might be of direct interest to the Navy, is difficult at best, especially in times when no national emergency appears to be present. There involvement in teaching is also quite limited as is evidenced by the strike of teaching assistants at the University of California in December 1992. It is graduate students, employed as teaching assistants to support them in their graduate studies, who perform much of the teaching at CIVINS at the undergraduate and masters level. In contrast, at NPS every class is taught by faculty. Senior students are not asked to teach incoming students! That this takes place in CIVINS was attested to recently when the NPS Superintendent, who is responsible for monitoring and paying the bills for the Navy CIVINS program, asked the naval officer students to write him regarding their progress and thoughts on their programs. At least one complained that he was being taught by naval officers in the same program in a more advanced stage, and that regular faculty were rarely available.

ASW

Evaluation of Under Ice Submarine Tactics

Surface Ship Torpedo Defense: Selected Anti-Torpedo Employment Tactics

EW

Assessment of Patriot Missile Systems for Potential Exploitation by ECM

Naval Theater Ballistic Missile Defense - An Analysis as a Test Case for Space and Electronic Warfare

JOINT C3

An Assessment of the Marine Tactical Command and Control System (MTACCS)

Army JTIDS: A C3 Case Study

SPACE SYSTEMS

Satellite Anomalies and Electrostatic Surface Discharges

Selection and Specification of a Data Link Protocol for VSAT Based Inter-Lan Communications

AERO ENGINEERING

Aircraft Vulnerability to Directed Energy Weapons

F-14 Overland Survivability Enhancement Through Fuel System Vulnerability Reduction (U)

ELECTRONICS SYSTEMS ENGINEERING

Communication Network Survivability

Computer Simulated Missile-Target Engagement with a Luenberger Observer and a Ground Observer

NAVAL ENGINEERING

Three Dimensional Pursuit Guidance and Control of Submersible Vehicles

Ship Roll Mode Information Extracted from Sea Trial Data

COMBAT SYSTEMS SCIENCES AND TECHNOLOGY

High-Gain, High-Power Free Electron Lasers

Ocean Bottom Simulation Using Fractal Geometry

AIR/OCEAN SCIENCES

Ambient Sound in the Ocean Induced by Heavy Precipitation and the Subsequent Predictability of Rainfall Rate

Determination of Near-Surface Velocity Fields in the CTZ Using Combined Altimetric and Inverse Modelling Techniques

COMPUTER SCIENCE

Searching for Shortest and Safest Paths Along Obstacle Common Tangents

OPERATIONS ANALYSIS

Mathematical Model of a Marine Corps Amphibious Landing Using Intelligence Estimates

Load Sharing in Anti-Air Warfare Coordination: Criteria and a Simulation Test Plan

OPERATIONAL LOGISTICS

The Economic Choice of the Transportation Routes for Logistics Materials

Sensitivity Analysis of the Modern Naval Combat Model

NATIONAL SECURITY AFFAIRS

Naval Arms Control: A Post-Cold War Reappraisal

Deterring Nuclear-Armed Third World Dictators: A Targeting Strategy for the Emerging Threat

MANAGEMENT

Tasking and Communication Flows in the F/A-18D Cockpit

Comparative Cost Analysis of P-3 Active and Reserve Aviation Forces

Table 4: A Sample of Recent MS Theses at NPS

4.3 Subspecialty Requirements

The third component of the NPS program is unique to this institution. At each curriculum review, a biennial event between NPS and the subspecialty primary consultant, discussions take place and agreements are reached on what are called Educational Skill Requirements (ESR's). These are broad statements of the capabilities the Primary Consultant desires in an officer who is to be awarded the subspecialty code. As an example Table 5 contains the major ESR's for the Operations Analysis program.

The graduate will:
DATA ANALYSIS: Possess the skills in probability, statistics, and data analysis required to formulate and execute analyses involving uncertainty, including military operations, logistics, and personnel problems; will be proficient in the principles of probability and statistics and one or more statistical graphics programs, and be able to apply a variety of methods to real data. The graduate will be able to analyze DoD data sets from operations, collected in the field, generated in the laboratory, etc., to answer specific operational questions.
OPTIMIZATION: Possess a solid understanding of what is feasible in the formulation and solution of optimization models of real-world problems, and will explore new and traditional applications of optimization to military problems in logistics, manpower planning, weapons assignment, RD&A project selection, mission planning, asset distribution, scheduling, and resource allocation. The graduate will have experienced the complete development of an optimization model for a military decision problem with emphasis on the creation and presentation of results that are useful to commanders with or without analytical background and defendable to technical experts.
STOCHASTIC MODELING: Be able to formulate and solve problems involving processes with uncertainty over time, including the ability to apply the theory to naval warfare, tactical decision analysis, target search and detection, operational logistics support, fleet maintenance and repair requirements, and military manpower systems.
WARFARE ANALYSIS: Be familiar with U.S./Allied and potential enemy capabilities, doctrine, and tactical concepts and will be able to model and analyze military operations using OR techniques. The graduate will further be able to develop new tactical and logistics concepts based on theory, exercise reconstruction, and analysis.
SYSTEMS ANALYSIS: Understand the principles of economic analysis and their application as reflected in DODI 7041.3, and be aware of the theoretical difficulties of extending these principles to the analysis of weapon systems. The graduate will acquire skill with specific measurement tools for military effectiveness and cost, and will apply them to decisions on tactics, systems and force structure. The development of cost and effectiveness analyses (COEAs) as required for all new weapons systems by DODI 5000.2M will be practiced.
HUMAN FACTORS: Have sufficient knowledge about the human-machine interface to quantitatively link weapon system design features to operator and maintainer performance. By extension the graduate will be able to measure the design's impact on mission capability. Graduates will be able to recognize designs that exploit the strengths and minimize the limitations of people operating combat systems.
INVENTORY: Have knowledge of current OR inventory management models of the three military services and of their analytical foundations. The graduate will understand which models are appropriate for each phase of a weapon system's life cycle. The graduate will be able to formulate new variants of these models as required to support the evolving structure of the joint forces.
JOINT AND MARITIME STRATEGIC PLANNING: Know U.S. and world military history and Joint and maritime planning including the origins and evolution of national and allied strategy; current American and allied military strategies which address the entire spectrum of conflict; the U.S. Maritime Component of National Military Strategy; the organizational structure of the U.S. defense establishment; the role of the Commanders of Unified and Specified Commands in strategic planning; the process of strategic planning; joint and service doctrine, and the roles and missions of each in meeting national strategy.

Table 5: Educational Skill Requirements for Operations Analysis

At NPS courses are designed and taught that include material necessary to meet the ESR's. The following one hundred and fifty five (155) courses, including twenty five (25) taught at the SECRET level and eleven (11) at the TOP SECRET level, are essentially unattainable at civilian institutions, and demonstrate the uniqueness of NPS education. Details of each can be found in the NPS Catalog available though the Office of the Registrar.

COURSE NAME	COURSE NUMBER
Department of Physics	
Non-Acoustic Sensor Systems	PH3002
Weapons Systems and Weapons Effects	PH3006
Physics of Underwater Weapons (SECRET)	PH3479
The Physics of Unconventional Weapons and Weapons Effects	PH3800
Advanced Concepts in Target Surveillance, Acquisition and Engagement	PH4051
Particle Beam and High Energy Laser Weapon Physics (SECRET)	PH4054
Free Electron Laser Physics	PH4055
EO/IR Systems and Countermeasures	PH4209
Sensors, Signals, and Systems	PH4253
Thermal Imaging and Surveillance Systems	PH4254
Physics of Nuclear Explosions (SECRET)	PH4856
Physics of High Velocity Impact Phenomena in Solids	PH4857
Weapons Lethality and Survivability	PH4858
Technical Aspects of Weapons Proliferation, Control and Disposal	PH4859
Simulation of Physical and Weapon Systems	PH4911
Weapons Systems Analysis	SE3004
Radiating Systems	SE3301
Technical Assessment of Weapons Systems (SECRET)	SE4006
Nuclear Warfare Analysis (SECRET)	SE4858
Intro. to the Sonar Equation	PH2401
Physics of Underwater Vehicles	PH3166
Survey of Electro-optic Devices and Systems	PH3200
Survey of Underwater Acoustics	PH3400
Underwater Acoustics	PH3402
Explosives and Explosions	PH3461
Laser Physics	PH4283
Department of Aeronautics and Astronautics	
Survey of Aircraft Missile Technology	AE3005
Aircraft Combat Survivability	AE3251
Missile Aerodynamics	AE3701
Air Defense Lethality	AE3705

Tactical Missile Propulsion	AE4452
Missile Aerodynamics	AE4503
Survey of Tactical Missile Systems	AE4712
Missile Flight Analysis	AE4703
Missile Design	AE4704
Intro. to Avionics (with Radar, EW)	AE3276
Aircraft and Missile Propulsion	AE3451
Propulsion for Launch Vehicles	AE3850
Aircraft Design	AE4273
V/STOL Aircraft Technology	AE4305
Helicopter Design	AE4306
Aircraft Engine Design	AE4451
Laser/Particle Beam Technology	AE4505
Spacecraft Design and Integration	AE4870
Spacecraft Design and Integration	AE4871

Department of Electrical and Computer Engineering

Principles of Radar Systems	EC3670
Navigation, Missile and Avionics Systems (SECRET)	EC4330
Navigation, Missile and Avionics Systems (Unclassified)	EC4340
Radar Systems (SECRET)	EC4610
Radar Systems (Unclassified)	EC4620
High Frequency Techniques (SECRET)	EC4660
Electronic Warfare (SECRET)	EC4670
Electronic Warfare Techniques and Systems (SECRET)	EC4680
Principles of Electronic Warfare	EC4690
Electronic Warfare Computer Applications	EO3780
Electro-optic Systems and Countermeasures (SECRET)	EO4730
Microwave Devices and Radar (SECRET)	EO4760
Electronic Warfare Systems (SECRET)	EO4780
Radar Cross Section	EC4950
Sonar Systems Engineering	EC4450

Department of Mechanical Engineering

Surface Ship Survivability	ME3950
Naval Ship Shock Design and Analysis	ME4525
Shipboard Vibration and Noise	ME4522
Material Selection for Military Applications	MS3505
Nuclear Power Systems	ME3230
Marine Vehicle Design	ME4721
Intro. to Naval Architecture	ME2301
Corrosion and Marine Environmental Degradation	MS3304

Departments of Meteorology and Oceanography

Meteorology for Antisubmarine Warfare	MR2413
Meteorology for Electronic Warfare	MR2416
Operational Acoustic Forecasting (SECRET)	OC3266
Remote Sensing and Atmospheric Factors in C3	MR3419
Advanced Air/Sea Interaction	MR/OC4414
Atmospheric Factors in Electromagnetic and Optical Propagation	MR4416
Coastal Meteorology	MR4800
Air/Ocean Remote Sensing for Interdisciplinary curricula	SS3525
Advanced Applications of Overhead Systems * (TOP SECRET)	SS4525
Polar Meteorology/Oceanography	MR/OC3212
Tropospheric and Stratospheric Meteorology/Laboratory	MR3234
Tropical Meteorology/Laboratory	MR3252
Operational Atmospheric Prediction/Laboratory	MR3262
Remote Sensing of the Atmosphere and Ocean	MR/OC3522
Operational Oceanography	OC3570
Ocean Acoustics and Prediction	OC4267
Elements of Ocean Prediction	OC4335
Ocean Acoustic Tomography	OC4490

Department of National Security Affairs

Intelligence Systems and Products (TOP SECRET)	NS3151
Naval Warfare and the Threat Environment	NS3152
Principles of Operational Intelligence (TOP SECRET)	NS3159
Problems of Intelligence and Threat Analysis	NS4152
Technology and Strategic Planning (SECRET)	NS4253
Nuclear Weapons and Foreign Policy	NS3280
Seminar on Arms Control and National Security	NS3950

Department of Operations Research

Introduction to Naval Logistics	OA3610
Campaign Analysis (SECRET)	OA4602
Test and Evaluation	OA4603
War Gaming Analysis (SECRET)	OA4604
OR Problems in Naval Warfare	OA4605
Applications of Search, Detection, and Localization Models to ASW (SECRET)	OA4606
Tactical Decision Aids	OA4607
Logistics in Naval Warfare (SECRET)	OA4611
Operational Logistics Models (SECRET)	OA4612

AIRLAND Combat Models I	OA4654
AIRLAND Combat Models II	OA4655
Operations Research for Electronic Warfare	OS3003
Human Factors for Antisubmarine Warfare	OS3402
Human Factors for Electronic Warfare	OS3403
Search, Detection, and Localization Models	OS3601
ASW Combat Analysis	OS3602
Simulation and Wargaming	OS3603
Architecture for C3I Systems (TOP SECRET)	OS3636
Test and Evaluation	OS4601
C3 Systems Evaluation	OS4602
Combat Models and Games	OA3601
Search Theory and Detection	OA3602
Reliability and Weapons System Effectiveness Measurement	OA4302
Mobilization	OA4610

Department of Computer Science

Computers in Combat Systems	CS3550
Advanced Robotic Systems	CS4313
Computer Security	CS4601
Software Engineering in Ada	CS4530

Department of Administrative Sciences

Navy Telecommunications Systems	CM3112
Financial Management in the Armed Forces	MN3154
Systems Acquisition and Project Management	MN3301
Principles of Acquisition and Contracting	MN3303
Contract Administration	MN3305
Project Management Exercise	MN3311
Material Logistics	MN3372
Imbedded System Software Acquisition Management	MN3309
Contracting for Major Systems	MN4301
Defense Resource Policy and Management	MN4302
Acquisition and Contracting Policy	MN4371
Defense Transportation and Systems (SECRET)	MN4376
Software Engineering and Management	IS4300
Public Policy and Budgeting	MN3172
Contract Pricing and Negotiations	MN3304
ADP Acquisition	MN3307
Contract Law	MN3312
Contracts Management and Administration	MN3371

Technology Transfer	MN3801
Policy Analysis	MN4145
Logistics Engineering	MN4310
C3 Academic Group	
Introduction to C3 (SECRET)	CC3000
Modeling C3	CC3001
C3 Mission and Organization (SECRET)	CC3111
C3 Systems Architecture and Engineering I (TOP SECRET)	CC4001
C3 Systems Architecture and Engineering II (TOP SECRET)	CC4002
C3 Systems Evaluation (TOP SECRET)	CC4003
C3 in NATO (SECRET)	CC4004
Policies and Problems in C3 (TOP SECRET)	CC4113
Combat Systems Engineering (SECRET)	CC4200
Advanced C2 Analytical Concepts	CC4006
Space Systems Academic Group	
Military Applications in Space (TOP SECRET)	SS3001
Decisions and Space Systems (TOP SECRET)	SS4001
Military Operations in Space (TOP SECRET)	SS4002
Introduction to Space	SS2001
Remote Sensing	SS3525

5. Efficiencies through Year-Round Operations and Workload

Approximately seventy percent (70%) of the cost of officer graduate education is the officer's salary, which of course is independent of the institution to which the officer is assigned. Because of this fact cost effectiveness obviously depends on the amount of education a student receives in a given period. Because of higher workloads and year-round operations the annual amount of education received at NPS is considerably higher than can be obtained at CIVINS.

The standard measure for education *workload* is class *contact hours per week*. If a student is enrolled in four classes, two of which meet 3 hours per week and two that meet 4 hours, the *student's workload* is 14 hours per week. If the course continued for 16 weeks (a semester) the student would receive a total *quantity of education* of 14x16 = 224 *contact hours*. In other words, this would be the time spent with a faculty member or teaching assistant receiving instruction. There are other activities that receive credit for education other than regular lectures in classes. Credit is also given for laboratory periods, thesis study and preparation, major field experiments etc. All educational institutions use factors to convert the time spent on such activities into *equivalent contact hours*. When comparing the amount of education at different institutions the appropriate measure to use is the total equivalent contact hours in a given time period. Since an officer is paid continuously, even if the institution does not operate continuously the appropriate time period to use is one full year.

NPS operates all year on a quarter system, each quarter of which is 12 weeks. Thus classes are in session 48 out of the 52 weeks. The standard workload at NPS is four 4-hour courses, or 16 hours per week. At CIVINS the norm for regular classes is two 16 week semesters for a total

of 32 weeks, with a very limited selection of classes available in a summer session (usually 6-12 weeks). During regular semesters, most CIVINS, especially the major research universities such as those listed in [1] limit the number of contact hours of graduate students to 12/week.

A survey of actual student loads taken from academic transcripts shows that the average workload achieved at NPS is approximately 17 equivalent contact hours per week. When this is multiplied by the number of weeks in class, an NPS student receives 17x12x4 = 816 contact hours per year. A survey of actual student loads taken from academic transcripts shows that the average workload achieved at CIVINS is approximately 13 equivalent contact hours per week during a regular semester, and 7 hours per week during a 10 week summer session. Thus a CIVINS student receives 13x16x2 + 7x10 = 486 contact hours per year, or approximately 59% of that obtained at NPS. It would take approximately two years at a CIVINS in regular academic session (summer courses almost always cover basic material taught by graduate students) to receive the quantity of education received at NPS in one year.

This large difference results from the inherent structure of NPS vis-a-vis CIVINS and is not something that will not change significantly in the foreseeable future. Such a change would require a restructuring of U.S. higher education. The nine campus system of the University of California moved to year-round operations in the late 1960's in an attempt to improve the utilization of its considerable investment in facilities. It failed and was abandoned after a few years.

6. Faculty, Research, and Navy Interactions

Like faculty at all institutions that offer quality graduate education, almost all civilian faculty at NPS hold a doctorate degree and carry out established research programs in addition to courses of instruction. Whereas at CIVINS the emphasis is on basic research supported in large part by the National Science Foundation (NSF), at NPS there is naturally considerable interest in, and support for, areas of specific benefit to Navy and DoD in general both at the basic and applied research levels. Faculty interested in defense-related areas often do not find the environment in many CIVINS supports their interests, and it is virtually impossible to engage in classified work at those institutions. NPS faculty also compete and win support from NSF, but other sources of NPS faculty research support include Navy laboratories, the SYSCOMS, OPNAV, Army and Air Force labs, DoD agencies and JCS. Table 6 contains titles of a sample of the more than 300 research projects under way at NPS at any time, most of which are funded reimbursably.

7. The Student Body

NPS educates military officers from all services and a broad spectrum of foreign countries. Graduates can be found in senior military and government defense positions in forty countries. In 1993 the total enrollment is approximately 1700, distributed as follows:

Navy	69%
Marine Corps	6%
Army	8%
Air Force	4%
Other US[1]	3%
International	10%

1. Includes Coast Guard, NOAA, DoD civilian, including Navy Labs.

ASW
Wavelets and Underwater Surveillance
Barents Sea Acoustic Tomography Experiment
EW
Impulse Radar Target Detection and Identification
Integrated Air Defense Networks
JOINT C3
Impact of C3 Information on Operations
Survivability of UHF Follow-On Satellite Communications
SPACE SYSTEMS
pace Thermoacoustic Refrigerator with No Moving Parts
Geolocation of Radar Emitters
AERO ENGINEERING
High-angle-of-attack Missile Aerodynamics
Unmanned Air Vehicle (UAV) Technology
ELECTRONIC SYSTEMS ENGINEERING
Electromagnetic Scattering and Low Observables
Radar Target Detection and Identification
NAVAL ENGINEERING
Dynamic Systems, Controls and Robotics for Underwater and Space Systems
Surface Ship Survivability Design Methods
COMBAT SYSTEMS SCIENCES AND TECHNOLOGY
Target Acquisition and Surveillance
Conventional and non-Conventional Weapons and Effects
AIR/OCEAN SCIENCES
Coastal Meteorology and Oceanography - Field Programs and Modeling
Remote Sensing of Aerosols in Coastal Regions
OPERATIONS ANALYSIS
Theater Ballistic Missile Defense Systems
Optimizations of Munitions, Sorties and Penetration Aids
OPERATIONS LOGISTICS
Wargaming and Analysis of Logistics
Stochastic Modeling and Simulations for Network and Ammunition Inventory Planning
NATIONAL SECURITY AFFAIRS
Strategic Conventional Deterrence
Ukrainian Defense and Security Perspective
MANAGEMENT
Defense Logistics and Transportation
Manpower, Personnel and Training Analysis for Navy and OSD
COMPUTER SCIENCE
Artificial Intelligence and Robotics
Ada Prototyping

Table 6: Sample of NPS Research Projects

Currently the number of foreign countries represented is 28. The Naval officers are distributed as follows:

Unrestricted Line	70%
Restricted Line	20%
Staff Corps	10%

This mix of officers from diverse communities work closely in both classwork and on research projects over a period of 18 to 24 months. There is a considerable amount of "education" that takes place through these interactions that is difficult to measure, but it is real. One tangible measure of its success is that Germany, Indonesia and South Korea each has its owns military graduate school based on NPS.

8. Summary

The Naval Postgraduate School was founded in 1909, primarily to ensure that the proven unrestricted line officer maintains the technical and managerial expertise required to acquire, operate and manage an increasingly technical and complex Navy. This requirement is even more true today. Recognizing the URL officer's educational background, specialized educational needs, and time restrictions placed on availability in a crowded career, NPS is structured to provide graduate education in the most efficient and cost-effective manner; it operates year-round with programs tailored to military officers with very limited time, and who for the most part do not qualify for direct entrance into technical programs at civilian universities. The programs and many of the individual courses NPS offers are unique and not available at civilian institutions.

9. References

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[3] An Act to establish the United States Naval Postgraduate School. Public Law 303, 31 July, 1947

[4] Secretary of the Navy Letter, serial 4868P21 dated 5 December 1951.

[5] Secretary of the Navy Letter, serial 562P24 dated 8 September 1947.

[6] BUPERS INSTRUCTION 1520.43A dated 7 April 1958.

[7] Chief of Naval Personnel letter, Pers-C1222-mns, dated 6 June 1956.

[8] NPS Superintendent letter, serial 1024.1 dated 15 June 1962 to Chief of Naval Personnel.

[9] Chief of Naval Personnel letter to NPS Superintendent, Pers-111-pal, dated 16 January 1963.

[10] Report of the Visiting Committee, Department of Business Administration and Economic, Dean W. F. Pounds, MIT (Chairman), 8 July, 1970.

[11] Report of Conference on Management Program Objectives at Naval Postgraduate School, R. G. Freeman, CAPT USN (Chairman), 15 January 1971.

[12] Report of the Navy Graduate Education Program Select Study Committee for the Secretary of the Navy, Provost G. J. Maslach, University of California at Berkeley (Chairman), 9 September 1975.

[13] NAVPERS 15839H, Manual of Navy Officer Manpower and Personnel Classifications, 1 May, 1992.

[14] OPNAV INSTRUCTION 1000.16G, Manual of Navy Total Force Manpower.

[15] DoD INSTRUCTION 1320.10, Policy on Graduate Education for Military Officers.

[16] OPNAV INSTRUCTION 1520.23B, Graduate Education.

[17] OPNAV NOTE 1520, Fully Funded Graduate Education Program, FY93.

[18] *Compilation of Abstracts of Theses*, Code 08, Naval Postgraduate School, Monterey, CA 93953.