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USMA SPACE CADETS: THE FIRST CLASS

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ABSTRACT

The United States Military Academy (USMA) at West Point has been developing leaders of character since 1802. This year's graduating class, the Class of 2020, includes West Point's first Space Science majors. The United States Army has officially had space professionals in its ranks since 1997 with the inception Space Operations Officer career field, also known as Functional Area 40 (FA40). It is only recently that the Army has shifted its focus to building the FA40 ranks from officer accessions programs (USMA, ROTC, and OCS). The establishment of the Space and Missile Defense Program under USMA's Physics and Nuclear Engineering (PaNE) Department shows the heightened priority of building space professionals for the Army. This program, that was first discussed in a paper submitted to the 23rd annual AIAA/USU Conference on Small Satellites, has been twelve years in the making. Now, West Point has risen to the level of its fellow-service academies in the realm of space education and research.

INTRODUCTION

I am in a unique position as 1 of 7 Air Force officers assigned as exchange instructors at the United States Military Academy. My interest in becoming an instructor at a service academy was fueled by my interactions with staff, faculty, cadets, and midshipman during my first assignment working in the DoD Space Test Program (STP) at Kirtland AFB, NM. It was during that assignment, working as a Space Flight Mission Design Manager, that I was able to see the level of impact the faculty and staff had on the cadets and midshipman.

As a Space Flight Mission Design Manager, I was a broker of rides to space. Through the DoD Space Experiments Review Board (SERB)[1] process primary investigators can bid for a ride to orbit by proving the military utility of their experiments. If accepted by the board the experiments are assigned a mission manager. I was assigned to STP from 2008-2011 and my specialty was CubeSats. The form factor was quickly becoming very popular because of its low cost and increasing accessibility to space as an auxiliary payload. This made it an ideal educational tool for the service academies.

It was as the mission manager for USMA's Black Knight-1 CubeSat that I made my first trip to West Point and met, then Major, Thomas Pugsley. Colonel Pugsley authored *Army Space Education: Closing the Gap with Operational Space*[2], on what a West Point space education program should look like. Twelve years later, I have circled back to the United States Military Academy. I am now one of two junior instructors in a new academic program to West Point: Space and Missile Defense. I will teach SP471 Astronautics next semester, which is the first of four foundational courses in the Space Science curriculum.

I will use this paper to provide an update on how far West Point has come since COL Pugsley identified the disparities between the Army and its fellow services in the realm of space education. I will show that West Point did close the gap through the hard work and persistence that is characteristic of the men and women of the United States Army. This is evidenced by the 18 new lieutenants that will graduate this week with a Bachelor of Science in Space Science and the 11 others who will graduate with a Space Science minor.[3]

BACKGROUND

Identifying the Problem

During the 2008-2009 academic year (AY) West Point filled a previously unoccupied Functional Area (FA) 40 billet. FA40s are Army Space Operations Officers - subject matter experts on all things space. The FA40 to fill the billet was COL Pugsley.

After settling into his position as an instructor COL Pugsley quickly realized there was quite the disparity in the early education of space professionals when comparing the Army to its fellow services. "…West Point has been slow to move into the space age, [and is] well behind the other two service academies in all aspects of space education."[2]

Researching the Issue

"Over the past several decades, the Army has emerged as the largest user of space capabilities in the DOD, and currently leverages space capabilities to increase combat power form the strategic to tactical level."[4] That is a significant statement that would support the early education of space professionals for the Army, so why was it not a focus area?

COL Pugsley embarked on the process of researching that question. To make a proper comparison he took a holistic look at the development of space professionals in the Army, Navy, and Air Force (for the remainder of this paper collectively to be referred to as the services). He compared the space training and education opportunities of each service from cadet to senior leader level, focused on the service academies' curriculum and training. That was the area he could, and did, make an impact.

The research did not include officer accessions from Reserve Officer Training Corps (ROTC) or Officer Candidate School (OCS). While these programs do bring officers into the service that will eventually become space professionals, they are not responsible for the curriculum offered to their cadets. ROTC relies on the civilian institution to manage their overall curriculum for degree awarding programs, and focuses on the Military Science, Naval Science, or Aerospace Studies classes that prepare civilian students for service as an officer. Both Navy and Air Force ROTC incentivize students to select a major by offering selection priority or scholarships. Currently they offer these incentives for Astronautical Engineering majors.[5]

The Findings

Each service has a unique relationship with the space domain which drives the construct of their guidance for space professional development. The services have both operators – the entities responsible for "flying" space assets – and users – consumers of the products or services generated by space assets. A significant factor in the construct of the space professional development between the services is the ratio of operators to users.

The Army has the greatest number of users but the lowest number of operators. The Air Force has the highest number of operators as is responsible most of the major military satellite constellations. The Navy falls in between as they still operate a major satellite communication constellation. The Navy and Air Force have a significant number of users which cannot surpass the Army simply due to authorized end strength. The recent standup of the United States Space Force (USSF) will change these ratios as the Air Force transitions its space mission to the Space Force.

COL Pugsley concluded that at the operational level, post-commissioning, "each service has a very different approach to acquiring and training its space professionals [but] all three services have reached what each believes to be a standard for education and training." Thus, the largest disparity between the Army and its fellow services lies in pre-commissioning education and training.

Next, COL Pugsley conducted an in-depth comparison of the service academies. The numbers made it quite apparent that COL Pugsley's hypothesis was correct: the Army by virtue of West Point was well behind its counterparts when it came to undergraduate space education.

Table 1: Space Related Curriculum Comparison 2008[2]

Academy	Majors	Courses	Faculty	Student Involvement
USMA	0	1	0	<1%
USNA	1	15	18	≈30%
USAFA	3	27	18	60%

COL Pugsley's findings culminated in the publishing of his paper for the 23rd Annual Small Satellites Conference and "establish[ed] a cornerstone from which the foundation of West Point's space education and research efforts could be built."[2] The remainder of this paper recounts the measures taken from COL Pugsley's initial findings and early initiatives in 2008 to USMA graduating its first cohort of Space Science majors/minors and qualified space professionals on 13 June 2020.

SPACE CENTRIC CIRRICULUM

Getting Started

Space Science has been a part of the West Point curriculum for about 180 years. The Academy has seen several observatories built over the years and there have been many firsts accomplished with them. The newest observatory adorns the Bartlett Hall Science Center which is named to William H.C. Bartlett, class of 1822, who built the first observatory at West Point in 1841.

For too long there had only been a single space-focused course available to cadets, as referenced in Table 1. PH472: *Space and Astrophysics*[6] was offered by the Department of Physics, which was renamed in 2009 to the Department of Physics and Nuclear Engineering. It was an all-in-one course that started with orbital mechanics and concluded with a section on stellar

evolution. If the Army was going to take advantage of the four years of undergraduate education and the 47-month cadet experience at West Point to begin development of space professionals, it had to start with growing the curriculum.

This posed a significant challenge "due to the very restrictive environment of the Academy…[and] the already overloaded academic catalog."[2] It would be difficult to get cadets into the new classes as well because their schedules are generally overloaded. Cadets generally free up space in their schedule by validating required courses or taking courses in the summer during the Summer Term Academic Program (STAP). This allows them to pursue elective courses that interest them. There was a great deal of interest among cadets to take electives in space related fields.

COL Pugsley's plan covered three areas: 1) seek approval to add new space centric courses to the catalog. 2) seek approval to stand up a satellite design and development program, and 3) establish a research group to serve as "a permanent center of knowledge and coordination authority for all space related research and education activities."[2]

With great internal support and with the assistance of some external partners that could put rivalry aside for the betterment of all, the plan was put into motion. West Point was about to start on a long journey to produce space professionals for the United Stated Army.

Adding Courses

From AY2008 to AY2009 three space centric courses were added to the course catalog and made available for cadets as electives. PH472: *Space and Astrophysics* stayed in place as the overall introductory space course. However, some new courses had to be created that would provide the cadets some tangible skills to support participation and success in the newly developed research programs and clubs.

The Department of Mathematical Sciences added MA488 and named the course *Mathematics for Space Applications*. The "Redbook,"[6] which is the designation for West Point's publication containing all curriculum and course descriptions, lists MA488 as *Special Topics in Mathematics*[6]. As listed the "course provides an in-depth study of a special topic in mathematics not offered elsewhere in the USMA curriculum. Course content will be based on the special expertise of the visiting professor or a senior mathematical science faculty member."[6]

In this case MA488 was used to "introduce students to the development of a wide variety of useful skills, as well as learning mathematical tools focused on applications relating to space." This included exploration of space-time coordinate systems and coordinate transformations. It also went in-depth into all manner of orbital analysis.

The Electrical Engineering and Computer Science (EECS) department followed suit an used their CS485: *Special Topics in Computer Science*[6] course and branded it *Space Systems Engineering*. CS485, "…introduced students to a broad range of space related topics, giving them hands on experience working a variety of problems dealing with the space environment, spacecraft design, spacecraft subsystems, and military satellite operations."[7]

CS485 was a course sponsored by COL Pugsley. The goals of the course were to produce more technically and operationally proficient leaders with an emphasis on space sciences by introducing concepts of spacecraft design and project management focusing on mission design and spacecraft subsystem integration. This course utilized the software suite, AGI Satellite Tool Kit (STK) now known as Systems Tool Kit and EyasSat, a fully functional nanosatellite, for hands-on mission analysis and testing.

Cadets completing PH472, MA488, and CS485 were prepared to enroll into EE401/402: *Senior Satellite Design Project (Black Knight 1)*. In prior years EE401/402 was dubbed *Electronic System Design 1 & 2*[6]. Black Knight 1 fit squarely into the designated scope for the course. "Projects are open-ended and must result in a product that performs within pre-determined or negotiated constraints. The system design problem draws from a variety of science and engineering experiences within the curriculum and requires significant cadet creativity and decision-making."[6] This was a project with the goal of getting a real satellite to orbit – a mission that elicited cadet excitement. More detail on Black Knight 1 will be presented in later sections of this paper.

West Point was on its way to operating at the same level as its fellow-service academies in the realm of space education. The initial course development was only one piece of the puzzle. The courses were not permanent as they were slated under special topic electives. Eventually they needed to be moved under the auspices of a degree program as a major or minor. There also needed to be an organization to champion the effort and maintain continuity as instructors rotated in and out of West Point assignments.

RESEARCH CENTER

One Small Step

During AY2009 COL Pugsley founded the Small Satellites Research Group (SSRG). "The purpose…of the SSRG was to provide a stable foundation from which to build West Point's infrastructure to support more advanced satellite research and design projects in the future."[7] The SSRG was tied directly to the development of Black Knight 1. The goals of the SSRG were to serve as the center for West Point's space education and training. Furthermore, COL Pugsley intended to use it as a platform to legitimize the work being done and introduce West Point as a new and "serious player in the university satellite and space research arena."[2]

The SSRG also helped to pull cadets into the Cadet Astronomy and Space Engineering Club. This venture was an expansion of two existing clubs, the Astronomy Club, the Amateur Radio Club, and The Electronics Experimenters Groups. This unity of effort between, then MAJ now LTC, Diana Loucks of PaNE, MAJ now COL Stephen Hamilton of EECS, and COL Pugsley, allowed West Point to offer space education opportunities to a larger group of cadets. Not being tied directly to courses, cadets were free to participate regardless of major or academic workload.

Big Army Buys In

While the SSRG was up and running further work was being done to secure the future of West Point's space education program. "An agreement was made between West Point and the Army's Space and Missile Defense Command (SMDC) to stand up the SMDC Army Research Center (ARC)…at West Point."[2]

By AY2010 the SMDC Research and Analysis Center (RAC), sponsored by PaNE, was directed by an SMDC representative from Massachusetts Institute of Technology Lincoln Laboratories (MIT/LL) and was actively supporting the West Point space education efforts. Its mission to this day is "[t]o promote and facilitate USMA cadet and faculty research in support of the US Army Space and Missile Defense Command (SMDC) objectives; enhance the professional development of the USMA faculty; and inspire cadets through space and missile defense education and research to face technical challenges with confidence."[8]

With the addition of the multidisciplinary space centric courses, a senior design project that would produce an on-orbit satellite, and the stand up of an Army Service Component Command sponsored research center, COL Pugsley's goals were met. There was buy-in from staff and faculty of multiple departments, there was backing from big Army, and there was an ever-increasing amount of cadet interest in space. The initial conditions were set to grow the program. However, there were still some lingering concerns.

Table 2: West Point Snapshot 2009[2]

Criteria	Values
Space Related Programs	0
Space Related Majors Offered	0
Space Related Educational Courses	4
Space Research Groups/Centers/Programs	3
Full Time Space Faculty	3
Satellite/Payload Launched	0
Student Body Involvement	1%

First, there was no clear home for the subject as West Point did not have an Astronautical or Aerospace Engineering program. Second, resources in terms of classroom space, laboratory equipment, and funding were limited. Third, the interdisciplinary nature of the subject creates challenges with course scheduling, credit, and continuity. Finally, getting the courses from a "Special Topic Elective" to a hard-coded course in the Redbook usually means a department must remove an existing course to have proper alignment of personnel. There would be resistance to that.

PROGRAM INITIATION

Expanding the Catalog

Over the next few years, the concerns put forth in COL Pugsley's briefing were addressed. In 2011 The Department of Geography & Environmental Engineering, affectionately known as Dirt with its own mascot Dirtman, was offering two pairs of sequenced courses which focused on the use of space-based capabilities. They provide cadets hands-on experience with the capturing and processing of space products. These courses are integral to the development of Army space professionals.

Digging in the Dirt

The first course pair consisted of EV398 and EV498. EV398 *Geographic Information Systems,* "…introduces basic theories and technologies of Geographic Information Systems (GIS), including the representation, acquisition, manipulation, analysis, and visualization of geographically related information."[6] This is followed by EV498 *Advanced Geographic Information Systems* which, "examines the analytical methods used in Geographic Information systems (GIS) and provides cadets with a clear understanding of the

theoretical/conceptual aspects of algorithms found in GIS software."[6]

The second Dirt course pair was EV377 *Remote Sensing* and EV477 *Advanced Remote Sensing*. EV377, "center[s] on the use of satellites to study the Earth. This course emphasizes…using both commercial and classified imagery. Cadets enjoy a wide range of practical exercises, which introduce them to several remote sensing systems to include conventional and color infrared photography, multispectral scanners, satellite imagery, thermal infrared, and radar. The capstone exercise offers each cadet the opportunity to perform real-time automated image classification using satellite data on their personal computer."[9]

EV477, "examine[s] advanced remote sensing theory and digital image processing techniques suitable for the processing of remotely sensed data. Emphasis is on the processing and analysis of state-of-the-art high spatial and spectral resolution data gathered by both airborne and satellite sensors. A wide range of practical exercises and in-class laboratory assignments provides hands-on experience with a variety of remotely sensed imagery ranging from multi-spectral to hyper-spectral data. The course culminates with a capstone term project that allows cadets to apply digital image processing skills to a scientific problem."[9]

It is Rocket Science

PaNE also introduced another course in utilizing the special topics elective course designated PH495. At this time, the course was named *Physics of Rockets, Missiles, Radar and Missile Defense Systems.*[9] Along with CS485, PH495 helped to focus the cadets on acquisition, research, and development of space systems. PH495 gave cadets an opportunity to develop a missile defense system. To succeed, the cadets had to choose subsystem components and integrate them in a manner that would result in a system that would provide the desired capability.

By the numbers, things were going well: the number of courses was growing, the number of faculty supporting space education in support of space education was growing, buy-in from other departments was growing, and hard-coded courses were becoming part of the space education curriculum at West Point.

Table 3: West Point Snapshot 2011

Criteria	Values
Space Related Programs	0
Space Related Majors Offered	0
Space Related Educational Courses	9
Space Research Groups/Centers/Programs	3
Full Time Space Faculty	5
Student Body Involvement	>1%

Now is the time

In the four-year span between 2011 and 2015 several significant events took place at West Point which would create the perfect setting to formalize the space education curriculum. First, curriculum transformation at the Academy was instituted that focused on creating leaders who could critically think and make educated and informed decisions in a 21st Century battlefield setting. It took a long time for West Point, as an institution, to increase its flexibility when it came to updating the structure of its curriculum. But West Point now regularly evaluates itself in-depth. This self-assessment allows cadets, instructors, programs, and departments to make changes within their scope of responsibility and to suggest changes at the higher levels.[22]

"During the past fifty years, West Point has participated in a journey that has dramatically altered the structure of its curriculum (Forsythe and Keith 2004). From 1802 through 1960, West Point offered students a prescribed curriculum; all students completed the same set of courses. Beginning in 1960, electives were introduced into the curriculum. By 1970, students selected concentrations that, by 1980, became fields of study. Majors were first introduced with the class of 1985 and became a graduation requirement with the class of 2005. Although all students complete a common core curriculum of twenty-six courses, West Point has sought to balance the completion of a breadth component (core curriculum) with the depth of study derived from a disciplinary major. External constraints necessitate that students complete all of the graduation requirements within forty-seven months (eight academic terms)."[16]

After about two years of in-depth review and assessment of the curriculum West Point pushed to further reduce the core curriculum in favor of allowing cadets access to increased number of courses within their disciplinary major. There was also a change in the timing of when cadets could choose their major, moving it to the end of their first year. This facilitated earlier scheduling of courses or electives within the

major. The catch was the departments had to agree this could be done without an increase in personnel.

Second, PaNE had assimilated the space-centric courses, that were mostly special topic electives, into the Interdisciplinary Science major as an Astronautics Track. This would be key in the future requests to create a new major, Space and Astronautics.

Third, the extensive renovations to Bartlett Hall Science were nearing completion. The multiyear, multimillion-dollar project resulted in a state-of-the-art science facility with some room for expansion. Along with its new "classatories" Bartlett Hall was also topped with a new observatory featuring motorized dome, a clean room, electronics shop, and modernized fabrication shop. Everything you could want to support a growing space science curriculum.

Finally, increased collaboration and partnerships were being established in support of West Point's space education initiatives. Fellow-service academies, post-graduate schools, national labs, and other DoD entities were getting involved and offering opportunities. LTC Stacy Godshall, an Army FA40 and future director of the SMD program, saw that the time was right to propose a new major at West Point, and had the support of PaNE leadership.

What's your major, Major?

In 2015 the request to create the Space and Astronautics major was submitted to the Office of the Dean. It is a 10-page memo titled "New Curricular Change Request for SPA0 (Space and Astronautics)." It contains 5 enclosures that discuss everything about the proposed major in detail. Every department at West Point can review, concur or non-concur, and provide feedback. The initial request for the curriculum change adding the Space and Astronautics major to West Point was disapproved. The space professional of USMA had some more work to do before they could claim victory.

Despite the setback of not having the curriculum change approved, support was growing. "The U.S. Military Academy at West Point's Space and Missile Defense, or SMD, program was initiated in 2015 after significant upgrades to research facilities that will be used for space-related research. The SMD program comprises: the space science major, the space science minor, and the astronautics track. The SMD program is also supported significantly by the Space and Missile Defense Command Research and Analysis Center, or SMDC-RAC."[(10)]

The initiation of the SMD program was another step closer to a full-on curriculum change that would include a space major. In 2016 the SMD program offered the Interdisciplinary Science degree with an Astronautics track. This was the pilot offering used to gauge cadet interest in a stand-alone Space Science major. The success of the Astronautics track was a primer to make a second request for a curriculum change.

The second memo sent to the Office of the Dean. This memo was titled "New Curricular Change Request for SPA0 (Space Science)." This memo highlighted the reasoning behind the request describing the recent curriculum changes academy wide, the updates to the infrastructure in Bartlett Hall, and the growing partnerships supporting space training and education. The memo also addressed the curriculum committee concerns that led to the previous disapproval and the mitigations for each.

Hard work was finally rewarded with a great success! The curriculum change was approved and in 2017 the Space Science major and minor were made available to the Corps of Cadets. The Class of 2020 will be the first cohort of to be awarded a Bachelor of Science in Space Science from the United States Military Academy.

Table 4: West Point Snapshot 2020

Criteria	Values
Space Related Programs	1
Space Related Majors Offered	1
Space Related Educational Courses	9
Space Research Groups/Centers/Programs	3
Full Time Space Faculty	5
Student Body Involvement	≈5%

Cadets who graduate from the Space and Missile Defense Program are expected to attain the following:

1) Cadets can apply mathematical and scientific knowledge to identify, formulate, and solve Space Science problems.

2) Cadets can conduct experiments, apply the scientific method, as well as analyze and interpret data.

3) Cadets can function on multidisciplinary teams to effectively formulate, state, describe, summarize, and communicate contemporary space issues, National Strategic Space Policy, and associated technology; analyze and examine the professional and ethical aspects of the aforementioned.

4) Cadets can describe and summarize the technology of a system, component, or process to meet desired needs within realistic constraints such as economic,

environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

5) Cadets can recognize the need for, and an ability to engage in life-long learning; explain relevant, contemporary issues and concepts needed as a space-enabled professional.

The curriculum is still heavily interdisciplinary in nature but is a program of space study founded in physics fundamentals and enhanced by studies in electrical engineering, remote sensing, and each cadet's chosen engineering sequence. There are four foundational Space Science courses taught by PaNE - SP471 *Astronautics,* SP472 *Space Physics,* SP473 *Observational Astronomy*, and SP474 *Astrophysics* - that took the place of many of the special topics electives that had been integrated into the Astronautics Track, but which are taught at greater depth. Remote Sensing and GIS, the first hard coded course from Dirt remained. Cadets must also choose a three-course engineering sequence from cyber, environmental, infrastructure, nuclear, robotics, or systems.

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	SP471 ASTRO-NAUTICS	SP472 SPACE PHYSICS	SP473 ASTRO-NOMY	SP474 ASTRO-PHYSICS

Legend (Space and Missile Defense areas of interest):

Directed Energy	Policy Development
Missile Defense	Space Science
Cyber Operations	

Figure 1: Space Science Example Schedule

It took 12 years from initial identification of the disparity in undergraduate space education between USMA, USAFA, and USNA to graduating West Point's first class of Space Science majors and minors. Graduation of 18 majors and 11 minors on June 13, 2020, is a testament to the hard work and innovative spirit of all involved over that period. Growing a curriculum, building a program, and getting a new major/minor approved were the initial hurdles that set the stage for in-depth space education at West Point. While these steps may have seemed challenging to those involved, the coursework is only one small piece of developing space professionals. Research is where the real fun is!

Table 5: West Point Space Science Enrollment

Graduating Class Year	Majors	Minors
2019 (Astronautics Track)	9	N/A
2020	18	11
2021	16	5
2022	18	15
2023	12	0

CADET INDEPENDENT RESEARCH

Black Knight Satellite

Black Knight 1 (BK1) was the product of the initial Senior Design Project from EE401/EE402. Utilizing the relatively new CubeSat form factor the course was set to maximize cadet opportunity to do hands-on work on a real satellite over three years culminating in a launch and on orbit operations. "Of the 34 total projects presented…seniors [that year], the BK1 project received 70% of the interest."[7] The goals of the program were to develop a low cost experimental spacecraft, educate future Army leader on space related topics, and build a foundation for satellite development at West Point. Without this capstone activity I believe the stand-up of the Space and Missile Defense Program and associated Space Science major/minor would not have been as successful as it is or may have not happened at all.

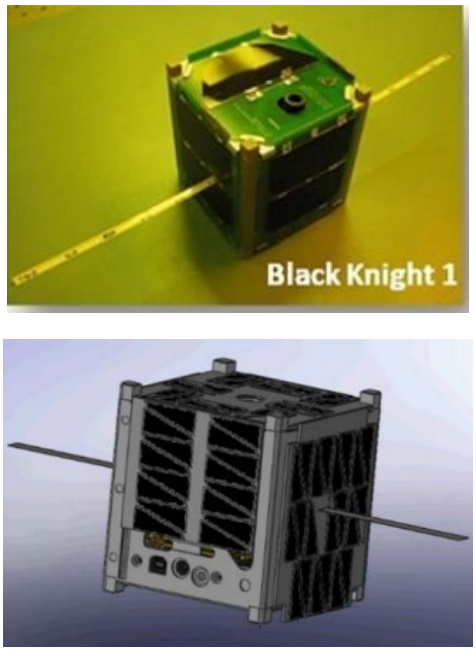

Figure 2: The Black Knight 1 Satellite

An Opportunity to Orbit

The Black Knight Satellite program is where I was introduced to the United States Military Academy at

West Point. I was a new Air Force second lieutenant and I had just graduated from Space 100, the Air Force's introductory space course. While I was at Vandenberg Air Force Base, California I received a note saying I was program officer from the Multi-Mission Space Operations Center to the DoD Space Test Program. I did not know what to expect, but I had just seen my first live launch, a test of the Minute Man III ICBM, and I was very excited to be part of the space enterprise.

When I returned to Kirtland AFB, New Mexico from Space 100, I checked in with my new team. They were very busy preparing for the Space Experiments Review Board (SERB). I was assigned responsibility for "shepherding" all the CubeSats on the list. Not having commissioned from a service academy I was surprised to see their level of involvement. They were bidding for a ride alongside satellites and payloads from Air Force Research Lab (AFRL), Navy Research Lab (NRL), and the National Aeronautics and Space Administration (NASA).

The next year I was introduced to COL Pugsley and he gave me an overview on the SSRG and the cadet senior design project BK1. I thought it was an awesome opportunity for cadets and great for their development as space professionals. It was that aspect of the program that would help to get their project selected by the SERB for manifest on a launch.

The SERB scores each experiment and assembles a ranked list with the most relevant and impactful project at the top. Finding launch opportunities for these experiments is the responsibility of the DoD Space Test Program. The top weighted criterion for SERB scoring is military relevance. For the service academies, the science is usually not the star of the show. For them, the opportunity for greater development of space professionals is the factor that makes the project relevant militarily. Combined with a form factor that is now common, this makes for greater opportunity to get to orbit.

A Ride to Space Secured

In June 2012 BK1 was officially manifested on the Operationally Responsive Space (ORS)-3[(11)] mission for a scheduled to launch in fourth quarter of 2013. BK1 was just one of 29 other satellites that were to launch on an Orbital Minotaur I launch vehicle from the NASA Wallops Flight Facility in Virginia. The mission was significant in that it represented to work of "300 budding scientists"[(11)] from all over the United States.

On November 19, 2013, the ORS-3 Mission successfully launched from the Mid-Atlantic Regional Spaceport. The Minotaur reached orbit with no issues and deployed its primary payload, the Space Test Program Satellite (STPSat)-3, before ejecting its 28 auxiliary payloads from NASA's Nanosatellite Launch Adapter System (NLAS).[(12)] That included West Point's first student built satellite.

Figure 3: ORS-3 Liftoff from Wallops (NASA)[(12)]

Failure is Part of Learning

Elon Musk said, "If things are not failing, you are not innovating enough."[(13)] I would take that advice from the owner of the company responsible for putting Americans back in space from American soil on an American rocket. The successful Demo-2 mission which launched just last week has made me even more excited to be part of this program at West Point. I think it is something that has also sparked the interest of the cadets and I hope it brings them to conduct some space research of their own.

In 2013, West Point had a budding Space Science program, cadet interest in space was growing rapidly, and a cadet-built satellite was just put into orbit. The cadets knew their hard work was now zooming around the earth at over 17,000 mile per hour. However, they could not contact it. No beeps, no squeaks, no data. Black Knight 1 was dead on arrival, but no one knew why. It was a hard blow to the team that had worked so tirelessly to achieve so much - but that did not stop them.

Today's Black Knight Satellite Program

Black Knight II was in the design stages immediately after BK-1 was completed. For AY2013 and AY2014 the cadets and faculty sought to improve upon the previous mission with Black Knight II, but a loss of key personnel in EECS stopped movement on the project. There was a struggle to keep the program going with the rotation of personnel and no set home or program to tie the research to directly.

The Black Knight Program has since been reinvigorated. The Space Science major/minor is pushing cadets toward these research opportunities. The right blend of staff and faculty is supporting the cadets in their research and a new partnership with USNA, USAFA, and USCGA is in the works.

"Black Knight III initiated a new design approach by partnering with D/PaNE with the investigation in the suitability of low-cost single-board computers for use in cube satellites. Cadets monitored the operation and condition of the Raspberry Pi Compute Module 3 while exposed to ionizing radiation and heavy particle bombardment. Tests results were promising and warrant continued investigation."[21]

When I found out I was selected for this assignment, I begin contacting my teammates from STP. In my time here, it is my goal to get West Point back to space. What I found when I arrived was the Black Knight CubeSat is just one cadet project that is looking to escape the bonds of earth. The cadets were working on their own ride to space. The cadets are building rockets!

Balloon Satellites

In May 2011 cadets from the Astronomy Club and Amateur Radio Club, guided by LTC Loucks and MAJ now COL Stephen Hamilton of the Army Cyber Institute, launched a satellite of their own. It did not get to orbit but it did make it well into the stratosphere. Ascending about 25 miles and traversing 15 miles from the point of departure the mission was a success on multiple levels.

"The balloon satellite program allows cadets from all majors to participate and learn about the many nuances of space technology and applications within the Army. The engineering process also occurs in the background and the cadets get instant feedback on their accomplishments."[15]

"Secondary to this, we now have an inexpensive launch platform that ensures five to 10 minutes of space flight time for any payload that goes up. The Space and Missile Defense Command Research and Analysis Center was started to further the outreach of space education and research at the academy and this is complementary to its goals,"[15]

Figure 5: Earth from Balloon Satellite[15]

In 2014, one year after the launch of BK-1, a group of cadets and aspiring space professionals launched a balloon satellite to an altitude of 119,000 feet. The cadets were given support by their faculty advisors, COL Hamilton, LTC Loucks, Dr. Paula Fekete, who is now the Program Director for the SMD program. The program is becoming a great platform for space education as well as experimentation with the ever-growing variety of payloads. During the last launch, the 10th overall, the balloon was fitted with radiation detection equipment and the first stages of a station keeping payload.

This year the cadets are diving deeper into the researching the station keeping ability of high-altitude weather balloons. SMDC is interested in the research cadets are conducting. Through the continued support of the SMDC-RAC at West Point cadets can work real-world problems for the Army. There is no better development tool for the future leaders and space professionals of the Army than working on current real-world issues.

SPace Engineering & Applied Research (SPEAR)

The SPEAR program was born of cadet excitement surrounding the stand-up of the new Space Science major. The cadets approached PaNE with a proposal for building a rocket. COL Pete Chapman, Deputy Department Head, "if a cadet is interested in something, and it has Army applications and great potential for academic development, we couldn't say 'no.'"[14]

In the first year, SPEAR teamed up with Operation Space with the goal of getting a rocket to the Kármán line. In May 2019, Dr. David Hutchinson and Major Jill Rahon '06, assistant professors with PaNE, took a group of SPEAR cadets to Spaceport America in New

Mexico, adjacent to U.S. Army's White Sands Missile Range, to participate in Operation Space's attempt to traverse the Kármán line. On May 31, its first 17-foot rocket cleared the tower and ignited its second stage but lost a fin and broke apart around 100,000 feet. On June 1, Operation Space launched a second rocket that made it approximately 85 percent of the way into space.

The goals have grown, and the path is being set for the cadets to try to go it on their own. They have broken out into several interdisciplinary teams tackling pieces of the overall effort. Some are working the rocket structure and separation design while others are working with boron – potassium nitrate (BPN) for ignitors. In concert with that work, other teams are designing and fabricating launch rails. Most recently, due to the delays caused by the COVID-19 outbreak some of the focus has shifted from launch to building a fully instrumented static fire test stand. There are plenty of projects and opportunities for cadet led research and they are excited about the potential for their research to help solve real Army problems.

Figure 4: 2 Stage Sounding Rocket Launch, 2019

SPACE PROFESSIONAL DEVELOPMENT

The endeavor to build a space-centric course of study at West Point was an arduous undertaking. It took many current space professionals several years to forge the program into what it is today. The importance of their task and position was not lost on them. It was recognized by Congress years before.

"In 2001, Congress, by way of the "Commission to Assess Unites States National Security Space Management and Organization", directed the Services to create and sustain a cadre of space professionals. The Commission recommended that the Services "must place a high priority on intensifying investments in career development, education and training to develop and sustain a cadre of highly competent and motivated military and civilian space professionals."[17]

Army Space Professionals

"The Army's space cadre is made up of Soldiers and civilians, across all Army warfighting functions, who have documented training and experience in the space domain and conduct daily missions of the space force. It is a diverse group with various areas of concentration, military occupational specialties, and occupational series with a common mission – to develop, plan, acquire and operate space capabilities to fulfill mission requirements."[18]

FA40s are the core of the Army's space cadre. They supported by a host of non-FA40 soldiers. These soldiers are designated as "Army Space Cadre" as well and they are awarded the Army Skill Identifier (ASI) of 3Y contingent on completion of their space specific training.

Cadets in a STEM major, who complete the curriculum and the Space Military Individual Advanced Development (MIAD), are ideal candidates to serve as FA40s. They can do this through the Voluntary Transfer Incentive Program (VTIP) or through Assured Functional Area Transfer (AFAT), discussed later.

Space MIAD

West Point has teamed up with the Army Space Personnel Development Office (ASPDO) to allow cadets, staff, and faculty the opportunity to attend the Army Space Basic Cadre Course. This course is a prerequisite for the award of the 3Y identifier. It is also the initial course for FA40s, if not already completed.

"The Army Space Cadre Basic Course sends a mobile training team to West Point in the summer to train approximately forty Cadets in the basics of Army and DOD Space Operations through the academy's Military Individual Advanced Development (MIAD) program. Cadets who complete the Space MIAD and who either major in Space Science or who major in Geospatial Information Sciences having taken both Astronautics and Space Physics earn the Basic Army Space Badge [and the 3Y identifier] upon graduation. Twelve of the badges will be awarded to graduates in the class of 2020 – 11 graduates from PaNE and one graduate from GEnE."[19]

Assured Functional Area Transfer

The Army does not have a branch for space operations like the Air Force, which brings officers into space operations direct from its accession sources. Therefore, newly commissioned Army officers must complete an initial tour in their operational branch, i.e. armor, infantry, or aviation, prior to transferring to a functional area. Previously, transferring to a functional area was

not guaranteed. The new AFAT program does just that, and the cadets are getting excited about the opportunity.

"[Space and Missile Defense Center of Excellence] is seeking to identify talented officers early and provide exciting opportunities for service in the future. In 2020, the first class of [AFAT] – FA40 officers were identified upon their graduation from West Point and ROTC. These hand-selected officers with STEM degrees and an aptitude for the talent priorities most essential to FA40 are guaranteed a transfer to FA40 between their third and fifth year of service, should they choose to do so….In the class of 2020, seven of the twenty Cadets selected for this program are from West Point. Of those seven, two each came from the Space Science major and the Geospatial Information Science Major."[19]

FUTURE ENDEAVORS

Partnerships

Many successes are built on strong partnerships. The creation of the Space and Missile Defense Program and its associated Space Science major is a prime example. The program is the namesake of our biggest partner, Space and Missile Defense Command. It could not have been created without the support of a network of space professionals from multiple organizations and locations. One of the main purposes of this paper and the presentation that will accompany it is to educate others in the DoD, academia, and industry about what we are doing at West Point with the hope that it will start a conversation.

The desire is to turn those conversations into meaningful partnerships that will be mutually beneficial to all parties. I have not stopped talking to everyone I know about what a privilege it is to be a part of West Point and the PaNE family. I am excited about what we are doing, and I want them to be excited about it too. I want you to be excited about it when you read this paper.

So far, we have teamed with Operation Space for an attempt at putting a rocket into space. We are working with our fellow service academies on a potential joint CubeSat project. We are talking to STP about how we can get support for our future activities. Yesterday, I had the pleasure to speak with an undergraduate student from Embry-Riddle Prescott and share ideas on mutual support of our rocket development programs. Networking is a key to gaining support for your cause and achieving long term success. That is something we want our cadets, the future Army leaders, to embrace.

Return to Space

As mentioned before, I have a personal goal of returning West Point to space before I move on to my next assignment. At the very least, I want to have something on an official manifest. If all goes as planned, I will not depart for another three years. Given the current state of the program and the progress that is being made with the independent cadet research I believe this is a reasonable goal.

Just like the story of the Space Science major, it cannot be done alone. It takes the support of a superior team of like-minded individuals to succeed in such a challenging endeavor. Luckily for me, there are an abundance here at West Point. I cannot think of a better place to be or a better time to be here.

CONCLUSION

The emphasis on successfully operating in the space domain has never been greater. The United States has created the world's first Space Force and officially recognized space as a warfighting domain. "Space has become essential to our security and prosperity…. Unfettered access to space is vital to national defense. Space systems are woven into the fabric of our way of life. Space affects almost every part of our daily lives and is fundamental to our economic system."[20]

"The Army requirements for space-based capabilities and services, including protection, tailored to the Army and its unique land force requirements in [Multi-Domain Operations] MDO cannot be met solely by reliance on another Service providing support."[4] Therefore it is imperative that the Army continue to develop Army space professionals. For development to be most effective quality training and education must start at the earliest stages of their accession into the armed forces. In support of this, USMA will continue to "educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army."[23] In addition, they will provide the Army with qualified space professionals who have in-depth expertise, can delivery space capabilities, and will integrate them into future operations.

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DISCLAIMER

The views expressed are those of the author and do not reflect the official policy or position of the United States Military Academy, US Army, US Air Force, Department of Defense, or the US Government.

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