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INTEGRATION AND IMPLICATION OF SPACE EDUCATION AT THE UNITED STATES NAVAL ACADEMY

by

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Space competency is critical to winning our future wars. Over the past 60 years, the United States Navy (USN) has played an essential role as an active enabler of space-based capabilities. In this day and age, when adversaries continue to mature their own space capabilities to deny U.S. capabilities, further developing space-based systems for Naval and Marine Corps operations is imperative.

While the USN's professional Naval Space Cadre has grown in numbers and improved its proficiency in recent years, the USN must invest in space support to the warfighter in order to increase space-based fleet training that will strengthen the cadre as well as the end users. This thesis identifies gaps in the space-based education that is being provided to the Midshipmen at the United States Naval Academy. This study finds that the United States Naval Academy needs to increase awareness of the Navy and Marine Corps' reliance on space-based systems, and to emphasize the growing need for space professionals, through education. Expanding curricula to Midshipmen on space-based systems and operations could be the key to enhancing the Navy Space Cadre for the future and protecting warfighters.

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INTEGRATION AND IMPLICATION OF SPACE EDUCATION AT THE UNITED STATES NAVAL ACADEMY

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF ACRONYMS AND ABBREVIATIONS

1/C	first class Midshipmen (senior)
2/C	second class Midshipmen (junior)
3/C	third class Midshipmen (sophomore)
4/C	fourth class Midshipmen (freshman)
AEDO	aerospace engineering duty officer
AIS	automated identification system
AQD	additional qualification designator
C3	command, control, and communications
CCDR	combatant commanders
CDRUSSTRAT-COM	Commander, United States Strategic Command
CNO N2N6	Deputy Chief of Naval Operations for Information Warfare
CNO	Chief of Naval Operations
COMFLTCYBER-COM	Commander, U.S. Fleet Cyber Command
COMTENTHFLT	Commander, 10th Fleet
COP	common operational picture
CSR	competency skill requirements
DC I	Deputy Commandant for Information
DC PP&O	Deputy Commandant for Plans, Policies, and Operations
DOD	Department of Defense
DODIN	Department of Defense Information Network
DoN	Department of the Navy
DS4	Director, Space Forces
DSC	defensive space control
DSP	Defense Support Program
EDO	engineering duty officer
EO	electro-optics
EOD	explosive ordinance disposal
ESR	educational skill requirements

FLTSAT	fleet satellite
FLTSATCOM	fleet satellite communications system
FY	fiscal year
G-2	intelligence
G-3	operations
G-6	security and communications
GEO	geosynchronous/geostationary earth orbit
GIS	geospatial information science
GPS	global positioning system
HEO	highly elliptical orbit
IMA	individual mobilization augmentees
IMINT	imagery intelligence
ISA0	interdisciplinary science major
ISR	intelligence, surveillance and reconnaissance
IW	information warfare
IWC	information warfare community
JFSCC	Joint Force Space Component Command
JO	junior officer
JP 3-14	Joint Publication 3-14
JSpOC	Joint Space Operations Center
JSTO	joint space tracking order
LEO	low earth orbit
LOS	line of sight
MAGTF	Marine Air Ground Task Force
MARFORSTRAT	Marine Corps Forces Strategic Command
MASINT	measurement and signature intelligence
MAWTS-1	Marine Air Wing Training Squadron One
MEO	medium earth orbit
METOC	meteorological and oceanography
MILSATCOM	military satellite communications
MOC	maritime operations center
MQS	midshipmen qualification standards

MSC	marine space cadre
MTP	Midshipmen Training Program
MUOS	Mobile User Objective System
NAVIFOR	Naval Information Forces
NAVSOC	Naval Satellite Operations Center
NPS	Naval Postgraduate School
NSC	Navy Space Cadre
NSDC	National Space Defense Center
NSSI	National Security Space Institute
NTM	national technical means
OPCON	operational control
OPNAVINST	Chief of Naval Operations Instruction
OSC	offensive space control
PCA	professional competency assessments
PCB	professional competency boards
PERS	Navy Personnel Command
PNT	positioning, navigation and timing
PQS	personnel qualification standard
PROKNOW	professional knowledge
R&D	research and development
S&T	science and technology
SATCOM	satellite communications
SCA	space coordinating authority
SCIF	Sensitive Compartmented Information Facility
SecDef	Secretary of Defense
SEP	space effects packages
SIGINT	signals intelligence
SMD	space and missile defense
SME	subject matter expert
SPA0N	space science minor
SSA	space situational awareness
SSAG	Space Systems Academic Group

SSC0	space science major
SSP	space support plan
SSR	space support requests
TTP	tactics, techniques and procedures
UFO	Ultra-High Frequency Follow On
UHF	ultra-high frequency
URL	unrestricted line
USAFA	United States Air Force Academy
USMA	United States Military Academy
USMC	United States Marine Corps
USN	United States Navy
USNA	United States Naval Academy
USSTRATCOM	United States Strategic Command

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I. INTRODUCTION

A. BACKGROUND

The United States Navy (USN) has been involved in space operations since post World War II with the inceptions of rockets, missiles, and satellites. The USN launched the nation's second satellite under the Vanguard program. Following the end of the Cold War, the Navy's role in space was reduced as the Air Force took over the majority of space based operations. However, the Navy continued its reliance on space systems for information and communication networks at sea and across the globe. Over the years, the Navy has been involved in many joint programs with the Army and the Air Force and has led the way through the use of ultra-high frequency (UHF) satellite communications (SATCOM) systems with Fleet Satellite Communications System (FLTSATCOM), Ultra-High Frequency Follow On (UFO), and continues today with the Mobile User Objective System (MUOS). The Navy built the space fence in 1961 and operated it until 2004 when the Navy relinquished responsibility to the Air Force.

During Operation Desert Storm, a new fighting domain was established by the United States that would shape the way for future wars. Satellite networks, integrated communications, and global positioning systems (GPS) were introduced, leveraging technical capabilities at the tactical level. In 2001, Congress highlighted a concern of space assets and their role in military operations. With national security as their highest interest, Congress appointed the Space Commission, formally known as the Commission to Assess United States National Security Space Management and Organization. "The Commission was directed to assess the organization and management of space activities in support of U.S. national security. … The Commission unanimously concluded that the

security and well-being of the United States, its allies and friends depend on the nation's ability to operate in space."[1]

As a result of the Commission, all services were required to form a space cadre. The formalization of the Navy Space Cadre (NSC) was a result of the commission to ensure the Navy's (and other services') abilities to operate in space. Directed by the Secretary of the Navy, the Navy Space Policy was introduced, directing both the Navy and United States Marine Corps (USMC) to develop and maintain a space cadre.[2] Members of the NSC were provided space education and experience but remained in their original communities: "By grooming talented, educated, and operationally proven people to assume key decision making positions in space, the Space Cadre cross-designator community enables warfighters to succeed across the spectrum of conflict."[3] At the time, the only formal source of space education for NSC members to earn a subspecialty code was the space systems operations and space systems engineering curricula at the Naval Postgraduate School (NPS). As a result of the Space Policy, the Space Systems Certificate Program was added to the NPS space curriculum in 2006, to expand space education to students other than the space systems engineers and operators and in distance learning setting.[4] In 2010, the NSC issued its own personnel qualification standard (PQS) that would allow individuals to assimilate without receiving a graduate level space education at NPS. In 2012, the additional qualification designator (AQD) structure was introduced; with the addition of NPS and the PQS, the Navy could now use the AQD to track its space cadre members and billets, ensuring the placement of qualified individuals in proper space-related billets for their experience level, supporting the needs

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[1] The Commission to Assess United States National Security Space Management and Organization was established pursuant to Public Law 106-65 on January 11, 2001. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization, Executive Summary, Pursuant to Public Law 106-65 January 11, 2001* (Washington, DC: Commission to Assess United States National Security Space Management and Organization, 2001), 7, https://fas.org/spp/military/commission/executive_summary.pdf.

[2] Department of the Navy, *Department of the Navy Space Policy*, SECNAVINST 5400.39C (Washington, DC: Department of the Navy Space Policy, 2004).

[3] Naval Network Warfare Command, *Navy Space Cadre Human Capital Strategy* (Virginia Beach, VA: Naval Network Warfare Command, 2004), 2.

[4] Naval Postgraduate School, *Academic Catalog, Space Systems Certificate* (Monterey, CA: Naval Postgraduate School, 2017), 154.

of the space cadre. Although many steps have been taken to grow the space cadre community, training and education, the NSC is still deficient based on current requirements in space operations compared to the United States Air Force and the United States Army.

Space is the new "high ground" of a battlefield. Over the past 60 years, the United States has operated with impunity in the space domain. Today, we are threatened by a contested space environment where multiple adversaries target the use of our innovative assets to gain knowledge, but also to exploit, deny and degrade U.S. capabilities. By relying on our freedom in the space domain, we have grown dependent on the luxury of owning space. We have allowed our technological advances to become our Achilles heel—one shot could have a crippling effect on fleet communications and operations. So how do we protect ourselves while maintaining our superiority of the space domain? We must generate a conversation and take action. The Army and Air Force both demand proficient members in their space communities who can provide technological expertise, with continuing career-long education in specific areas, such as engineering, science, and space application that directly affect the space domain and provide mission effectiveness. Naval and Marine forces are not carrying their weight to help in this fight because they do not provide a formal career path in space with sustained education. We must advocate for a smarter Naval and Marine force to prove ourselves more space capable in a contested environment and it is essential we start with a knowledge baseline of space education. Sustaining space competency will be critical to winning our future wars.

The Air Force and Army are taking advantage of this opportunity to grow their space communities by incorporating space education and space operations into their service academies' undergraduate curriculum. The U.S. Naval Academy (USNA) is not preparing its young leaders to take on these roles because it does not provide them with a space-based education at the undergraduate level. The United States Military Academy (USMA) at West Point and the United States Air Force Academy (USAFA) both offer majors programs that include a "space operations" type curriculum or classes. Young naval officers are entering the fleet lacking knowledge of the current, everyday systems used in space application, whether in the air, on the ground or at sea, or of the adversaries

who oppose them, leaving us vulnerable. By accepting the fact that the Navy and Marine Corps are vulnerable in the area of space education, it is imperative for us to diversify our space capabilities for the near future. In doing so, we can adopt practices that will provide education that increases awareness of our joint reliance on space-based systems as well as the need for qualified space professionals.

B. PURPOSE

This thesis was derived from OPNAVINST 5400.43B, (draft, soon to be released, current version is 540.43A), "Navy Space Policy Implementation," which was directed by Chief of Naval Operations (CNO) for Information Warfare, Vice Admiral Jan Tighe. The purpose of the OPNAVINST is to establish Navy roles and responsibilities for implementing Department of Defense (DOD) and Department of the Navy (DoN) space policies, and to provide an organizational structure with regard to identifying specific requirements which support space-related education and training. The OPNAVINST identifies the Navy's warfighting needs in the space domain and amplifies the need to provide enhanced coordination of space issues in order to support them.[5]

The Navy will continue to enhance space support to the warfighter, increase space-related fleet training, and strengthen its cadre of space professionals. It will continue to provide space-related, mission-essential products and services and maintain a comprehensive knowledge of adversary space and counter-space capabilities. Additionally, the OPNAVINST states that the USNA will provide education that increases awareness of the Navy's reliance on space-based systems, and provide space professionals to the fleet.

The scope of this thesis is to identify methods to integrate space-based capabilities into training, education and employment for Midshipmen at the USNA. By conducting analysis of current education programs of the USNA, space education may be implemented into the Midshipmen core curriculum which may have great implications that could set the conditions for smarter and better equipped operating fleet forces.

[5] Department of the Navy, *Navy Space Policy Implementation: Responsibilities*, OPNAVINST 5400.43B (Draft) (Washington, DC: Chief of Naval Operations, 2017).

C. RESEARCH QUESTIONS

The following research questions frame the problem at hand:

- Is the USNA providing education that increases awareness of the Navy and Marine Corps' reliance on space-based systems, as well as the need for space professionals?
- Is the fleet meeting the requirements of developing and sustaining a trained and educated cadre of space professionals?
- What is the minimum educational criterion that all Midshipmen should know about space?
- Should there be a second level of classified information that should be included?

D. BENEFIT OF STUDY

This thesis identifies the issue that space education is not just a problem within the USNA, but within the service of the Navy and the Marine Corps as a whole. The USNA is just a small branch of the problem; however, it is a strong location to start. Space is a critical enabler of the Navy's and Marine Corps' maritime and Marine Air Ground Task Force (MAGTF) operations. Space is no longer a luxury but a necessity as it has become a contested domain destined for war. As our adversaries continue to mature their space capabilities and deny U.S. capabilities, it has become critical that we invest in space education to provide for a smarter Navy and Marine Corps. By adding a space-based curriculum at the USNA, we are building a stepping stone to developing a more space capable Navy and Marine Corps.

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II. ANALYSIS OF U.S. NAVY AND MARINE CORPS SPACE CADRE AND SUPPORT REQUIREMENTS

A. POLICY

Under the Navy Space Policy, the Navy and Marine Corps are responsible for providing space capabilities throughout the DoN and joint forces. They will provide assistance in shaping joint plans and considerations on future space system capabilities in order to ensure mission effectiveness over all maritime operations across the globe. Additionally, it is the responsibility of the Navy and Marines to recruit, educate, qualify, and retain a professional space cadre. Both entities will ensure that the integration of space-based systems, capabilities, knowledge and training are understood by commanders and warfighters across the services.[6]

B. SPACE RELIANCE

The Navy and Marine Corps heavily rely on space systems to provide intelligence, surveillance and reconnaissance (ISR), positioning, navigation and timing (PNT), persistent communications, meteorological data, and early missile warning. The use of these capabilities is a requirement to winning naval and maritime operations. Sailors and Marines are constantly at sea, across the globe. Without the use of space assets, the Navy becomes blind and limited in its capabilities. Arguably, due to the decentralized and disaggregated disposition of the Navy and Marine Corps, the two services rely on the use space capabilities more than any other service. Denial of space assets due to adversary interference or natural phenomena could cripple fleet operations resources and timeliness. Operating in such a severely contested environment, such as the space domain, requires the Navy and Marine Corps to accelerate and advance its level of space expertise among all of their warfighters. The NSC and marine space cadre (MSC) must be able to integrate basic space knowledge into training and education in order to develop and sustain a constant force of readiness in the space domain just as they do with air, surface, subsurface and expeditionary readiness.

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[6] Department of the Navy, *Department of the Navy Space Policy*, SECNAVIST 5400.39D (Washington, DC: Secretary of the Navy, 2015), 2.

C. MANPOWER NAVY SPACE CADRE

Due to the Navy's high reliance on space-based systems, it is critical for the NSC to possess trained and billeted space experts across the maritime and joint domain; however, the NSC has proven that it lacks these much needed space experts and training. The NSC is distributed over 23 designators; 42% information warfare (IW), 30% unrestricted line (URL), 26% engineering and aerospace engineering duty officer (EDO/AEDO), and 2% categorized as "Other," for a total of 374 members.[7]

Current challenges faced by the NSC are the lack of a formal community and a lack of space experience. The cadre does not possess a detailer or community manager nor does it draw a line of a formal career path. Gaps in key billets are filled with unqualified officers as multiple space tours are rare and perceived as career killing. In addition, space is viewed as a low priority on selection boards (#19 for Space Cadre and #20 for URL), which makes it difficult to hold a stable community of NSC members.[8]

D. RESPONSIBILITIES

1. Navy Space Cadre Responsibilities

The NSC is an active force which provides technical expertise on space capabilities to establish a standard range of Navy and Joint warfighting requirements. Commander, U.S. Fleet Cyber Command (COMFLTCYBERCOM) Commander, Tenth Fleet (COMTENTHFLT), is the authority for the Navy's space constellations and the head of space in support of maritime forces across the globe.[9] According to the Joint Publication 3-14 (JP 3-14), "The USN is DOD's lead Service for narrowband SATCOM, performing satellite operations from the Naval Satellite Operations Center [NAVSOC]."[10] Located at Naval Base Ventura County, NAVSOC controls the Navy's three satellite constellations, ground systems, and the Naval Satellite Control Network. These systems provide

[7] Brian Brown, "Navy Space Cadre Overview" (PowerPoint presentation, Naval Postgraduate School, August 2017), 3.

[8] Brown, 5.

[9] Chairman of the Joint Chiefs of Staff, *Space Operations*, Joint Publication 3-14 (Washington, DC: Chairman of the Joint Chiefs of Staff, 2018), III–5, https://fas.org/irp/doddir/dod/jp3_14.pdf.

[10] Chairman of the Joint Chiefs of Staff, III–5.

narrowband UHF SATCOM global support to Naval and joint forces, as well as other partnered agencies. It is the responsibility of the NSC to provide operational support and expertise on space capabilities to the commander and staff. Additional responsibilities include:

- Provides operational support and expertise on space capabilities to the commander and staff
- Integrates and synchronizes space force enhancement capabilities including missile warning Defense Support Program (DSP), navigation (GPS), environmental monitoring, and SATCOM into operational plans and execution
- Ensures the [space support plan] SSP supports current operations, as well as future plans
- Ensures that [space effects packages] SEPs are tailored to adequately support the SSP
- Prepares, submits, monitors status, and tracks changes for strike group [space support requests] SSRs
- Monitors the joint space tasking order (JSTO), and informs appropriate staff of any potential impacts to space systems related to JSTO events
- Coordinates with other space operations entities, such as other strike group space operations officers in theater, [maritime operations center] MOC space operations officers, and the theater [space coordinating authority] SCA via the [Director, Space Forces] DS4
- Plans for and coordinates the effects of offensive and defensive space control (DSC) measures on operations
- Integrates appropriate emerging space capabilities into plans and operations[11]

The NSC is comprised of officers, enlisted (active duty and reserves), and civilians who formulate Navy space policy, conduct space-related science and technology (S&T) and

[11] Naval Network Warfare Command, *Naval Space Handbook* (Norfolk, VA: Naval Network Warfare Command, 2018), 51–53.

research and development (R&D), acquire Navy, joint, and national space systems, operate spacecraft and employ space-based tactics, techniques and procedures (TTPs) for maritime operations.

2. Marine Corps Space Cadre Responsibilities

The Marine Corps Space Cadre manages the education training and experience of space subject matter experts (SMEs) who are designated as either space officers (8866) or space operations staff officers (0540). Marine Corps billets are located throughout the Marine Corps operating forces and the joint community.[12] It is the responsibility of the Marine Corps Space Cadre to provide operational support and expertise on space capabilities to the commander and staff. Additional responsibilities include:

- Monitor JSTO and inform appropriate staff of potential impacts of JSTO events to operations
- Provide PNT systems capabilities input to G-3/6 for planning and operations [The letter "G" is a representation of the staff level and the number "3" specifies the specific shop or structure, i.e., G-3 represents operations, G-6 represents security and communications.]
- Ensure informational paths for missile warning messages are properly integrated
- Provide SATCOM systems space segment expertise to G-6
- Provide space-based ISR capabilities to expertise to G-2 [Intelligence]
- Advise command of space or terrestrial weather impacts to space systems or capabilities
- Plan for and coordinate the effects of offensive and DSC measures on operations
- Integrate space capabilities into the planning process
- Coordinate space requirements
- Capture space lessons learned

[12] Naval Network Warfare Command, 71.

- Integrate space operations into training exercises[13]

Collectively, the Navy and Marine Corps oversee a vast amount of responsibilities in regard to the space domain. In an era where space is considered to be the new high ground, it is imperative that the Navy and Marine Corps generate a conversation and take action in order to adapt to the future battlefield of space.

E. FUTURE OF THE NAVY SPACE CADRE

The NSC recognizes gaps within the community and is working toward solutions to effectively provide a more space-capable force through sustained education and career opportunities. Currently, the NSC is considering transferring the assistant space cadre advisor duties from Navy Personnel Command (PERS) 45, the Navy Distribution Management office to PERS 47, the Navy information warfare community (IWC). The NSC advisor role currently resides within Naval Information Forces (NAVIFOR).[14] Integrating the NSC into IWC affords an opportunity to develop a specialty career path for officers in the space community at the O4/LCDR level where they may remain in their parent community. As a growing community, it seems logical to include the NSC in IWC as it is the responsibility of the Deputy Chief of Naval Operations for Information Warfare (CNO N2N6) to coordinate naval matters with regard to space-related policy and strategy, along with many other responsibilities.[15]

Additionally, the NSC is reviewing the current AQD standards, specifically how to grow space knowledge and to more effectively utilize space experience. Setting new AQD standards and integrating the community as previously mentioned, builds an area to develop a specialty career path for restricted and URL officers in the space community. In doing so, space may be leveraged as a higher priority when it comes to selection boards and career opportunity, where it has been perceived as detrimental in the past.

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[13] Naval Network Warfare Command, 74.

[14] Joseph Spegele, email message to author, March 2, 2018.

[15] Department of the Navy, *Navy Space Policy Implementation*, 2.

To date, the Navy Space Leadership Council has been re-established to promote, influence and guide space initiatives to provide commanders with combat effective naval forces and to develop a professional NSC. Extensive billet-based reviews have been conducted to identify critical billets to better align required experience. Changes to the AQD standards will help to build space expertise earlier in careers and provide qualified officers to those key billets. Additionally, space has been added as a critical skill in IWC selection boards for fiscal year 2018 (FY18) to increase the priority of space on selection boards.

F. FUTURE MARINE SPACE CADRE

The Commander, Marine Corps Forces Strategic Command (MARFORSTRAT) is the USMC Component Commander to U.S. Strategic Command (USSTRATCOM), who advises the USMC commands and supporting establishment in space capabilities, as well as a variety of necessary competencies to ensure joint situational awareness and successful integration of USMC operations with USSTRATCOM. Currently, the Marine Corps is transitioning the responsibility of the space proponent from the Deputy Commandant for Plans, Policies, and Operations (DC PP&O) to the Deputy Commandant for Information (DC I). DC I is awaiting confirmation as Commander of MARFORSTRAT. Marine Force Space is advocating for a more sufficient space structure and facilitating support to new USMC billets, such as at the National Space Defense Center (NSDC).

MARFORSTRAT wants to establish organic space capabilities, such as Marine Space Aggressor Teams and Marine Space Support Teams (similar to the Air Force Space Aggressor Squadron and Army Space Support Teams), using space individual mobilization augmentees (IMA) detachments for denied and degraded training at Marine Air Wing Training Squadron One (MAWTS-1). Additionally, the Marine Corps is billeting MAGTF staffs with space operations officers to provide capabilities and expertise in the space domain to educate and train commanders and warfighters on the reliance on space systems in the arenas of air, land, sea, and cyber.[16]

[16] Joseph Horvath, "Space Operations Warfighting Seminar MARFORSTRAT" (PowerPoint presentation, Naval Postgraduate School, February 25, 2018).

III. THE UNITED STATES NAVAL ACADEMY PROFESSIONAL AND ACADEMIC DEVELOPMENT

A. MIDSHIPMEN PROFESSIONAL DEVELOPMENT

The United States Naval Academy (USNA) requires Midshipmen to attain a core professional knowledge (PROKNOW) prior to commissioning as Ensigns and Second Lieutenants in the Navy and Marine Corps services. To accomplish these requirements, the USNA training department has developed the Midshipmen Training Program (MTP) that consists of six components: midshipmen qualification standards (MQS), references, instruction periods, fourth class Midshipmen (freshman) (4/C) pro-quizzes/exams, professional competency boards (PCB), and professional competency assessments (PCA). These six segments are intended to prepare Midshipmen for summer training, service assignment preferences, and life as a junior officer in the fleet.[17] Integrating space education into the MTP could have great implications for Midshipmen professional development. Segments of space operations pertaining to Midshipman rank may be added to MQS with ease, securing a standard knowledge and baseline for space education for all Midshipmen prior to graduation.

B. MIDSHIPMEN ACADEMIC DEVELOPMENT

It is a requirement at the USNA that each Midshipman achieves a foundation of courses which form a core curriculum including mathematics, science, engineering, humanities and leadership courses. According to the USNA academics program, "The core curriculum is the intellectual foundation for midshipmen. The academic interdisciplinary core consists of an integrated program of studies that prepares midshipmen to pursue a major, receive post-graduate technical training, serve in any warfare specialty, and pursue a career serving their country as professional officers in the

17 "Training, Professional Knowledge," United States Naval Academy, 2017–2018, https://www.usna.edu/Training/_files/documents/References/4C%20MQS%20References/Pro%20Book%202017-2018.pdf#search=pro%20knowledge.

Naval Service."[18] Within the core course requirements, there are areas in which space education may be integrated with appropriate curriculum. Courses identified that would have a natural flow and considered required for graduation are: SI110, Introduction to Cyber Security; NN310, Advanced Navigation; ES300, Naval Weapons Systems, and the NS42xx, junior officer (JO) practicum courses that include surface warfare, submarine warfare, naval aviation, Marine Corps, special warfare, and explosive ordinance disposal (EOD).

JO Practicum courses are a comprehensive introduction of basic concepts for first class (1/C) Midshipmen who are about to enter the fleet as JOs. Naval Weapons Systems, ES300, provides Midshipmen with an introduction to weapons systems used in the fleet and focuses on sensors, tracking, and delivery methods used to employ these systems. Advanced Navigation, NN310, provides Midshipmen with advanced navigation and seamanship skills built upon the prerequisite courses. It introduces advanced technologies for navigation, such as radar and electronic navigation. Lastly, Cyber Security, SY110, is an introduction on the principles and use of operations for computers and networks. Adding space education to these core courses has great implications for expanding Midshipmen's academic development and prepares them to contribute to a more space capable fleet upon graduation.[19]

C. OFFERED SPACE EDUCATION AT THE USNA

The Naval Academy possesses a space related department that offers one space related major with 15 space related educational courses; however, the program is tailored to Aerospace engineering and Astronautics track students only.[20] Providing the "Navy and Marine Corps with engineering graduates who will grow to fill engineering,

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[18] United States Naval Academy, *United States Naval Academy Core Learning Outcomes* (Annapolis, MD: United States Naval Academy, 2015), https://www.usna.edu/Academics/_files/documents/assessment/CLOsandPreamble%20FEB%202015.pdf.

[19] "Academics, Majors and Courses," United States Naval Academy, March 15, 2018, https://www.usna.edu/Academics/Majors-and-Courses/Course-Requirements-Core.php.

[20] Thomas S. Pugsley, "Army Space Education: Closing the Gap with Operational Space" (paper presented at 23rd Annual AIAA/USU Conference on Small Satellites, Utah State University, Logan, UT, August 10–13, 2009), 8.

management and leadership roles in the Navy, government industry, while maturing their fascination with air and space systems"[21] is the Aerospace Engineering Department's mission. According to the National Center for Education Statistics, the combination of Aerospace, Aeronautical and Astronautical/Space Engineering department at the USNA is averaged to 70 students per graduating class out of roughly 1,053 students.[22] Where the engineering program at the USNA is very heavy, it lacks on operations and is a definite weakness of the program curriculum that is typically "glossed" over. There is no particular course dealing with operations, except an elective that is taught on occasion that follows the NSC PQS.[23]

Figure 1 is a representation of the course matrix for Midshipmen on the astronautics track in the aerospace engineering major.

[21] "Departments, Aerospace Engineering," United States Naval Academy, accessed March 15, 2018, https://www.usna.edu/AeroDept/.

[22] "United States Naval Academy, Programs," College Navigator, accessed April 23, 2018, https://nces.ed.gov/collegenavigator/?q=united+states+naval+academy&s=all&id=164155#programs.

[23] Jeffery King (permanent military professor, Aerospace Engineering Department, USNA), in discussion with the author, April 19, 2018.

Class: 2018 Major: EASA AEROSPACE ENGR (ASTRO)

Total Matrix Credit Hours: 145

NS101, 2	SI110, 3	NN210, 2		NL310, 3	NN310, 2		NS43X, 2
NL110, 2		NE203, 3					NL400, 2
CHEM1, 4	CHEM2, 4	SP211, 4	SP212, 4		ES410, 4	ES300, 3	
CALC1, 4	CALC2, 4	SM221, 4	SM212, 4	EE331, 4	EC310, 3		
HE111, 3	HE112, 3			HH2XY, 3	HH216, 3	HM SS1, 3	HM SS2, 3
FP130, 3	HH104, 3						
		EM221, 4	EM232, 3	EA322, 4			MJ EL1, 3
				EM319, 3	EA365, 3	EA465, 3	MJ EL2, 3
			EA222, 3	EA305, 3		EA461, 3	EA470, 3
		EA203, 3	EA204, 3		EA362, 3	EA364, 3	
			EA308, 2			EA467, 2	
[18]	[17]	[20]	[19]	[20]	[18]	[17]	[16]

This matrix is adapted from USNA Aerospace Engineering Department core courses. The addition of the highlighted boxes represents core curricula for an astronautics track student in aerospace engineering major.

Figure 1. Representation of the Course Matrix for Midshipmen on the Astronautics Track in the Aerospace Engineering Major.[24]

The highlighted courses represented in Figure 1, in accordance with the core curriculum for the astronautics/aerospace engineer program include: Principles of Aerospace Engineering I, Materials for Aerospace Engineers, Principles of Aerospace Engineering II, Engineering Analysis, Structures for Aerospace Engineering, Aero/Gas Dynamics, Rocket Propulsion, Astrodynamics I, Spacecraft Communications and Power, Space Environment, Spacecraft Attitude Dynamics and Control, Spacecraft Systems Laboratory, Spacecraft Design, and two major electives.

[24] Adapted from "Major Matrix," United States Naval Academy, accessed April 9, 2018, https://www.usna.edu/AeroDept/_files/documents/EAS%20Matrix.JPG.

IV. SPACE EDUCATION AT THE UNITED STATES AIR FORCE ACADEMY, UNITED STATES MILITARY ACADEMY AND NAVAL POSTGRADUATE SCHOOL

A. U.S. AIR FORCE ACADEMY ASTRONAUTICAL ENGINEERING, SPACE OPERATIONS, SYSTEMS ENGINEERING (SPACE SYSTEMS)

Of the service academies, the USAFA produces the most robust space education program. The USAFA places a great deal of importance on its space education, which parallels the demands of space professionals essential to the Air Force mission. Space education has been critical to the USAFA, "Since 1965, an entire department exists dedicated to space education and research, offering undergraduate majors in Astronautical Engineering and Systems Engineering (Space Systems)."[25] In 2015, the USAFA space operation major was discontinued due to the lack of interest and the need to reduce the number of majors offered at the academy. However, due to a large push for STEM majors in the Air Force space operating career field, the space operations major was reintroduced in 2018.[26] The USAFA offers one space related department with three space related majors and 27 space related educational courses. "Engineering is the broad application of science and engineering to aerospace operations. Special emphasis is placed on astrodynamics, aerospace systems design, and control systems. Thus, the cadet is prepared for Air Force duty with specialization in research, design, development and analysis of space technology and aerospace avionics."[27]

As of March 2018, the Commander of Air Force Space Command recognized an increasing interest in the space operations career field. The USAFA has made a major contribution to this interest by creating a space operations major comprised of existing approved courses in order to prepare officers to be professional leaders in the increasingly more relied-on space domain. The newly established major falls under the

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[25] Pugsley, "Army Space Education: Closing the Gap with Operational Space," 7.

[26] Stephanie Patterson, personal communication, June 5, 2018.

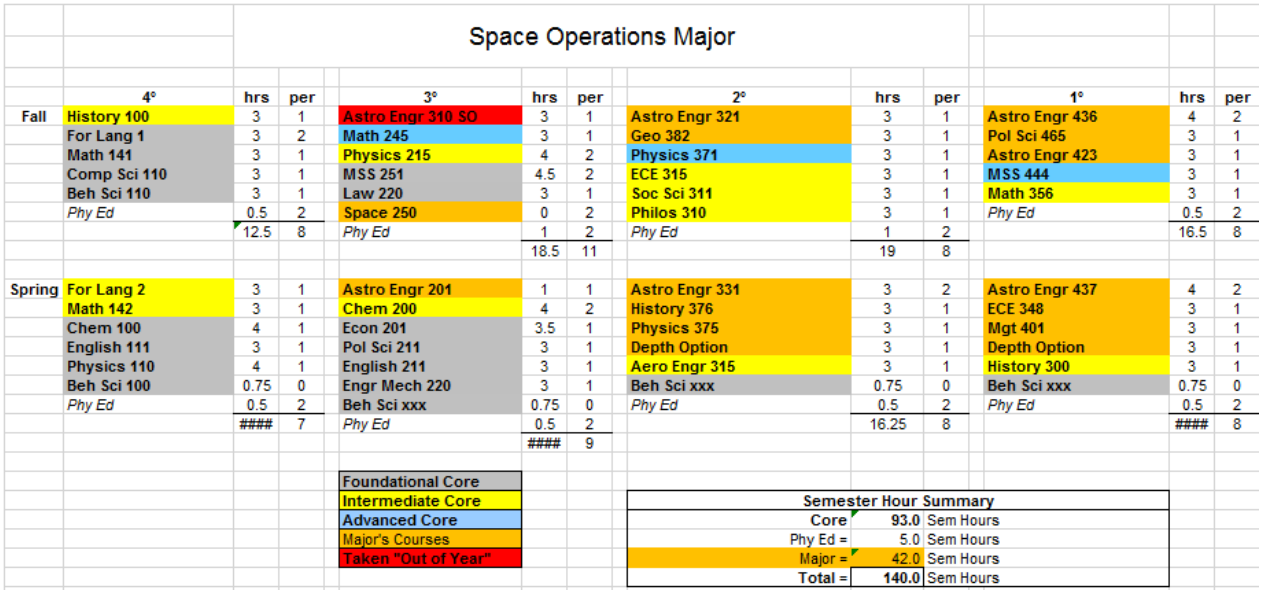
[27] United States Air Force Academy, *Curriculum Handbook, The Astronautical Engineering Major at a Glance* (Colorado Springs, CO: United States Air Force Academy, 2017), https://www.usafa.edu/app/uploads/CHB.pdf.

Astronautical Engineering Department and is regarded as an interdisciplinary major. The major is a broad variety of science, engineering and policy related to preparing future officers for employment of space forces and operational space missions: "Graduates of this degree will receive cadet space operations badges and be certified to fly the FalconSat series of satellites."[28]

Built off of a very engineering-heavy program, the space operations major is ideal for cadets who are interested in the space domain but hesitant to take on the vigorous engineering degree. Cadets enrolled in the space operations major must possess knowledge of orbital mechanics, the space environment, spacecraft design, communications, the space mission areas, and national space policy. In addition to the USAFA 93 semester hours of core courses and the additional athletic courses of five semester hours, the space operations major will require 42 semester hours for a total of 140 semester hours.[29] Cadets in the space operations major will additionally be allowed to select two courses to delve into specific areas of interest related to space. These courses include: Thermodynamics, Rocket Propulsion, Human Spaceflight, Advanced Astrodynamics, Space Chemistry, Linear Systems Analysis and Design, Linear Control Systems Analysis and Design, Mechanics of Deformable Bodies, Technical Writing and Communicating, and Advanced Remote Sensing and Image Analysis. Figure 2 is an example of a course sequence for a Cadet enrolled in the space operations major. Being in its infancy, the space operations major at the USAFA has attracted 13 cadets thus far and expects to see a vast amount of growth in the future.

[28] Martin France, "Curriculum Change Proposal" (official memorandum, Colorado Springs, CO: Department of the Air Force, HQ USAFA, 2018), 1.

[29] France, 3.



Space Operations Major

	4°	hrs	per	3°	hrs	per	2°	hrs	per	1°	hrs	per
Fall	History 100	3	1	Astro Engr 310 SO	3	1	Astro Engr 321	3	1	Astro Engr 436	4	2
	For Lang 1	3	2	Math 245	3	1	Geo 382	3	1	Pol Sci 465	3	1
	Math 141	3	1	Physics 215	4	2	Physics 371	3	1	Astro Engr 423	3	1
	Comp Sci 110	3	1	MSS 251	4.5	2	ECE 315	3	1	MSS 444	3	1
	Beh Sci 110	3	1	Law 220	3	1	Soc Sci 311	3	1	Math 356	3	1
	Phy Ed	0.5	2	Space 250	0	2	Philos 310	3	1	*Phy Ed*	0.5	2
		12.5	8	*Phy Ed*	1	2	*Phy Ed*	1	2		16.5	8
					18.5	11		19	8			
Spring	For Lang 2	3	1	Astro Engr 201	1	1	Astro Engr 331	3	2	Astro Engr 437	4	2
	Math 142	3	1	Chem 200	4	2	History 376	3	1	ECE 348	3	1
	Chem 100	4	1	Econ 201	3.5	1	Physics 375	3	1	Mgt 401	3	1
	English 111	3	1	Pol Sci 211	3	1	Depth Option	3	1	Depth Option	3	1
	Physics 110	4	1	English 211	3	1	Aero Engr 315	3	1	History 300	3	1
	Beh Sci 100	0.75	0	Engr Mech 220	3	1	Beh Sci xxx	0.75	0	Beh Sci xxx	0.75	0
	Phy Ed	0.5	2	Beh Sci xxx	0.75	0	*Phy Ed*	0.5	2	*Phy Ed*	0.5	2
		####	7	*Phy Ed*	0.5	2		16.25	8		####	8
					####	9						

Foundational Core
Intermediate Core
Advanced Core
Major's Courses
Taken "Out of Year"

Semester Hour Summary		
Core	93.0	Sem Hours
Phy Ed =	5.0	Sem Hours
Major =	42.0	Sem Hours
Total =	140.0	Sem Hours

Figure 2. Representation of Suggested Course Sequence for a Cadet in the Space Operations Major.[30]

B. WEST POINT SPACE SCIENCE MAJOR AND MINOR

At the USMA at West Point, the institution provides a core curriculum for a major and minor degree in space science.

> Space Science is the science of the space environment as well as the science behind the technology of spacecraft, satellites, and space exploration. Some of those technologies and systems that society has benefitted from include: space weather and terrestrial weather forecasting satellites; PNT enabled devices such as GPS; satellite communications; missile defense systems; and remote sensing systems used to observe our planet, our heliosphere, and beyond our solar system.[31]

Recognizing a shortfall of an insufficiently trained and educated Space Cadre, USMA has recently created the space science major (SSC0), the space science minor (SPA0N), and interdisciplinary science—astronautics track (ISA0).[32] The space and

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[30] Adapted from France, 4.

[31] "Department of Physics & Nuclear Engineering, Space Science Major & Minor," United States Military Academy, accessed February 28, 2018, https://www.westpoint.edu/pne/SitePages/Space%20Science.aspx.

[32] Stacy Godshall, "Space and Missile Defense Program/Space Science Major Development to Mitigate Shortfalls in Space Workforce's Education" (abstract presented at the AIAA Space 2017 Conference, San Antonio, TX, February 5–9, 2017), 1.

science major and minor will educate cadets on an array of space science and astronautics-related courses. In addition, the curriculum with provide cadets with the chance to conduct space-related research, small satellite design, testing and building. The expansion of a space education based curriculum at the USMA is an extension of the Space and Missile Defense Program (SMD) that will continue to produce well educated and trained Army space enablers and professionals to the Space Cadre.

The space science program was comprehensively paralleled beside other peer aspirant institutions in order to determine the correct path in course development. Each of the 13 academic departments of the USMA composed a curriculum committee review board that underwent extensive review of the proposal to support the SMD program, additional courses required, the purpose, program structure, program framework, program assessment, and course implications. See Figure 3.

> The subjects addressed in the SSC0 major include: Astronautics, Space Physics, Astronomy, Astrophysics, Intermediate Classical Mechanics, Modern Physics, Intermediate Electrodynamics, Applied Optics, Laser Physics, Remote Sensing, and Military Geospatial Operations. These courses were selected as a result of the benchmarking and aforementioned curriculum change proposal. These courses are supported by a USMA core program of 24 courses, three complementary support courses outside the department, and a 3-course engineering sequence in one of the following engineering disciplines: cyber, electrical, environmental, infrastructure, nuclear, or systems.[33]

[33] Godshall, 1–2.

4th Class Yr		3rd Class Yr		2nd Class Yr		1st Class Yr	
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
CH101 CHEMISTRY	PH205 PHYSICS 1	PH206 PHYSICS 2	SS202 POL. SCIENCE	PL300 MILITARY LEADERSHIP	SS307 INT'L. RELATIONS	PH456 SCIENCE & POLICY	LW403 LAW
EN101 ENGLISH	EN102 ENGLISH	SS201 ECON.	PY201 PHILOSOPHY	3 COURSE ENGINEERING SEQUENCE			MX400 OFFICER-SHIP
MA103 INTRO TO CALCULUS	MA104 CALCULUS 1	MA205 CALCULUS 2	MA364 ENGINEER MATH	PH ELECTIVE PH365 or PH381	PH384 OPTICS	PH485 LASERS	EV478 MIL. GEOSPATIAL OPERATIONS
HI10_ US HISTORY	HI10_ REGIONAL HISTORY	L_203 LANGUAGE	L_204 LANGUAGE	PH382 ELECTRO-DYNAMICS	EE301 ELEC. ENG.	HI302 MILITARY ART	EV377 REMOTE SENSING
IT105 INFO. TECH.	PL100 PSYCH.	MA206 PROB & STAT	EV203 GEOGRAPHY	SP473 ASTRO-NAUTICS	SP472 SPACE PHYSICS	SP475 ASTRO-NOMY	SP474 ASTRO-PHYSICS

Legend (Space and Missile Defense areas of interest):

Directed Energy
Missile Defense
Cyber Operations
Policy Development
Space Science

Figure 3. USMA SMD Program/SSC0 Academic Plan, USMA.[34]

The interdisciplinary science major ISA0 allows cadets to choose four courses in science disciplines other than physics, in addition to the astronautics, space physics, astrophysics, and intermediate classical mechanics courses. Other courses cadets may choose from are chemistry, life science, computer science, or mathematics. The ISA0 courses are supported by the USMA's 24-course core program. The SPA0N also includes astronautics and space physics; however, it allows for two electives that support space-related topics, such as missile defense, directed energy or cyber operations that respectively concentrate on SMD critical areas. Figure 4 is a structure overview of the SPA0N related to the SMD critical areas of interest with related electives.

[34] Adapted from Godshall, 2.

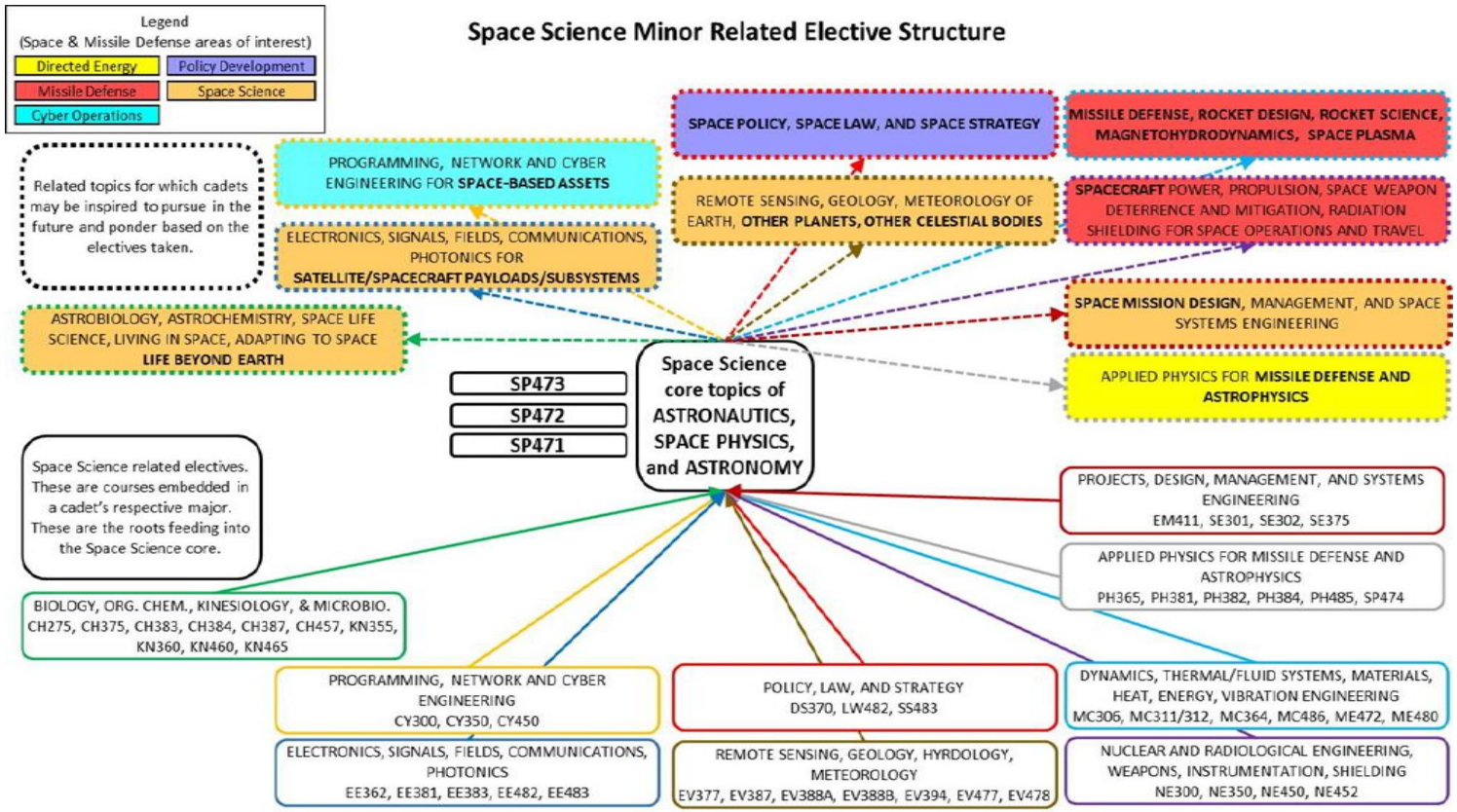

Figure 4. SPA0N Electives, USMA[35]

[35] Adapted from Godshall, 3.

Outlined in the solid brown rectangle are the courses taken by a geospatial information science (GIS), physical geography or environmental science major. From this group, following the solid brown line will introduce cadets in those majors that would also take the space science courses in the center of the figure. Following the dashed brown line, leading to the dashed brown rectangle provides more space related topics connected to remote sensing, exploration of earth, planets and other celestial bodies. For this example, the color coding for the related electives is brown and the color coding for the related critical areas of interest is orange. This figure shows the mapping from the related electives at the bottom of Figure 4 to the SMD critical areas of interest at the top of Figure 4.[36]

The development of the SSC0 major, ISA0 major, and SPA0N minor all support the SDM program and leverage the capabilities provided by USMA to produce Army Space Cadre and operations space enablers and professionals. To date, the program has yielded 36 cadets and an additional six from other majors involving space-related research. Three cadets will graduate this year with a degree in Interdisciplinary Science with a focus in Astronautics. 16 additional cadets will earn the Army's Space Enabler 3Y Skill Identifier this year. Eight cadets will graduate next year with a degree in Astronautics, and a total of 38 cadets in the class of 2020 and class of 2021 are in the SSC0. A total of 25 cadets in the classes of 2020 and 2021 are in the SPA0N. Overall, about 90 cadets at the USMA are involved with the USMA SMD program at this time, a number in which the service academy expects to grow in the future. The newly introduced program has been successful in bridging the gaps within the lack of trained and educated space professionals, greatly improving the Army's space community as a whole.

C. NAVAL POSTGRADUATE SCHOOL

NPS provides graduate-level education in 75 different programs offered by 14 departments. The Space Systems Academic Group (SSAG) is a combination of space operations (366) and space engineering (591) student officers spanning all services. Post-

[36] Godshall, 3.

graduation, officers are prepared to provide technical expertise to future commands that include space systems' "design, development, installation and maintenance of spacecraft, space payloads, supporting earth stations, terminals and [command, control, and communications] C3 connectivity."[37] In addition to the operations and engineering programs, NPS also provides a space systems certificate curriculum, space systems operations (international curriculum), and space systems engineering PhD curriculum.

Specifically, the 366 curriculum is an interdisciplinary association in which graduates require a minimum of 32 quarters-hours with a minimum of those hours being 15 hours of 4000-level courses. It is a graduation requirement that each student write a space-oriented thesis approved by the department's chair. The 366 program adheres to a number of competency skill requirements (CSR) that make up the courses in the curriculum. There are five CSR that students must possess to perform successfully. These CSRs include: CSR 1, space system processes; CSR2, space systems capabilities and design; CSR3, space systems assessment and analysis; CSR4, space liaison; CSR5, decision superiority.[38]

Along with the CSRs, student officers must also possess specific educational skill requirements (ESR) to understand fundamental concepts of space systems and operations. Specific ESR's required for the Space Systems Operations curriculum are: orbital mechanics and space environment, spacecraft design, national security systems, management and acquisition, communications, remote sensing, analysis and evaluation, architecting missions, information warfare fundamentals, operational mission planning, advanced concepts and technology, space national policy, and research.[39] Figure 5 is an example of a 24-month space systems operations curriculum matrix for 366 students at NPS.

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[37] "Space Systems Academic Group, Objectives," Naval Postgraduate School, accessed April 28, 2018, https://my.nps.edu/web/ssag.

[38] Department of the Navy, *Report of Curriculum Review of Resident Curriculum Space Systems Operations, Space Systems Academic Group* (Monterey, CA: Naval Postgraduate School, 2017).

[39] Department of the Navy.

0S	MA1113 Single Var Calc	MA1114 Matrix Algebra	PH1121 Mechanics	NW3230 Strategy & War
1F	PH2514 Space Environment	EC1010 Introduction to MATLAB	PH1322 Electricity & Magnetics	SS3011 Space Technologies & Applications
2W	NS4677 Space & International Security	SS3610 Space Communications Systems	PH3052 Remote Sensing	SS3400 Orbital Mechanics, Launch and Space Operations
3S	SS3041 Space Systems & Ops 1	SS3613 MILSATCOM Systems	AE4830 S/C Systems I	SS3600 Modeling & Simulation
4S	SS3051 Military Applications of DoD & Commercial Space Systems	SS3001 Military Applications of Space	AE4831 S/C Systems 2	Elective
5F	SS4051 Military Space Systems/Arch	SS0810 Thesis Research	Elective	NW3285 NSDM
6W	SS3055 Space Operations for the Warfighter	SS0810 Thesis Research	Elective	NW3275 JMO Part 1
7S	SS0810 Thesis Research	SS0810 Thesis Research	IW3101 Military Ops in the Information Env.	NW3276 JMO Part 2

Figure 5. NPS Space Systems Operations Student Matrix.[40]

[40] Adapted from Naval Postgraduate School, *366 Space Systems Operations, Navy 21 month + Refresher Matrix* (Monterey, CA: Naval Postgraduate School, 2017).

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V. ANALYSIS AND RECOMMENDATIONS

The current trends of the service academies' involvement and development in space operations education are encouraging. The Army at WestPoint and Air Force in Colorado Springs are taking an important role in promoting the need for more space-related education for future officers at the undergraduate level. The Naval Academy must follow suit to fulfill requirements of providing space-based education and space professionals to the fleet.

A. U.S. NAVAL ACADEMY ANALYSIS

The USNA produces a robust space education program for Midshipmen in the aerospace/astronautics engineering major. Engineering majors or "group one" majors make up roughly 35% of students at the USNA. From the Aerospace Department, that is averaged to about 70 midshipmen per class.[41] Although this may seem like a significant number of space professionals entering the fleet each year, it does not consider the pipeline or warfare specialty that is limiting the distribution of these graduates' space knowledge. Many of these graduates are funneled down the same career path, not spreading their education across the fleet. According to the USNA Aerospace Department, "About 90% [of Aerospace major graduates] are selected for Naval Aviation."[42] This is compared to the 71% of midshipmen who do not select naval aviation as their warfare specialty. Meaning that, on average, over 71% of the fleet is not gaining space professionals from the USNA graduating class each year. These numbers are based on results from analysis conducted on the graduating class of 2017.[43]

[41] "Enrolled Grad Data," United States Naval Academy, Aerospace Engineering Department, accessed May 15, 2018, https://www.usna.edu/AeroDept/Enroll-Grad-Data.php.

[42] "Program Educational Objectives," United States Naval Academy, Aerospace Engineering Department, accessed May 15, 2018, https://www.usna.edu/AeroDept/peo.php#_ftnref.

[43] Dominique Wright, personal communication, May 24, 2018.

B. INTEGRATING SPACE-RELATED EDUCATION AT THE USNA

Benchmarking current space-related courses provided from the Aerospace Engineering Department and other departments in mathematics and science, humanities and social sciences, and professional development at the USNA against courses from the USAFA, USMA, and NPS reveals gaps of where the USNA can improve its space education to a larger majority of Midshipmen, if not all. Conducting an analysis of courses from the above institutions provides a primer for how the Naval Academy may integrate space-related education into its curriculum. Based on analysis of the MTP, required core courses, and current structure of the aerospace engineering major, I have created a three-tier architecture of recommendations for integrating space education at the USNA.

C. TIER ONE: INTEGRATED SPACE EDUCATION IN THE MIDSHIPMEN TRAINING PROGRAM

To increase the production of space professionals at the USNA, the most informal way to introduce a basic level of education is to apply it to the MTP via plebe pro-knowledge, third class Midshipmen (sophomore) (3/C) and second class Midshipmen (junior) (2/C) MQS components. In doing so, all Midshipmen will be exposed to space-related education that increases awareness of the Navy's reliance and use of space-based systems.

At the 4/C (freshman) level, the MTP can introduce space fundamentals that should be required knowledge to all future junior officers. This would include a brief history, orbits, GPS, SATCOM, satellite constellations, capabilities and limitations. Just like with all other professional development areas, the 4/C Midshipmen will study these components for the week leading up to their pro-quiz, where they will then be graded on their understanding of space fundamentals. At the 3/C and 2/C levels, the MTP can introduce more complex information that will include more cognitive material on space-based systems. This would include space fundamentals, space operations and joint functions, organizations, roles and responsibilities, and policy. The Appendix provides examples of what a 4/C and 3/C and 2/C MQS should look like. The space-related

information from these examples is derived from the Naval Space Handbook and the JP 3-14, Space Operations.

D. TIER TWO: INTEGRATION OF SPACE EDUCATION INTO EXISTING CORE CURRICULA

Tier two of space-based education integration at the USNA consists of adding space-related objectives to already available curricula. Critical review of the following courses' syllabi reveals areas for integration of appropriate space-based education. The reviewed courses are: SY110, Introduction to Cyber Security; NN310, Advanced Navigation; ES300, Naval Weapons Systems; and the NS42xx, JO Practicum courses which include surface warfare, submarine warfare, naval aviation, marine corps, special warfare, and EOD.

1. NN310: Advanced Navigation

The NN310, Advanced Navigation course, is a core requirement at the USNA. The purpose of this course is to prepare future officers in the fleet by educating, training and mentoring them by means of naval science knowledge and navigation skills. The course is organized into three blocks. Block One reinforces and expands upon the concepts learned in NN210, Block Two introduces advanced concepts for navigation, and Block Three focuses on practical application and a culmination of events. Specifically, Block Two deals with GPS/datum and community navigation. According to the NN310 2016 syllabus, the duration of the GPS class only requires 50 minutes of lecture and an outdated chapter of GPS from *Dutton's Nautical Navigation*.[44] While the objectives appear valid, the duration is not a sufficient amount of time to cover GPS, and could be assumed to be "glossed" over. With the increasing capabilities of our adversaries' deception tactics, it is critical that Midshipmen (future Naval and Marine officers) understand the importance of GPS, its advantages and disadvantages, how the receivers work, the different uses and sources, automated identification system (AIS), jamming capabilities and other GPS systems controlled by foreign countries.

[44] Department of Seamanship and Navigation, *Syllabus and Study Guide: NN310-Advanced Navigation, Academic Year 2016* (Annapolis, MD: United States Naval Academy, 2016).

2. ES300: Naval Weapons Systems

The ES300, Naval Weapons Systems course, is a required core competency at the USNA. According to the ES300 syllabus, the basis of the naval weapons systems course includes but is not limited to: "radar, sonar, electro-optics, communication and guidance systems, explosives and ballistics."[45] The objectives require each Midshipman to understand basic principles employed by Navy and Marine Corps in regard to naval weapon systems. By analyzing weapons systems, energy propagation, sensor resolution, radar operations, electro-optics (EO) and many other systems' performance, students will demonstrate the components of air, surface, and subsurface systems used by the Navy and Marine Corps.[46] Many of the topics covered are relevant to space-related systems; however, they do not discuss many of the essential space-based systems that the Navy and Marine Corps rely on to target and deliver weapons systems successfully. Topics found in this course that are directly related to space operations are interference and phased array antennas, ballistics and fire control, electronic warfare, EO, and EO systems and detector performance. Integrating a knowledge of space systems that compliments these weapons systems could improve this course and meet the requirement to expose Midshipmen to space-related education, while increasing awareness of the Navy's reliance on and use of space-based systems.

3. NS42xx: Junior Officer Practicum

The purpose of the NS42xx, JO Practicum series of courses is to prepare future Naval and Marine Corps officers for maritime operations. This course provides mentors from the sea, air and land domains to train and deliver their fleet-time experience with the Midshipmen in their classes. This required course for 1/C Midshipmen could be the perfect location to tie in space-related education to increase awareness of the Navy's reliance on space-based systems and produce more space-savvy officers. Referencing the NS433-Naval Aviation Practicum syllabus, "By studying different elements of naval

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[45] United States Naval Academy, *Syllabus and Introduction: ES300-Naval Weapons Systems, Academic Year 2015* (Annapolis, MD: Department of Weapons and Systems Engineering, 2015), https://www.usna.edu/WSE/_files/documents/courseDescriptions/ES300.pdf.

[46] United States Naval Academy.

warfare students will understand how naval doctrine aligns with the larger National Security Strategy."[47] According to the most recent edition of the National Security Strategy released in December 2017, U.S. military dominance of the space domain is of critical importance, "As U.S. dependence on space has increased, other actors have gained access to space-based systems and information […] This 'democratization of space' has an impact on military operations and on America's ability to prevail in conflict."[48] It is critical that the future leaders of the Navy and Marine Corps (1/C Midshipmen) can comprehend America's dependence on space assets, and the actors who try to deny those assets.

E. TIER THREE: INTEGRATION OF A NEW SPACE OPERATIONS MAJOR AT THE USNA

Tier Three of space-based integrated education consists of a complete curriculum review to establish a space operations major at the USNA. By benchmarking current courses provided from the Aerospace Engineering Department and other departments in mathematics and science, humanities and social sciences, and professional development at the USNA against courses from the USAFA, USMA, and NPS, the USNA has the resources to produce a space operations major.[49]

By comparing the core course requirements for an aerospace engineering major with the USAFA space operations major, USMA SSC0 and NPS space systems operations major, it is clear that the Naval Academy has the means to adopt a space

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[47] Department of Seamanship and Navigation, *Syllabus and Topic Guide, NS433-Naval Aviation Practicum, Academic Year 2018* (Annapolis, MD: United States Naval Academy 2018).

[48] Donald J. Trump, *National Security Strategy of the United States of America* (Washington, DC: The White House, 2017), 31.

[49] The information contained in this recommendation is a combination of USNA syllabi and USNA course descriptions. Department of Seamanship and Navigation, *Syllabus and Topic Guide, NS433*; United States Naval Academy, *Syllabus and Introduction: ES300*; "Aerospace Engineering Course Information," United States Naval Academy, accessed March 15, 2018, https://www.usna.edu/Academics/Majors-and-Courses/course-description/EA.php; United States Air Force Academy, *USAFA Course Handbook, "Curriculum Handbook, The Astronautical Engineering Major at a Glance* (Colorado Springs, CO: United States Air Force Academy, n.d.), accessed March 13, 2018, https://www.usafa.edu/app/uploads/CHB.pdf; United States Military Academy, *United States Military Academy, Academic Program, Class of 2020 Curriculum and Course Descriptions, Office of the Dean* (West Point, NY: United States Military Academy, 2016), https://www.usma.edu/curriculum/SiteAssets/SitePages/Course%20Catalog/RedBook_GY2020_20170803.pdf?Mobile=1.

systems major. The basis for the USAFA, USMA and NPS course structures are concentrated on astronomy, astrophysics, communications, electronics and cyber, orbital mechanics, project management, remote sensing, rocket propulsion, the space environment, space operations, space policy, and spacecraft design. Figures 6 and 7 in the Appendix provide a side-by-side analysis of the competencies provided by the name institutions by semester hours.

While the Aerospace Engineering Department does not have an astronomy course, the Physics Department does. Astronomy (SP310) offers fundamentals of astronomy covering stellar and galactic astronomy and the physical and mathematical science behind it. Both the USAFA and USMA space majors offer astronomy in their core curriculums. Additionally, the USNA Physics Department also offers Astrophysics I and II (SP445 and SP446), which study astronomical objects, such as stars and galaxies and the physics behind it.

Being that the Navy is one of the larger users of SATCOM, it is critical that space operations students be introduced to SATCOM and communications classes. The USAFA provides cadets with ECE348: Telecommunication principles that cover space systems applications to cyber operations and SATCOM. Additionally, NPS offers SS3610: Space Communications Systems: Fundamentals and Analysis and SS3613: Military Satellite Communications. These courses focus on SATCOM and understanding basic elements of these systems and their relationship to performance. The Aerospace Engineering Department at the USNA provides one course, Spacecraft Communications and Power (EA465), which emphasizes fundamentals of digital communications and control of spacecraft. In addition, the USNA Electrical Engineering Department and Systems Engineering Department offer Signals and Systems (EE322) and Introduction to Communications and Information Systems (ES421) and Modern Communication and Information Systems (ES422) courses. These courses provide a foundation for processing noise and digital signals, and principle techniques in doing so. They also cover current technology and everyday communications devices. These courses could satisfy the requirement of SATCOM and communications principles.

The Air Force Academy, West Point, and NPS each provide courses in orbital mechanics. The aerospace engineering major at the USNA provides an introduction to Astrodynamics (EA362), which covers classical two-body problems, orbital parameters and maneuvers, orbits, ballistic missile trajectory and much more. This course would satisfy the requirement of orbital mechanics.

A consensus from the USAFA, USMA, and NPS is that remote sensing is a must-have course for space-related education. The USAFA requires Remote Sensing and Imagery Analysis (GEO382), the USMA requires Remote Sensing (EV377), and NPS requires Physics of Space and Airborne Sensor Systems (PH3052). These courses cover the principles of sensor systems and need for satellites, as well as the limitation imposed by the atmosphere.

The space environment course is also required by the USAFA, USMA and NPS. The Aerospace Engineering Department provides a space environment course (EA461), which introduces students to the properties of radiation belts, the upper atmosphere, solar weather, and the effects it has on spacecraft. This course would be sufficient for an USNA space operations major.

The Air Force Academy, West Point, NPS, and the USNA all provide some form of space operations courses; however, the space operations course at the USNA in the aerospace engineering major is an elective not taught on a regular basis. NPS requires its students to take Space Technology and Application (SS3011), Space Systems and Operations (SS3041), Military Applications of DOD and Commercial Space Systems (SS3051), Space Control (AE4860), and Space Operations for the Warfighter (SS3055). At the Air Force Academy, cadets are required to take Physics of Space Situational Awareness (Physics375), with the additional courses of Basic Space Operations (Space251), Basic Space Operations II (Space252), and Advanced Space Operations Upgrade (Space350), which allows cadets to become qualified to fly their FalconSat series of small satellites, as well as training to prepare cadets for a career in the Air Force. At West Point, Military Geospatial Operations (EV478) is a requirement for cadets designed to teach space operations in the military and understanding of the operational picture of the space domain. The Aerospace Engineering Department offers Space

Operations (EA463) as an elective. When available, it follows the NSC PQS, mission planning and operations in space. With a little more attention, this course could satisfy the space operations requirement.

Again, the Air Force Academy, West Point, and NPS require a space policy course for their space professionals. The USAFA requires the following courses: History of Space Power: Conquest of the New Frontier (History376) and U.S. National Space Policy (PolSci465). USMA requires SSC0 cadets to take Science and Policy (PH456) and NPS requires Space and International Security (NS4677). While the Aerospace Engineering Department does not provide a similar course, the Political Science Department offers courses on: Intelligence and National Security (FP407), Nuclear Weapons and National Security (FP460A) and U.S. National Security Strategy (FP485E). These courses provided by the Political Science Department could suffice for a space operations major requirement in space security.

Lastly, in a space operations curriculum, spacecraft design is critical. The Aerospace Engineering Department demonstrates a robust program for spacecraft design, just like at the USAFA and NPS. Courses provided by the USNA are: Spacecraft Attitude Dynamics and Control (EA364), Spacecraft Systems Laboratory (EA467), Spacecraft Vehicle Design (EA440) and Spacecraft Design (EA469/470).

Paralleling space operations and space science courses at the USAFA, USMA, and NPS, with USNA courses, the Naval Academy can integrate space operations students with engineering students to provide an even more robust space and spacecraft design program.

VI. CONCLUSION AND FUTURE WORK

A. CONCLUSIONS

The USN has been a dependent user of space systems and operations for the past six decades and until recently, has operated with impunity in the space domain. Every graduate from the USNA will eventually lead Sailors or Marines while operating technology that is dependent on space systems. If not all, a larger majority of midshipmen must be educated on the Navy's reliance on space-based systems and the importance of understanding the space domain. While the NSC and MSC are enhancing their communities through restructuring and reviews, more can be done to educate young officers on the Navy's reliance on space systems and its need for space professionals.

This thesis found that the USNA is not adequately meeting the threshold to produce space professionals and increase awareness of its reliance of space systems (when compared to its sister service academies) per the CNO for IW requirements, published in the OPNAVINST 5400.43B (in Draft). Although the Naval Academy produces a robust space program through the Aerospace Engineering Department, they are limiting the distribution of space professionals across all warfare specialties.

A critical review of the professional development program and academic development program has proven gaps of space education. Integrating space education through the MTP, core course requirements, and the creation of a space operations major similar to that of the USAFA, USMA, and NPS, can fill these gaps. By integrating a foundational level of space education through the MTP via plebe pro-knowledge, 3/C and 2/C MQS components, all Midshipmen will be exposed to space-related education that increases awareness of the Navy's reliance and use of space-based systems. Additionally, by benchmarking courses at the USNA against required courses from the USAFA space operations major, the USMA SSC0 and NPS space systems operations major, it is clear that the Naval Academy has the means to adopt a space systems major. By integrating space-related education to all Midshipmen at the Naval Academy, the space cadre communities, as well as the warfare specialties throughout the fleet will experience

significant, good implications as a result of the increasing the number of space professionals developed at the Naval Academy.

B. FUTURE WORK

Through my work in this thesis, a foundation of future research related to space education has been established with room for expansion of space-related topics and improvements at the USNA.

1. Course Improvement and Course Development

Continued review of core courses and electives at the USNA can provide space-related enhancement of curriculum for Midshipmen across engineering, mathematics and science, and humanities and social science majors. As the space domain continues to develop and change, education must change with it to keep space enablers current. The additional development of space-related courses could be beneficial to meet naval requirements with academic requirements.

2. Integration of Space Operations and Cyber Operations

As the space and cyber space domains continue to mature, integrating space operations within the Cyber Operations Department could have significant implications for graduates entering this new warfighting domain. Is there enough capacity and capability to build a cyberspace and space relationship at the USNA? What exactly would that relationship look like?

3. Classified Level Education

Since the Naval Academy is gaining a Sensitive Compartmented Information Facility (SCIF) in the new Hopper Hall, Cyber Operations building, could there be room to structure a course specifically on national systems and their role in the DOD? In doing so, graduates would enter the fleet with an extensive understanding of national systems and how they can shape the warfighting domain.

4. PQS Qualification for USNA Space Operations Major

If Midshipmen graduate with a space operations major, could there be an added subspecialty code to qualify these graduates as space professionals or become certified under the Navy space PQS? Could a space operations major graduate become designated "basic" as VS5 in the AQD structure having performed advanced space education? If so, these graduates could enter the fleet and instantly make an impact within the NSC.

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APPENDIX

A. NAVAL SPACE HANDBOOK AND JOINT PUBLICATION 3-14

The following examples for Midshipmen 4/C PROKNOW, 3/C and 2/C MQS are direct replications from the JP 3-14, Space Operations and the *Naval Space Handbook*. These publications provide the fundamentals of what every USNA graduate should understand about the space domain and how the U.S. Navy and Marine Corps operate in it.[50]

1. History

> The United States has been a world leader in the advancement and use of space capabilities for over half a century. Space services have become intricately woven into almost every facet of civilian life including farming, weather forecasting, resource management, communications, finance and transportation.
>
> Space is also a warfare domain that provides access to any location on Earth. Space capabilities such as robust satellite communications, remote imaging, signals collections, positioning, navigation and timing all enhance warfighting capability and are significant force multipliers. As these capabilities have continued to evolve and improve, the U.S. military has become increasingly dependent on them—a fact well-known to our adversaries who strive to exploit this dependence.
>
> The Navy recognized decades ago the importance of space to dispersed, global operations, and was an early contributor of many significant space capabilities. In 2003, when the overall responsibility for space operations was assigned to the Air Force as DOD executive agent for Space, Navy space involvement and expertise began to decline, In recent years there has been an increasing focus on re-invigorating Navy Space, and NETWARCOM Space Directorate has been at the forefront of these efforts.
>
> The Marine Corps also recognizes the importance of space operations to the MAGTF. Space-based capabilities enable the MAGTF to gain and maintain initiative across the spectrum of conflict. Although the Marine

[50] Naval Network Warfare Command, *Naval Space Handbook.*

Corps does not develop or operate space systems, the Marine Corps is a significant end-user of space-enabled services and capabilities.[51]

2. Orbits

a. Low Earth Orbit (LEO)

Orbit: Circular

Altitude: 160–2000 km (100–1250 mi)

Period: ~90 minutes

Missions: Manned (ISS), Reconnaissance, Weather, Communications

b. Medium Earth Orbit (MEO)

Orbit: Semi-Synchronous

Altitude: 20,350 km (12,650 mi)

Period: 12 hours

Missions: Global Positioning System (GPS)

c. Highly Elliptical Orbit (HEO)

Orbit: Prograde = 63.4 deg inclination

Retrograde = 116.6 deg inclination

Altitude: 500 km (perigee) to 40,000 km (apogee)

310 miles (perigee) to 24,850 miles (apogee)

Period: 12 hours

Missions: Provides Polar coverage. Communications Relay, Missile Warning

d. Geosynchronous/Geostationary Earth Orbit (GEO)

Orbit: Geosynchronous = any inclination

Geostationary = 0 degrees inclination (equator)

Altitude: 35,786 km (22,000 mi)

[51] Naval Network Warfare Command, *Naval Space Handbook*, 8.

Period: 24 hours

Missions: Communications, Missile Warning, Weather[52]

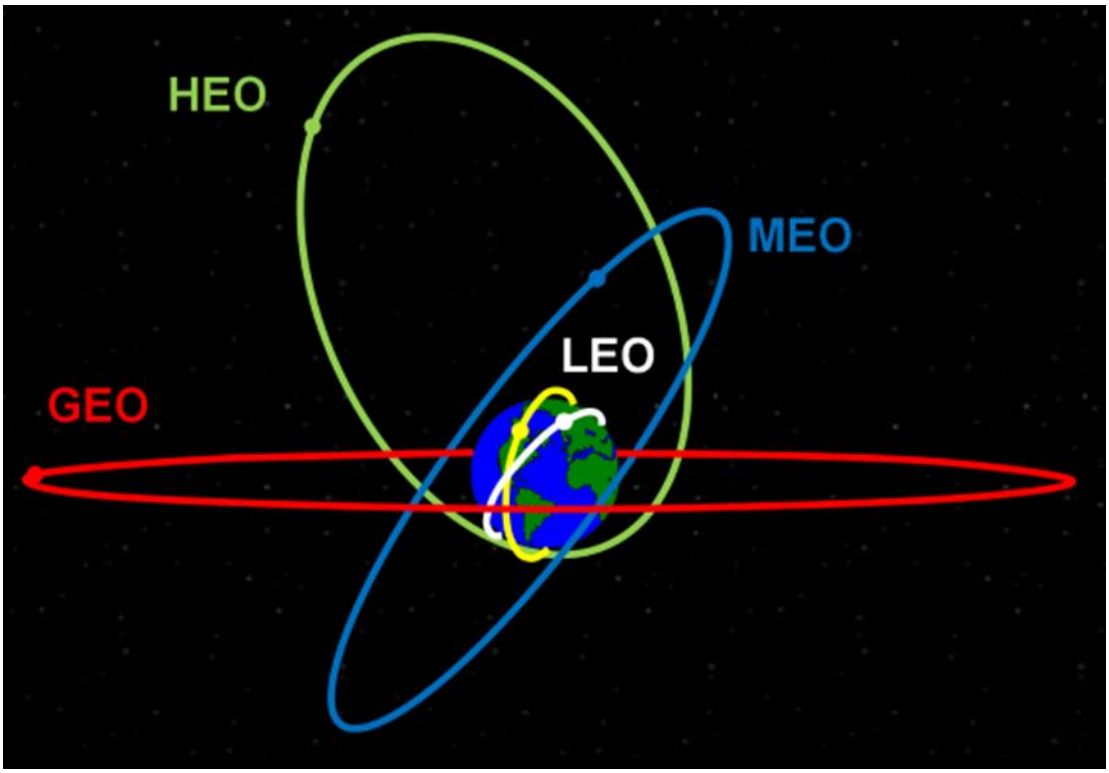

Figure 6. Satellite Orbits: LEO, MEO, GEO, HEO.[53]

3. Global Positioning System

Mission: GPS provides positioning, navigation, and timing (PNT) data to users, weapon systems, and networks. GPS allows an unlimited number of users on Earth and in orbit to obtain extremely accurate position data in three dimensions (latitude, longitude, and altitude).

[52] Naval Network Warfare Command, 10.

[53] Source: Naval Network Warfare Command, 10.

Figure 7. Global Positioning System Constellation.[54]

Orbit: MEO

Altitude: ~20,200km

Period: ~ 11 hours 58 minutes

Inclination: 55 degrees

Constellation: Six planes of four satellites. GPS receivers must acquire four separate satellite signals to determine a three-dimensional position. There are usually nine GPS satellites in view at any given time.[55]

4. Satellite Communications

SATCOM allows users to communicate from anywhere on the globe. SATCOM provides the primary means of communication and data transfer for ships at sea, covers a wide range of frequencies, supports all DOD missions, and enables command and control of widely separated forces.[56]

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[54] Source: Naval Network Warfare Command, 24.

[55] Naval Network Warfare Command, 24.

[56] Naval Network Warfare Command, 19.

Military SATCOM (MILSATCOM) is divided into three categories based on throughput and robustness:

- Narrowband: Data rates of 64 kbps or less; supports tactical and mobile forces and is often the primary means of SATCOM for allied and coalition operations.
- Wideband: Data rates greater than 64 kbps; deemed the "workhorse" of military SATCOM, supports the majority of network communications.
- Protected: Designed to provide survivable communications to strategic forces, originally at low data rates.[57]

a. MILSATCOM Advantages

- Provide global access (including denied areas)
- Little to no terrestrial infrastructure needed
- Immediate; timely
- Longevity
- Safe from harm
- All weather; day/night

[57] Naval Network Warfare Command, 20.

B. NAVAL SPACE SYSTEMS (PROVIDE MISSION, PICTURE, DISTINGUISHING FEATURES, CAPABILITIES)

1. Fleet Satellite Communications System

The Navy's oldest SATCOM satellite in space with two satellites still mission capable.

Figure 8. The FLTSAT Communications System.[58]

The FLTSAT Communications System is the Navy's oldest SATCOM systems in space.

Orbit: Geosynchronous
Current Constellation: 2 satellites
Mission: MILSATCOM
Capabilities: UHF, SHF, 30 x 25 kHz channels (voice) 5 x 5 kHz channels
Design Life: 5 years[59]

[58] Source: "Fleet Satellite Communications System," SPAWAR, PEO Space Systems, accessed June 1, 2018, http://www.public.navy.mil/spawar/PEOSpaceSystems/technology/Pages/FLEETSATGraphics.aspx.

[59] Naval Postgraduate School, "Space Systems Academic Group, SS3011: Space Technology and Applications" (lesson, Naval Postgraduate School, Monterey, CA, 2016), lesson 12, slide 17.

2. Ultra-High Frequency Follow On Satellite

Figure 9. UFO Satellite Constellation Provides Tactical, Narrowband UHF Communications to the Navy and the DOD.[60]

Orbit: Geosynchronous
Current Constellation: 8 satellites
Mission: MILSATCOM, ship-to-shore communications
Capabilities: UHF, EHF, Ka-band, Fleet broadcast, 4800 bps Data, 2400 bps Data/Voice, 75 bps Secondary Communications
Design Life: 14 years[61]

[60] Source: "Ultra-High Frequency Follow On," SPAWAR, PEO Space Systems, accessed June 1, 2018, http://www.public.navy.mil/spawar/PEOSpaceSystems/technology/Pages/UHFGraphics.aspx.

[61] Naval Postgraduate School, "Space Systems Academic Group, SS3011: Space Technology and Applications," lesson 12, slide 18.

3. Mobile User Objective System

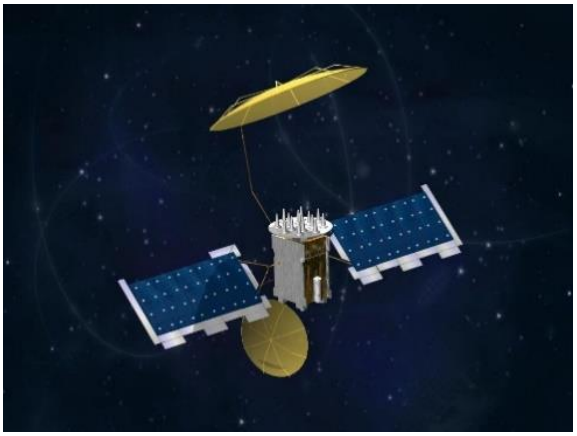

Figure 10. MUOS.[62]

Orbit: Geosynchronous
Constellation: five satellites
Mission: MILSATCOM, Designed to support users that require greater mobility, higher data rates and improved operational availability.
Capabilities: 16 x more communications capability than entire UFO constellation including simultaneous

C. 3/C AND 2/C ADVANCED MQS INFORMATION

1. DOD Space Organization

- U.S. Strategic Command (USSTRATCOM): Integrates and synchronizes DOD space capabilities to ensure the most effective use of these resources. USSTRATCOM plans, directs, coordinates, and controls space assets and forces for daily operations, for crisis action planning, and in the event of war against the United States and/or its allies.
- Joint Force Space Component Command (JFSCC): The JFSCC coordinates, plans, integrates, synchronizes, executes, and assesses space operations, as directed by Commander, United States Strategic Command (CDRUSSTRATCOM), and facilitates unified action for joint space

[62] Adapted from Sam LaGrone, "Mobile User Objective System," USNI News, November 3, 2016, https://news.usni.org/2016/11/03/final-muos-satellite-place-italian-ground.

operations. CDRUSSTRATCOM has delegated SCA to the JFSCC to plan space operations in operational-level support of USSTRATCOM's Unified Command Plan responsibilities.[63]

- Joint Space Operations Center (JSpOC): JSPOC provides a [common operational picture] COP to the Joint Force Space Component Commander JFSCC to enable broad, shared awareness of the JFSCC's critical information requirements, status of forces, SSA, and the full range of military activities arranged in time, space, and purpose.[64]
- Fleet Cyber Command (COMFLTCYBERCOM): The USN conducts space operations and has the ability to contribute to the achievement of space superiority for Commander, Fleet Cyber Command. COMFLTCYBERCOM serves as the USN central operational authority for USN networks, cryptology, SIGINT, IO, cyberspace, EW, and space. Commander, Tenth Fleet, serves as the numbered fleet commander for Fleet Cyber Command and exercises operational control (OPCON) of assigned Navy forces.[65]
- Navy Network Warfare Command: The Navy Network Warfare Command is designated to execute tactical-level C2 to direct, operate, maintain, and secure Navy communications and network systems for Department of Defense Information Network (DODIN) and to leverage joint space capabilities for Navy and joint operations as assigned by Commander, Tenth Fleet.[66]
- NAVSOC: It is the DOD's lead service for narrowband SATCOM. It operates, manages, and maintains three satellite constellations and ground systems, to include the Naval Satellite Control Network. These provide

63 Chairman of the Joint Chiefs of Staff, *Space Operations*.

64 Chairman of the Joint Chiefs of Staff.

65 Chairman of the Joint Chiefs of Staff.

66 Chairman of the Joint Chiefs of Staff.

enduring global space support, in direct support of USN forces, the joint warfighter, and interagency partners.[67]

Figure 11. Representation of the Service Component Structure for the Air Force, Navy, Army, and Marine Corps.[68]

2. Navy Space Cadre

Space cadre membership is achieved by attaining an AQD that signifies a level of space competence based upon a combination of education and experience. Space-related AQDs are designated by the VS prefix followed by a number.

- All designators and grades can qualify
- The duration of the qualification is indefinite
- Open to Active and Reserve Components[69]
- Roles and Responsibilities of Navy Space Operations Officer

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[67] Chairman of the Joint Chiefs of Staff.

[68] Adapted from Horvath, "Space Operations Warfighting Seminar MARFORSTRAT."

[69] Naval Network Warfare Command, *Naval Space Handbook*, 104.

- Provides operational support and expertise on space capabilities to the commander and staff
- Integrates and synchronizes space force enhancement capabilities including missile warning (DSP), navigation (GPS), environmental monitoring, and SATCOM into operational plans and execution
- Ensures the SSP supports current operations, as well as future plans
- Ensures that SEPs are tailored to adequately support the SSP
- Prepares, submits, monitors status, and tracks changes for strike group SSRs
- Monitors the Joint Space Tasking Order (JSTO), and informs appropriate staff of any potential impacts to space systems related to JSTO events
- Is familiar with Blue/Red/Grey space systems, and their capabilities and limitations
- Advises staff of any impacts to space systems or space capabilities caused by space or terrestrial weather
- Assists N2 staff with requests for information
- Coordinates with other space operations entities, such as other strike group Space Operations Officers in theater, MOC Space Operations Officers, and the theater SCA via the DS4
- Plans for and coordinates the effects of offensive and DSC measures on operations
- Integrates appropriate emerging space capabilities into plans and operations
- Employs space tools, such as SATVUL, GIANT, etc.
- Reaches back to NNWC Space Directorate for support, and to provide lessons learned for updating the naval space concept of operations[70]

3. Marine Space Cadre

The Marine Corps manages a cadre of educated, trained, and experienced space SMEs. These SMEs are designated as either space operations officers (8866) or space operations staff officers (0540). Marine Corps space cadre billets are located throughout

[70] Naval Network Warfare Command, 52–53.

the Marine Corps operating forces, the support establishment, the joint community, and within selected agencies.[71]

- **Space Operations Officers (8866):** Space operations officers are designated after successfully completing a Master of Science degree in Space Systems Operations or Space Systems Engineering at either the Naval Postgraduate School or the Air Force Institute of Technology. They are tasked with:
    - Supporting the G/S-3, G/S-6, and G/S-2, while leveraging all space capabilities.
    - Acting as the conduit between MAGTF operators and the capability providers.
    - Advocating MAGRF space requirements to service, joint and interagency organizations.[72]
- **Space Operations Staff Officers (0540):** Space operations staff officers are designated after completing the Space 200 course at the National Security Space Institute (NSSI). They are responsible for:
    - Making recommendations to decision makers in space systems acquisition management.
    - Developing requirements for space systems
    - Participating in space operations planning.[73]

4. Space Operations and Associated Capabilities

- **Space Situational Awareness (SSA):** Understanding the current and predictive knowledge of the space and operational environments upon which space operations depend.
- **Space Control**: Employs offensive and DSC operations to ensure freedom of action in space and when directed, defeat efforts to interfere with or attack U.S. or allied space systems.

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[71] Naval Network Warfare Command, 71.

[72] Naval Network Warfare Command, 71, 77.

[73] Naval Network Warfare Command, 73.

- **Offensive Space Control (OSC):** Denies adversary freedom of action in space through negation and offensive prevention measures of deception, disrupting, degrading, denial, or destruction.
- **DSC**: Protects space capabilities and is based on protection and defensive prevention measures

- **Positioning, Navigation, and Timing (PNT)**: Military users depend on PNT systems for precise and accurate geolocation, navigation and time reference services. GPS provides the global community largely uncontested access to space-based PNT services.

- **Intelligence, Surveillance, Reconnaissance (ISR)**: Space-based ISR systems are often referred to as national technical means (NTM) or national systems. They are space-based sensors which can provide imagery intelligence (IMINT), signals intelligence (SIGINT), and measurement and signature intelligence (MASINT) data collection capability.
- **Satellite Communications (SATCOM)**: or Military SATCOM (MILSATCOM), provides beyond line of sight (LOS) connectivity. This includes narrowband, wideband, and protected geostationary constellations that provide global coverage, real-time voice and data transmissions, terrestrial communications architecture, flexibility, and support to mobile forces.
- **Environmental Monitoring**: Space-based environmental monitoring satellites monitor the terrestrial environment using meteorological and oceanography (METOC) sensors and can also carry space weather sensors. These satellites may be the only source of environmental information in areas where other collection capabilities are limited or denied.
- **Missile Warning**: Provides reliable, accurate, and timely information to missile defense systems. This mission includes both national and theater means to enable active missile defense an attack operations against hostile forces.
- **Nuclear Detonation Detection**: Nuclear detonation detection capabilities provide a persistent, global, and integrated sensor capability to provide surveillance coverage of critical regions of the globe and provide warning and assessment recommendations to the President, Secretary of Defense (SecDef), and combatant

commanders (CCDRs), indicating place, height of burst, and yield of nuclear detonations.[74]

D. USNA SPACE OPERATIONS COURSE ANALYSIS

Courses	NPS	USAFA	USMA	USNA	USNA Other
Astronomy	0	3	2.5	0	3
Astrophysics	0	0	2.5	0	6
Communications	7	3	0	0	10
Electronics & Cyber	0	3	5.5	0	11
Orbital Mechanics	4	4	2.5	9	0
Project Management	5	6	0	0	0
Remote Sensing	4	6	5	0	3
Rocket Propulsion	4	3	0	3	0
Space Environment	4	3	2.5	3	0
Space Operations	15	6	2.5	0	3
Space Policy	4	6	2.5	0	6
Spacecraft Design	10	11	0	11	0
TOTAL	57	54	25.5	26	42

Figure 12. Benchmarked Space Operations Courses by Semester Hours.

[74] Chairman of the Joint Chiefs of Staff, *Space Operations*.

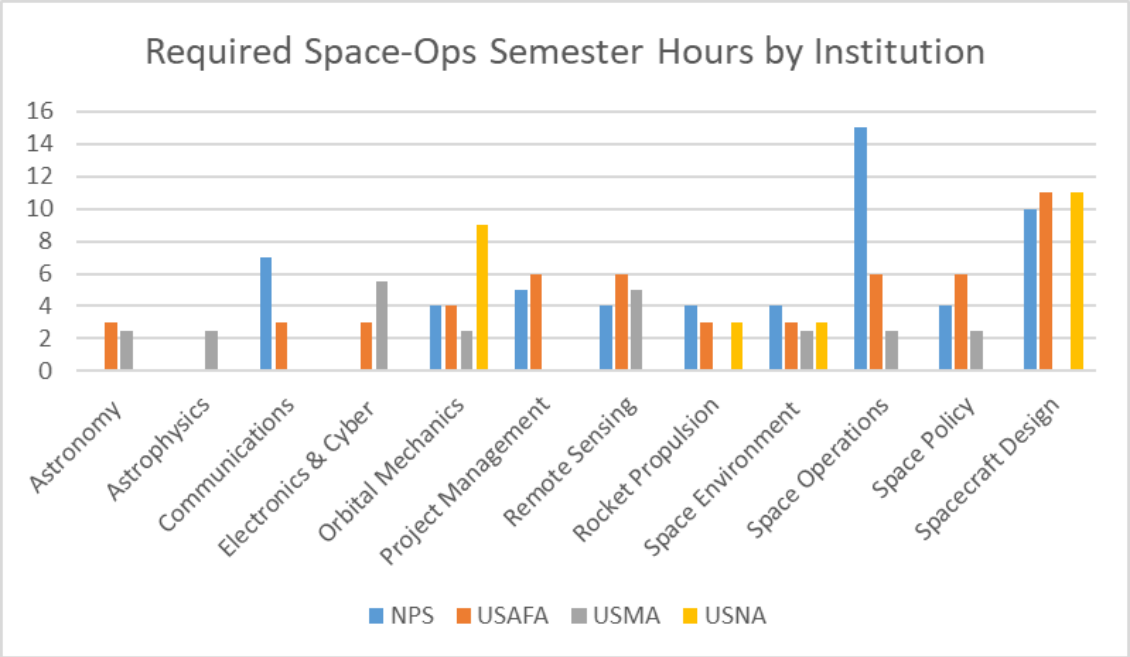

Figure 13. Benchmarked Space Operations Courses Graph.

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LIST OF REFERENCES

Chairman of the Joint Chiefs of Staff. *Space Operations*. Joint Publication 3-14. Washington, DC: Chairman of the Joint Chiefs of Staff, 2018. https://fas.org/irp/doddir/dod/jp3_14.pdf.

College Navigator. "United States Naval Academy, Programs." Accessed April 23, 2018. https://nces.ed.gov/collegenavigator/?q=united+states+naval+academy&s=all&id=164155#programs.

Commission to Assess United States National Security Space Management and Organization. *Report of the Commission to Assess United States National Security Space Management and Organization, Executive Summary, Pursuant to Public Law 106-65 January 11, 2001*. Washington, DC: Commission to Assess United States National Security Space Management and Organization, 2001. https://fas.org/spp/military/commission/executive_summary.pdf.

Department of Seamanship and Navigation. *Syllabus and Study Guide: NN310-Advanced Navigation, Academic Year 2016*. Annapolis, MD: United States Naval Academy, 2016.

———. *Syllabus and Topic Guide, NS433-Naval Aviation Practicum, Academic Year 2018*. Annapolis, MD: United States Naval Academy 2018.

Department of the Navy. *Department of the Navy Space Policy*. SECNAVINST 5400.39C. Washington, DC: Department of the Navy Space Policy, 2004.

———. *Department of the Navy Space Policy*. SECNAVIST 5400.39D. Washington, DC: Secretary of the Navy, 2015.

———. *Navy Space Policy Implementation: Responsibilities*. OPNAVINST 5400.43B (Draft). Washington, DC: Chief of Naval Operations, 2017.

———. *Report of Curriculum Review of Resident Curriculum Space Systems Operations, Space Systems Academic Group*. Monterey, CA: Naval Postgraduate School, 2017.

Godshall, Stacy. "Space and Missile Defense Program/Space Science Major Development to Mitigate Shortfalls in Space Workforce's Education." Abstract presented at the AIAA Space 2017 Conference, San Antonio, TX, February 5–9, 2017.

LaGrone, Sam. "Mobile User Objective System." USNI News, November 3, 2016. https://news.usni.org/2016/11/03/final-muos-satellite-place-italian-ground.

Naval Network Warfare Command. *Naval Space Handbook*. Norfolk, VA: Naval Network Warfare Command, 2018.

———. *Navy Space Cadre Human Capital Strategy*. Virginia Beach, VA: Naval Network Warfare Command, 2004.

Naval Postgraduate School. *366 Space Systems Operations, Navy 21 month + Refresher Matrix*. Monterey, CA: Naval Postgraduate School, 2017.

———. *Academic Catalog, Space Systems Certificate*. Monterey, CA: Naval Postgraduate School, 2017.

———. "Space Systems Academic Group, Objectives." Accessed April 28, 2018. https://my.nps.edu/web/ssag.

Pugsley, Thomas S. "Army Space Education: Closing the Gap with Operational Space." Paper presented at 23rd Annual AIAA/USU Conference on Small Satellites, Utah State University, Logan, UT, August 10–13, 2009.

SPAWAR, PEO Space Systems. "Fleet Satellite Communications System." Accessed June 1, 2018. http://www.public.navy.mil/spawar/PEOSpaceSystems/technology/Pages/FLEETSATGraphics.aspx.

———. "Ultra-High Frequency Follow On." Accessed June 1, 2018. http://www.public.navy.mil/spawar/PEOSpaceSystems/technology/Pages/UHFGraphics.aspx.

Trump, Donald J. *National Security Strategy of the United States of America*. Washington, DC: The White House, 2017.

United States Air Force Academy. *Curriculum Handbook, The Astronautical Engineering Major at a Glance*. Colorado Springs, CO: United States Air Force Academy, 2017. https://www.usafa.edu/app/uploads/CHB.pdf.

———. *USAFA Course Handbook. "Curriculum Handbook, The Astronautical Engineering Major at a Glance*. Colorado Springs, CO: United States Air Force Academy, n.d. Accessed March 13, 2018. https://www.usafa.edu/app/uploads/CHB.pdf.

United States Military Academy. "Department of Physics & Nuclear Engineering, Space Science Major & Minor." Accessed February 28, 2018. https://www.westpoint.edu/pne/SitePages/Space%20Science.aspx.

———. *United States Military Academy, Academic Program, Class of 2020 Curriculum and Course Descriptions, Office of the Dean*. West Point, NY: United States Military Academy, 2016. https://www.usma.edu/curriculum/SiteAssets/SitePages/Course%20Catalog/RedBook_GY2020_20170803.pdf?Mobile=1.

United States Naval Academy. “Academics, Majors and Courses.” March 15, 2018. https://www.usna.edu/Academics/Majors-and-Courses/Course-Requirements-Core.php.

———. “Aerospace Engineering Course Information.” Accessed March 15, 2018. https://www.usna.edu/Academics/Majors-and-Courses/course-description/EA.php.

———. Aerospace Engineering Department. “Enrolled Grad Data.” Accessed May 15, 2018. https://www.usna.edu/AeroDept/Enroll-Grad-Data.php.

———. Aerospace Engineering Department. “Program Educational Objectives.” Accessed May 15, 2018. https://www.usna.edu/AeroDept/peo.php#_ftnref.

———. “Departments, Aerospace Engineering.” Accessed March 15, 2018. https://www.usna.edu/AeroDept/.

———. “Major Matrix.” Accessed April 9, 2018. https://www.usna.edu/AeroDept/_files/documents/EAS%20Matrix.JPG.

———. *Syllabus and Introduction: ES300-Naval Weapons Systems, Academic Year 2015*. Annapolis, MD: Department of Weapons and Systems Engineering, 2015. https://www.usna.edu/WSE/_files/documents/courseDescriptions/ES300.pdf.

———. “Training, Professional Knowledge.” 2017–2018. https://www.usna.edu/Training/_files/documents/References/4C%20MQS%20References/Pro%20Book%202017-2018.pdf#search=pro%20knowledge.

———. *United States Naval Academy Core Learning Outcomes.* Annapolis, MD: United States Naval Academy, 2015. https://www.usna.edu/Academics/_filtes/documents/assessment/CLOsandPreamble%20FEB%202015.pdf.

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