SPACE OPERATIONS EDUCATION RESEARCH:
STUDYING UNDERGRADUATE EXPERIENCES AS PREDICTORS OF EARLY CAREER PERFORMANCE FOR MILITARY SPACE OPERATIONS OFFICERS

A Report
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ABSTRACT

Undergraduate students who go on to operate space systems, e.g., satellites, launch systems, and ground-based systems, come from a diverse set of demographics and undergraduate experiences. The United States Space Force (USSF), and United States Air Force (USAF) before them, like many professions, have a demonstrated interest in who enters their ranks, but have had limited research available to them to inform their recruiting, selection, training, and early career development policies and processes.

This *Profession-Based Education Research* study, a term introduced here in contrast to Discipline-Based Education Research, focused on the military space operations profession. This study analyzed newly commissioned USAF and USSF space operations officers from 2018-2022 to baseline the *relationship between undergraduate experiences* and *early career performance.* The study's conceptual framework was based on Becker's (1993) *Human Capital Theory (HCT),* Collins' (2019) *Credentialism Theory,* and Lent and Brown's (1996) *Social Cognitive Career Theory (SCCT)* by considering the applicable *formal education, training, other qualifications, person inputs, environmental influences, and learning experiences* elements as potential predictors of early career *performance*. Additionally, this study used engineering education's *pipelines, pathways, and ecosystems* paradigm to illustrate the progression from undergraduate student into and through the early portion their space operations career (Lee, 2019). This *non-experimental, retrospective, quantitative study* analyzed proxy variables from multiple USAF- and USSF-provided databases to investigate relationships between undergraduate experiences and early career performance at initial space training (Johnson, 2001).

Key results from the confirmatory and exploratory analysis included statistical significance from three readily available variables: *GPA*, *officer aptitude*, and *race*. Although statistically significant, they all had low practical or meaningful significance in their relationship to performance at initial space training, the first early career milestone for space operations officers. Noticeably absent from the list was the lack of significance from an officer's undergraduate *major*, the primary factor used by the USAF and USSF for making career field selections during the study's timeframe. This led to the principal implications for changes to officer selection criteria and initial space training curriculum.

The study's other conclusions and implications from its methodology focused on additional recommendations to shape evolving USSF guidance for space operations officer recruiting, selection, training, and professional development. They also inform future research opportunities for space operations, other military career fields, and other professions by outlining specific considerations for study design, data collection, analysis, and policy. Key recommendations included increasing rigor in initial space training; resolving gaps, accessibility issues, and lack of standardization in key data sets; and collecting other education experience and early career performance data.

This Profession-Based Education Research should inspire USSF and other professions to identify and collect undergraduate and professional performance data to better understand the impact that higher education has *after* the graduation milestone, not just *during* educational activities.

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LIST OF ABBREVIATIONS

AETC	Air Education and Training Command
AFOCD	Air Force Officer Classification Directory
AFOQT	Air Force Officer Qualification Test
AFPC	Air Force Personnel Center
AFRS	Air Force Recruiting Service
AFSC	Air Force Specialty Code
DoD	Department of Defense
DOTmLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy
DT	Development Team
EPA	Education Partnership Agreement
ESED	Engineering and Science Education Department
FY	Fiscal Year
GPA	Grade Point Average
HCT	Human Capital Theory
HQ AFSPC	Headquarters Air Force Space Command
IRB	Internal Review Board
IT	Information Technology
OTS	Officer Training School
PGL	Program Guidance Letter
ROTC	Reserve Officer Training Corps
RQ	Research Question
SCCT	Social Cognitive Career Theory
SPD	Spacepower Discipline
SpOC	Space Operations Command
STARCOM	Space Training and Readiness Command
STEM	Science, Technology, Engineering, and Mathematics
UPP	University Partnership Program
USAF	United States Air Force
USAFA	United States Air Force Academy
USSF	United States Space Force
UST	Undergraduate Space Training

CHAPTER ONE

INTRODUCTION

Several professions have studied the relationships between undergraduate educational experiences and job performance, each with their own conclusions on the best predictors, if any. Most of these talent management and workforce studies included the students' academic performance and their major field of study. Some considered the type or caliber of the higher education institution attended and several have included other factors tied to personal motivation, extracurricular involvement beyond core academics, and personal demographics. The results were intended to support recruiting, retention, academic programming, and other workforce planning and development aspects for those professions.

This study leverages that research and applies it to military space operations with a focus on newly commissioned officers entering active duty in a growing and very dynamic career field. By studying the relationship between undergraduate experience and early career performance during the 2018-2022 timeframe, this study will allow key stakeholders to better measure the impact of any talent management, education, and training decisions made during this baselined timeframe to inform future policy and process decisions for this unique profession. When significant relationships are not found, this study should then serve as a call to action to seek out other variables that better predict the desired performance of space operations officers, or consider that early career performance is not related to undergraduate experience. This study's methodology, results, and implications can also be used by other professions as they continue to study and refine their own evolving talent management and workforce policies and processes.

1.1 Study Context

The space industry continues to grow with the emergence of new launch systems, new satellite technologies, a potential expansion into tourism and other industries, and the relatively recent establishment of the United States Space Force (USSF, as there will be several acronyms in this report, page viii contains a list of abbreviations). With that growth, there is a proportional growth in the need for educated and trained personnel. Those personnel needs include engineers who build the space systems, users who seek to benefit from them, support personnel who enable them, and a unique group of personnel who *operate* them. Although the relatively nascent USSF refers to all its members as *Guardians,* this study will use the term, *space operator*, to describe those who specifically operate space systems now, or as part of the United States Air Force (USAF) prior to the establishment of USSF (USSF, Guardian Ideal, 2019).

In addition to ensuring the right quantity of educated and trained space operators exists, USSF must also ensure the right overall quality exists, in both the total sum of all officers and the diversity among individuals' specific capabilities (USSF Guardian Ideal, 2019). Those qualities develop over time through personal attributes, education, training, and experience. The building blocks to develop those capabilities leverage common primary and secondary education outcomes, and therefore, are significantly shaped in the undergraduate environment, especially for officers. As a prerequisite for commissioning, all space operations officers must earn an undergraduate degree but are not limited to a specific major or to other aspects of their undergraduate experience (Air Force Personnel Center, Air Force Officer Classification Directory, 2018).

This multidisciplinary nature of space operations warrants a deep look at various undergraduate experiences to identify which ones may relate to desired performance *after* graduation when the officers are serving on active duty in their specific career field, i.e., profession. Some key experiential factors to consider include the choice of major, the type of institution, the level of academic success, and the level of involvement in military- or space-related co-curricular and extracurricular activities (Becker, 1992). Finally, a key determinant of success as a space operations officer may also be based on the level of desire, i.e., motivation, each operator had when they sought space operations out as a potential career choice (Lent & Brown, 1996). This motivation may be fueled by the experiential factors listed above or from access to space-related influences within their environment.

The USSF, and its predecessor organizations that resided in the USAF, serve as a large and relatively homogeneous subset within the space operations profession, thus providing sufficient data for this study. USSF space operators, specifically officers, come from a diverse set of demographics and undergraduate experiences, e.g., majors, institutions, academic performance, and other factors. Each officer's career field preferences are also an important outcome of their undergraduate experience, but the nature of selfless military service means officers are not fully free to choose their career field upon commissioning. Instead, they must rely on the USAF and USSF selection processes for their specific commissioning year. Prior to commissioning, individuals submit their top preferences via their "dream sheet" and, based on military needs at that time, the USAF, prior to 2020, and USSF, for 2020 and beyond, assigns them to their career field (AFPC, Form 53, 2018). While changes have occurred over time, this basic selection process for space operations has been continuous since the 1980s. In short, the military may be the chosen profession for all officers, but their eventual career field may or may not be their top preference.

1.2 Definition of Terms

Since this study's design, methods, and results are also intended to benefit other professions, the uniqueness of the military space profession and its educational environment warrants specific descriptions of the people, organizations, and processes that are not common outside of that community. See Figure 1-1 for a visual depiction of some of these unique military elements to assess their equivalents, if any, to other professions.

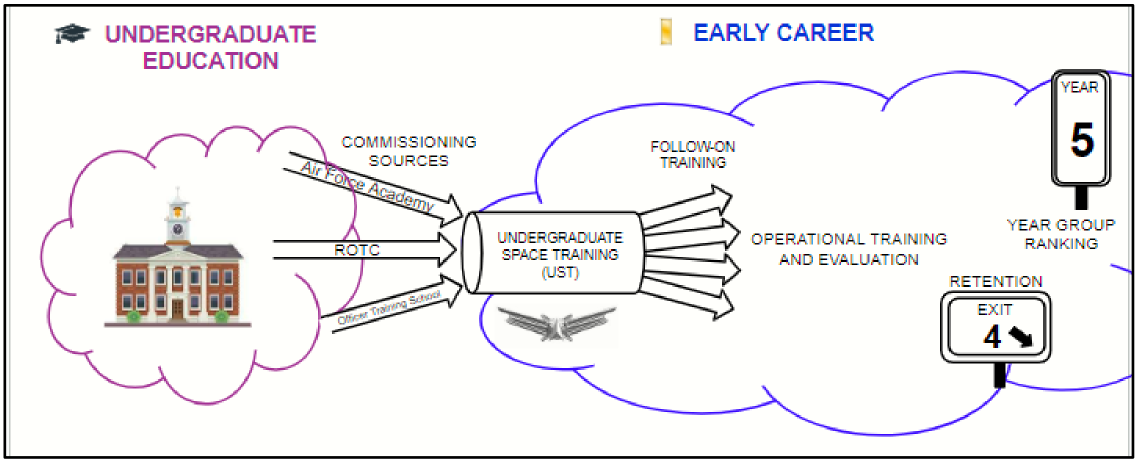


Figure 1-1. Military Space Operations Officer Early Career Milestones.

This peek into the military space profession allows us to understand the characteristics that contribute to its success and can serve as a framework to examine other disciplines and professions.

Of historical note, a key milestone occurred in December of 2019 with the stand up of the United States Space Force, the first new military branch since the Air Force was established in 1947. Since this occurred in the middle of this study's timeframe, this section will also address the people, organizations, programs, and processes that were redefined in the wake of USSF's stand up. For example, prior to USSF, initial training for new space operators was conducted on Vandenberg Air Force Base by the 533rd Training Squadron, a part of the 381st Training Group, 2nd Air Force, and Air Education and Training Command within the Air Force. The training is still conducted by the 533rd Training Squadron, however, that unit is now located on Vandenberg *Space* Force Base as part of Delta 1 and Space Training and Readiness Command within the Space Force.

Many of these nuances may be transparent to the reader but are highlighted here to help explain differences when they occur.

The human subjects of this education research study have various identities and descriptors as they transition from undergraduate students into space operations officers. The term, *student*, may be applied to their time as an undergraduate prior to receiving their degree, but it may also apply to their time as a student in a military training program. After graduation from college and being commissioned, the student assumes an *officer* identity as they enter active duty service while also assuming the identity for their specific career field. *Pilot, nurse,* and *missileer* may be familiar career field monikers, but for those operating space systems, the common term used is *space operator.* While the terms *student, officer,* and *space operator* will be primarily used for this study, the terms *Airman* and *Guardian* will also be used to describe any member of the Air Force or Space Force, respectively, regardless of their career field.

While the numbers change each year, approximately 110 space operations officers within the Air Force and now, Space Force, receive their commission through one of three commissioning sources, i.e., *pathways.* Those who receive their military officer development *while an undergraduate student at a civilian institution* go through the Reserve Officer Training Corps (ROTC) at one of 144 Detachments on various campuses throughout the country. Those who receive their military officer development *after they have already received their undergraduate degree* go through Officer Training School (OTS) in Alabama. And finally, a third option is to receive their military officer development *while earning their undergraduate degree* at the United States Air Force

Academy (USAFA) in Colorado. While each commissioning source has its own set of experiences, the end result is the same: a commission as an officer in the USAF or USSF.

Finally, it may also be helpful to understand the early career path for space operations officers as that is the focus of this study. After commissioning, officers will attend *initial space training* at Undergraduate Space Training (UST) from the 533rd Training Squadron, mentioned above. UST lasts several months where officers also receive their assignment to a specific space-related operational unit upon graduation. Depending on their assignment, they may also attend Spacepower Discipline (SPD) training in Colorado for *follow-on training* in their specific discipline, i.e., Orbital Warfare, Electronic Warfare, or Space Battle Management. After initial and follow-on training, space operators will receive *operational training* in their specific space system, e.g., satellite or radar, and then be certified to perform operations after a successful evaluation. They will continue to serve for 1-3 years before moving to a new assignment and possibly a new space system. They will not repeat UST or the same SPD course but may attend a different SPD course if their new system is in a different spacepower discipline.

Two other noteworthy milestones also occur early in their career. Almost all space operations officers serve an initial four-year service commitment and may separate from active duty at that point. Retention beyond four years would be another indicator of early career performance which could relate to undergraduate experiences. Up until recently, at the five-year point, each junior officer's performance record was assessed and ranked by a Development Team of senior space operations officers to provide an early career look at their past performance and provide a recommendation for future assignments and development. This ranking among their year group peers is another indicator of early career performance.

In summary, the key terms are defined as:

- *United States Space Force (USSF)*: established on December 20, 2019, creating the first new branch of the armed services since 1947
- *Guardian*: any member of USSF
- *Space operator*: specific career field descriptor for those who operate space systems, e.g., satellite, rockets, and space-related ground and communications systems
- *Commissioning Source*: one of three pathways for USAF and USSF officers to earn their commission as a second lieutenant and serve on active duty.
    - *Reserve Officers Training Corps (ROTC)*: a program for USAF and USSF officers to earn their commission at a civilian institution of higher education while earning their undergraduate degree
    - *Officer Training School (OTS)*: a program for USAF and USSF officers to earn their commission in Alabama after earning their undergraduate degree
    - *United States Air Force Academy (USAFA)*: a program for USAF and USSF officers to earn their commission at the Academy in Colorado while earning their undergraduate degree

- *Undergraduate Space Training (UST)*: initial space training conducted in California for all new USAF and USSF space operators entering the career field
- *Spacepower Discipline (SPD) training*: follow-on training after UST, conducted at Colorado for space operators entering one of three specific disciplines, i.e., Orbital Warfare, Electronic Warfare, or Space Battle Management
- *Operational training:* after initial and follow-on training, space operators will receive training on their specific space system in their operational unit and then be certified to perform operations after a successful evaluation

1.3 Problem Statement

Despite significant documented interest in educating and developing space operators, very little is known about the extent of how each individual's attributes and their undergraduate experience may relate to performance as a space operations officer. The Air Force Personnel Center's (AFPC) Program Guidance Letter (PGL) and Air Force Officer Classification Directory (AFOCD) have largely defined the limited selection criteria for both *quantity* and *quality* of space operations officers, respectively (Headquarters USAF, PGL, 2019; AFPC, AFOCD, 2018). Specifically, the PGL determines the number of space operations officers needed from each commissioning source for each fiscal year (FY). The AFOCD provides the minimum qualities, or education, needed by each officer. The latter is almost entirely based on undergraduate majors, with an associated emphasis on Science, Technology, Engineering, and Mathematics (STEM) degrees. These legacy criteria may or may not align with the new USSF aspirational approach for talent management which seeks to take a "targeted approach to cultivate and secure…diverse talent" (USSF, 2021). As those efforts evolve, this study's outcomes will provide a baseline from which future changes to recruiting, selection, and talent acquisition efforts could be measured.

With significant changes occurring within USSF, this study attempts to fill a significant gap in literature for military space operations, addressed in other professions, by studying relationships between undergraduate experience and job performance. With very little research on what happens to the *left of commissioning*, as shown in Figure 1-1, that might predict what will happen to the *right of commissioning*, this study will create an initial methodology, baseline results, and identify implications for future consideration in this dynamic profession.

1.4 Study Significance

As the relatively nascent USSF continues to mature, a few slight adjustments to selection and training processes occurred in 2021 and continue to evolve each year. Major changes occurred in 2023, after this study's timeframe, to both selection processes and the UST curriculum. Like the policy changes that informed selection and training processes prior to 2023, there does not appear to be significant research in educational outcomes to help inform those changes. This study will allow appropriate comparisons and inform future research to continually improve talent management processes, i.e., recruiting, selection, educating, training, and early career performance.

Specifically, this study will support internal research and policy decisions for key USSF organizations, and more broadly, other talent management and professional development organizations in other industries seeking to understand the relationship between undergraduate education experiences and performance in their chosen professions. For USSF, the Enterprise Talent Management Office (ETMO), Space Training and Readiness Command (STARCOM), and Space Operations Command (SpOC) can leverage the methodology and results of this study to inform future data collection and analysis when assessing current and future policy decisions related to selecting, training, and developing space operations officers. The Air Force Recruiting Service (AFRS) and commissioning programs can also use these results for recruiting and retaining officer candidates for OTS and cadets for ROTC and USAFA. In addition to the quantitative results of this study, the limitations discovered when collecting available data and the identification of relevant new data are perhaps the most significant outcomes of this study.

1.5 Purpose Statement

By focusing on officers commissioned between 2018-2022, this study will establish a baseline understanding and research methodology for officers selected and trained in that legacy environment, and help inform how adjustments to recruiting, selection, education, and training occurring in 2023 and beyond may impact early career performance. Those legacy officers selected and trained in this study's timeframe continue to serve and will lead those who follow them who were selected and trained under different policies and processes.

1.6 Central Research Question

This study will focus on the answer to the following *central* research question (Creswell & Creswell, 2014):

> *To what extent do undergraduate experiences predict early career performance for legacy USAF and new USSF space operations officers?*

This *central* research question was further refined once informed by the current environment of the study's population, see Chapter 2:

> *To what extent does readily available undergraduate data relate to performance at initial space operations training?*

In Chapter 3, this *central* research question was further refined into *associated subquestions* to incorporate the conceptual framework and availability of data to support the study (Creswell & Creswell, 2014).

1.7 Positionality

As a 28-year career space operations officer in the USAF, retiring as USSF was newly established, I have experienced first-hand the evolution of recruiting, selection, education, and training within my profession. This experience was multi-faceted and in depth as I experienced it as:

- an *undergraduate student* and ROTC cadet seeking selection into the career field
- a *newly commissioned officer* receiving initial training at UST and other legacy training programs equivalent to current early career training programs
- a *newly certified space operations officer* performing space operations
- a *peer* to other space operations officers in the same professional pipelines, pathways, and ecosystems
- a *supervisor* assessing the performance of junior space operations officers
- an *operational commander* and senior officer at various levels responsible for talent management decisions involving junior officers and making recommendations to related organizational policies
- an *Air Force ROTC detachment commander* gaining first-hand knowledge and input into officer selection processes while in the higher education environment
- a current *educational researcher* seeking to add academic rigor in supporting my former profession as they evolve their talent management policies, while

also helping academia improve their contributions to the development of future space operators

I am assuming a post-positivist perspective for this study in that certain types of undergraduate experiences may predict future early career performance for space operations officers. Alternatively, the data may instead reveal those undergraduate experiences that may not be relevant to professional performance. The quantitative approach described below will attempt to uncover how predictive those undergraduate experiences relate to specific performance after graduation and commissioning.

Finally, this study was sparked by a request from the Air University commander in 2019 for ROTC units to enter agreements with their respective universities to help address Air Force needs. The confluence of that request, my background, and the uniqueness of the Engineering and Science Education Department at my host university came together to kickstart this study and maintain persistence during the research process.

1.8 Report Structure

This report follows a five-chapter format. This chapter serves as the introduction covering the context, problem, significance, purpose, and my positionality. Chapter 2 will provide the literature review that supports the problem statement, theoretical frameworks, and design, which all lead to a description of the conceptual framework for this study. To develop the conceptual framework, this study incorporated key elements of Human

Capital Theory, Social Cognitive Career Theory, and Credentialism Theory. It also leveraged engineering education paradigms related to how undergraduate students navigate their education experience.

Chapter 3 will contain the research methods used, to include the specific research questions, design, participants, data collection, and analysis. As delimitations, the scope of the study was contained to new military space operators entering the profession directly from their undergraduate experience in fiscal years 2018-2022. This quantitative study incorporated several military databases and used a *non-experimental, retrospective* research design to provide both descriptive and relational outcomes. Chapter 3 will also contain the quality considerations and limitations of this unique study. Some of the most significant limitations included unstandardized data among the three commissioning sources and across the five years of the study; changing conditions due to COVID, the standup of USSF and subordinate organizations, and dynamic updates to selection processes and training programs in that same time period; and gaps in available data due to limitations in USAF and USAF databases and the lack of priority or resources within USAF and USSF to provide the data. Chapter 4 will provide the study's results and Chapter 5 will contain the conclusions and implications for the space operations profession, military and other professions, and broader applications.

CHAPTER TWO

REVIEW OF THE LITERATURE

This chapter provides the literature review to support the problem statement mentioned in the introduction and the theoretical frameworks that formed the basis of the conceptual framework and design. The chapter concludes with a description of the conceptual framework used for this study which informed the methods described in the following chapter.

2.1 Literature Review Supporting the Problem Statement

A review of available literature yielded plenty of discussion on the *importance* of educating and developing space operations officers. However, there was little, if any, literature that spoke to officers' undergraduate experiences as a precursor to the Professional Military Education (PME), civilian graduate education, professional development, and military training opportunities discussed. As mentioned above, the recruitment and selection of space operators almost exclusively focused on academic major and commissioning source, but there was no study available that drove the decision-making for those selection policies. To summarize, a significant gap exists in space operations education research at the undergraduate level, i.e., on the experiences *prior to* commissioning and entrance on active duty.

2.1.1 Congressional, Department of Defense, and Command-level Military Studies and Policies

While plenty of recent literature exists on developing space professionals leading up to the establishment of USSF, a seminal, congressionally mandated study in 2001 served as a prophetic milestone to the eventual December 2019 establishment of the USSF (Commission, 2001). Unfortunately, the 2001 Space Commission and its conclusions were overshadowed by the September 11th terrorist attacks that year which appropriately diverted attention to much more pressing National Security needs at the time. However, in the context of this research area, the fifth and final conclusion of the commission highlighted the need to look at space operator education. Specifically, it mentioned the need to "invest in science and technology resources—people…[who] play an active, deliberate role in expanding and deepening the pool of military and civilian talent in science, engineering, and *systems operations* [emphasis added]".

More recent references further demonstrate the emphasis on developing space professionals, but unfortunately, also with no equivalent emphasis placed at the undergraduate level. The 2018 congressional report that set in motion the eventual establishment of USSF, poignantly called out the need for the Department of Defense (DoD) to "establish human capital development processes, including…identifying *additional education strategies*, to ensure a robust supply of joint space warfighters" (DoD, 2018). While strategies existed and were energized within Air Force programs, no such focus was applied to pre-commissioning academic pursuits at the undergraduate level.

In the same year, a think tank study also found that "the needs and ambitions of emerging *operators, researchers, and educational efforts* must be considered" in tackling rapidly evolving space operations issues (Vedda & Hays, 2018). A third Air Force initiative, the Headquarters Air Force Space Command (HQ AFSPC) Space Cadre Leader Development Framework (2018), established strong recommendations tied to the education of space operators and even included a section on the pre-commissioning phase. Unfortunately, it falls short by not addressing academia's contributions and only referenced inherent Air Force educational programs. In fact, the singular reference to pre-commissioning only spoke to Air Force-owned officer accession curricula within the three commissioning sources: Reserve Officers Training Corps (ROTC), Officer Training School (OTS), and the United States Air Force Academy (USAFA).

The following year, 2019, saw an explosion in military-related organizational changes which included an associated emphasis on the personnel needed to populate them. The August 2019 re-establishment of United States Space Command, a unified combatant command that had been previously subsumed by United States Strategic Command in the wake of the September 11th terrorist attacks, included a key mission to develop "ready and lethal" personnel (DoD, United States Space Command, 2020). On its coattails was the establishment of USSF in December 2019 as the first new military branch of service in over seventy years. As a new "organize, train, and equip" branch within the Department of Defense (DoD), it also highlighted the need to "develop military space professionals" as a core mission (DoD, USSF, 2020). These two organizations and the related personnel development aspects of their missions add further justification for studying the educational experiences of those who enter their ranks.

From a financial perspective, the USAF also increased its budget requests associated with the growing and evolving need for space operators. For example, the USAF's 2020 unfunded list sent to Congress earmarked $30 million to expand experiential learning opportunities and new curricula in active duty programs as steppingstones to "increasing USSF's capability to develop the space warfighters essential to winning in an increasingly contested and congested [space] domain" (Hudson, 2020). However, there was a notable lack of references to pre-commissioning academic programs or efforts that would feed these military initiatives once the officers entered active duty.

There was one promising development in space operations human subjects research in the form of a project charter between Headquarters Air Force Space Command, since subsumed by USSF, and the Air Force Personnel Center. The charter showed promise with the study of human factors related to a space operations predictive model (Air Force Personnel Center, Project Charter 2019). While not geared toward educational experiences, it appeared to attempt using existing attribute models to predict high performance in the career field, and perhaps also increase retention rates. Any space operations education research would nicely dovetail with this human factors' study in helping recruit, identify, and select officers who would likely better succeed as space operators.

2.1.2 Other Military Studies and Policies

For full transparency, a 2009 academic paper attempted to seek answers on the relationship between technical undergraduate degrees and success as a space or missile operator (Tolmoff, 2009). The paper findings stated, “an expensive [technical] degree is not required for a…space operator”. This non-peer reviewed academic paper provides a good historical touch point but lacks validity due to the lack of rigor in the research and the confluence with another career field, i.e., the merger of space and missile operations which had existed at the time but ended soon after. Two more recent, peer-reviewed journal articles addressed undergraduate experiences and active duty performance for space operations officers (Lee et al., 2021; Stewart & Agrawal, 2021). However, they, too, primarily focused on undergraduate degrees as the basis of their articles and included self-reported, significant limitations in their research, leading to a recommendation for “further analysis with more complex databases” (Stewart & Agrawal, 2021). This study directly addressed this need for more analysis with more complex databases.

Additionally, the RAND Corporation conducted two studies that are also relevant to this study, however they fell short in direct connections between undergraduate experiences and the space operations career field as it exists today (Harrington et al., 2014; McLeod et al., 2016). The 2014 study attempted to outline STEM degree requirements for all Air Force career fields and determine whether enough numbers of officers and civilians would be available to fulfill them (Harrington et al., 2014). This RAND study is also a victim of the space and missile merger that existed at the time which dilutes any findings that might be relevant today now that the career fields are no longer merged.

This RAND study does, however, establish useful terminology, taxonomies, and some methodology that was leveraged for this study. For example, Chapter Two of the RAND study specifically described the Air Force-approved definitions of STEM versus non-STEM, the relationship between the Air Force's taxonomy for classifying academic majors using Academic Specialty Codes with the Department of Education's Classification of Instructional Program codes, and the methodology used by the Air Force for factoring undergraduate majors into career field selection. This background was helpful during the analysis phase of this study to ensure findings are relevant within the context of existing USAF and USSF processes for selecting space operations officers and where improvements to recruiting, selection, retention, education, and training could be made.

The second RAND study was space-focused and looked at the resilience of space capabilities using non-materiel means (McLeod et al., 2016). It used the well-established Department of Defense multi-faceted approach to solving capability gaps: DOTmLPF-P (Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities, and Policy). The study showed promise in its deep look at Leadership and Education, the "L" in DOTmLPF-P. Like the government efforts mentioned above, the study primarily focused on training *after* an officer enters active duty but did briefly mention ensuring qualified personnel existed. Unfortunately, it fell short in providing specifics, i.e., recommending required undergraduate degree or other qualifications, which in turn further supports the need for this study. In a relatively short segment of the report, it states:

> Current qualifications to become space operators were developed when space was relatively benign… [Space operators] may not have the right technical or other qualifications or background to respond quickly, efficiently, and effectively to adversary counterspace actions. In the near term, Air Force Space Command [now USSF] should review and assess qualifications to become space operators…While some experienced space operators argue that it is important to increase the average level of technical capability among those currently in the space career field, others argue that there is a need for a wider range of backgrounds, including the liberal arts. (McLeod et al., 2016)

To sum up this point, one of this RAND study's main findings stated, "In the near term, Air Force Space Command [now USSF] should review and assess qualifications to become space operators, taking into account that space is now congested, contested, and competitive." It goes on to state, "This topic requires further research that is beyond the scope of this project" (McLeod et al., 2016). The scope of this study specifically addresses that topic.

One recent landmark USSF document provides their aspirational intent for ideal talent management, which includes a need to focus on "attracting, identifying, developing, and retaining a diverse workforce placed into high-performing teams" to achieve USSF priorities (USSF, 2021). This *Guardian Ideal* document does not establish specific selection criteria but does speak to seeking a "fresh approach to attract, individually develop, and retain the best and brightest talent". This study can help USSF "identify potential competency shortfalls and support assessments about [USSF] effectiveness in…applicant tracking" and "identify potential candidates based on requirements", two key aims of the *Guardian Ideal*.

Finally, while not specifically military-focused, a recent article examined talent management during these dynamic, i.e. "turbulent", times in the aeronautics and space industries (d'Armagnac et al., 2022). The study interviewed 62 talent managers and outlined strategies they are using to evolve their selection processes. The study noted that well-established processes are facing significant challenges, like existing definitions of hiring profiles. As one senior space industry executive stated, "We do not know how things are going to change, so we must have people who think differently." That study also concluded that the evolution of Talent Management is not well documented in academic literature, however, they found talent managers have an important role in articulating the changing needs of the industries, and consequently, also adapting and responding to those dynamic needs when managing talent. With this in mind, this study provides a baseline of legacy selection strategies for military space operations and identifies implications for what should be considered in that particular dynamic talent management environment.

2.2 Literature Review Supporting the Frameworks and Design

A review of available literature also yielded insights into how other non-space-related professions considered the relationship between educational experience and job performance. The studies were selected based on applicability to this study, but also to include diversified inputs from multiple professional industries; from the studies' many frameworks, theories, methodologies, and designs; and from a historical perspective, i.e., from late the 1980s when the Air Force was beginning to establish its selection processes to the present day. The intent was to seek transferability from these industries to military space operations, while also allowing the results of this study to be transferable to other industries and professions as well.

The literature review included studies from the following professional industries: information technology, sports management, engineering research and development, civil engineering, general engineering, nursing, and multi-industry. While serving in military space operations does not require an engineering background, several engineering-related studies were reviewed due to the high priority USAF and USSF put on engineering and other technical majors in their current selection policy. Table 2-1 summarizes the literature reviewed for this study to put their frameworks, design, and variables in context for this study. Specific details from each study are included in applicable sections below.

Table 2-1. Literature Review Summary for Relationships Between Undergraduate Experience and Professional Performance.

Industry	**Article**[1]	**Framework(s)// Design**	**Qualitative Coding or Quantitative Variables**[2]
Aerospace & Space	d'Armagnac et al. 2022	Temporal, agency-based// Grounded-theory	QUAL - Axial coding (past, present, future)
Information Technology	Oni & Kabia 2012	HCT, Credentialism// Survey	QUANT – Certifications and job experience//Self-reported job-related data
Sports Management	LeCrom 2016	Social Cognitive Theory// Database, survey	QUANT - Demographic, undergrad and job-related// Graduate and job-related
Multi-industry	Donhardt, 2004	HCT, Credentialism// Regression, ANOVA	QUANT - GPA//Earnings
Engineering Research	Dalessio 1986	None provided// Correlations	QUANT - GPA//Promotion rate, supervisor rating, and production
Multi-industry	Kuncel et al. 2004	Intelligence theories// Meta-analysis	QUANT - Miller Analogies Test//Other tests, academic, and job criteria
Civil Engineering	Bae et al. 2022	CareerEDGE model// Semi-structured interviews	QUAL - CareerEDGE components and thematic coding
Engineering Students	Kim & Seo 2014	SCCT// Survey	QUAL - SCCT elements// SCCT outcome expectations
Nursing	Dyer 1987	None provided// Stepwise regression	QUANT - GPA, ACT, and three inventories// Supervisor ratings

Notes:
[1]*Articles are listed in order of appearance in this document*
[2]*Quantitative variables are listed as "independent/predictor variables" // "dependent/outcome variables"*

2.2.1 Related Studies from Non-Space-Related Professions

Amid the literature relating undergraduate or other education experiences to professional performance, two studies from the information technology (IT) (Oni & Kabia, 2012) and sports management (LeCrom, 2016) professions informed the early stages of development for this study. Although those professions and associated proxy variables were not a perfect match with space operations, these studies were very helpful in developing the initial framework, design, and methods described below (Oni & Kabia, 2012; LeCrom, 2016). The two studies had mixed results. With respect to the IT study, the form of education studied, i.e., IT-related certifications, and years of experience were shown to predict self-reported job competency but not self-reported job performance (Oni & Kabia, 2012). With respect to the sports management study, results indicated that while none of the independent variables significantly predicted either graduate school or early career success, short-term career success was significantly correlated with undergraduate GPA and age (LeCrom, 2016). Of note, the sequential post-undergraduate dependent variables in the sports management study, i.e., graduate school and early career success, are similar to the sequential dependent variables of a space operator's early career in this study, i.e., UST, as an academic-heavy training program, and other early career performance.

Additionally, a multi-industry study provided a potential framework for leveraging Human Capital Theory (HCT) in researching the relationship between academic achievement and financial success in the workplace after graduation (Donhardt, 2004). That study's research questions and methods aligned with this study as it considered similar undergraduate-focused independent variables used for recruitment and selection, i.e., GPA, major, gender, race, etc., and their relationship to earnings after graduation. The results showed GPA, as an indicator of academic achievement, did not have a significant role with respect to workplace earnings. However, it did conclude that academic major was a significant factor. This led to the conclusion that Certification Theory (Donhradt, 2004) or credentialism (Becker, 1992; Collins, 2019), not HCT, appears to be driving hiring decisions and success in early career earnings. From Becker, "Human capital analysis assumes that schooling raises earnings and productivity mainly by providing knowledge, skills, and a way of analyzing problems. An alternative view, however, denies that schooling does much to improve productivity, and instead it stresses 'credentialism'— that degrees and education convey information about the underlying abilities, persistence, and other valuable traits of people." Since the USAF, and now USSF, selection process emphasizes academic major as the key selection criteria for space operations, this study considered how credentialism versus the key elements of HCT and SCCT relate to success on active duty for space operations officers.

A study specific to researching academic success and job performance among entry-level personnel in an engineering research and development organization also found GPA was not generally related to job performance, although there was a somewhat stronger relationship for those who had attended a less prestigious university (Dalessio, 1986). And finally, a nursing study did find GPA, along with variables from a biographical inventory, accounted for most of the variance in job performance. While there may be relationships unique to the nursing profession, the impact of the biographical inventory spoke to considering these SCCT-like variables in performance as the inventory items described the community, school, and home life of the nurses, as well as their preferences, frustration, values, objectives, and self-perceptions (Dyer, 1987).

Finally, one meta-analysis study examined if one construct could predict academic performance, career potential, creativity and job performance by analyzing 127 independent studies (Kuncel et al., 2004). The study concluded that the Miller Analogies Test for cognitive abilities shares measurements with other cognitive instruments and that those measurements are valid predictors of academic and vocational, i.e., professional, performance and potential. The study's findings also contradicted the notion that intelligence in professional environments is wholly different from intelligence in academic environments. This informed this study's use of undergraduate predictors of early career job performance *and* added validity to using performance at initial training, an academic environment, as a good representation of early career performance.

2.2.2 Engineering Education Paradigms

Other academic literature, while not specific to USSF or space operations, provided useful constructs and findings that helped articulate the undergraduate experience and connection to professional performance. The first two of four articles address students' flow through their undergraduate experience using pathway, pipeline, and ecosystem paradigms for those studying engineering (Lee, 2019; Lord, 2019). The application of these concepts will help describe the undergraduate *ecosystem* en route to commissioning, the three commissioning *pathways* toward selection as a space operations officer, the initial training *pipeline* that exists for all officers at Undergraduate Space Training (UST), the *pathways* that best describes follow-on training and certification after UST, and the professional *ecosystem* that exists early in officers' careers.

The other two articles, from Benson (2019) and Ronfeldt and Grossman (2009), address identity development for engineers and other careers which have similarities to identity formation of space operations officers as they journey through their undergraduate experience and into the profession. For this study, elements of identity formation were leveraged to help understand why or how future officers may develop a *desire* for space operations and add it to their assignment "dream sheet" preferences. However, a more in-depth look at identity formation is left for future studies that incorporate complex qualitative or mixed methodologies to determine motivations for space operations preferences and associated early career performance. These four engineering articles were helpful in forming a conceptual framework and common terminology for this non-traditional, multi-discipline profession, i.e., space operations.

2.3 Theoretical and Conceptual Frameworks

Two primary theories were considered as potential frameworks for this study, Human Capital Theory (HCT) and Social Cognitive Career Theory (SCCT). A third theory, credentialism, was also considered as a related theory to HCT due to its direct applicability to USAF and USSF selection policies.

2.3.1 Human Capital Theory (HCT) and Credentialism

The first primary theory, HCT from Becker (1993), states that investments in human capital, e.g., education, training, medical care, etc., lead to increased productivity and profits for the company, and lifetime earnings for the individual. This focus on education as a key element of human capital and its relation to success in the workforce provided a strategic framework for studying how the undergraduate experience might relate to performance on active duty for space operators. This theory, and related literature review, also revealed some key aspects for consideration in the study. For example, too much emphasis on educational outcomes may lead to the concept of credentialism, and how the focus on degrees and the prestige of the institution where they were earned may not "convey information about the underlying abilities, persistence, and other valuable traits of the people", like natural intelligence and work ethic (Becker, 1992). This informed this study's research to find appropriate proxy variables beyond just educational outcomes to study the phenomenon and to explain or influence the current USSF policy for selecting space operators.

Two related shortfalls in Human Capital Theory led to considering other theories and frameworks to help mitigate those shortfalls. The first shortfall is HCT's focus on traditional *for-profit* businesses and associated earnings and wages for individuals as these do not necessarily directly apply to the *non-profit* nature and *standardized salaries* found in USAF and USSF careers. Therefore, appropriate substitutes were needed for measuring workforce performance beyond those traditional financial metrics, i.e., how does USSF measure success? Secondly, the HCT literature did not provide detailed sub-elements of the educational experience and primarily focused on levels and years of education. Although a Human Relations Development adaptation of HCT was helpful in articulating "individuals' knowledge, skills, abilities, and other characteristics", it still fell short in providing many additional details applicable to this study (Ju, 2019). It was during this consideration that Social Cognitive Career Theory proved to be a helpful addition.

2.3.2. Social Cognitive Career Theory (SCCT)

Lent and Brown's (1996) Social Cognitive Career Theory, adapted from Bandura's general social cognitive theory, focuses on three elements of the individual experience, i.e., person *attributes*, *external environmental factors*, and *overt behaviors*, and how the interaction among them leads to academic and career interests, choices, and *performance*. These subsets show that there is more to the educational experience identified in Human Capital Theory that influences workplace performance beyond the degree, level, and number of years. One potential shortfall in SCCT, at least in relation to this study, is its application to career interest and choice. Although undergraduate students in USAF and USSF commissioning programs express their preferences in pursuing a particular career field (interest), the final decision (choice) is ultimately USSF's to make based on personnel and mission needs at the time. When integrated, these HCT and SCCT provided context for the study of educational experiences and their potential relationship to professional performance, while also providing specific sub-elements of that experience to consider when selecting variables for comparison. Figures 2-1 and 2-2 identify the key elements of HCT and SCCT, respectively, that served as a focus for this study.

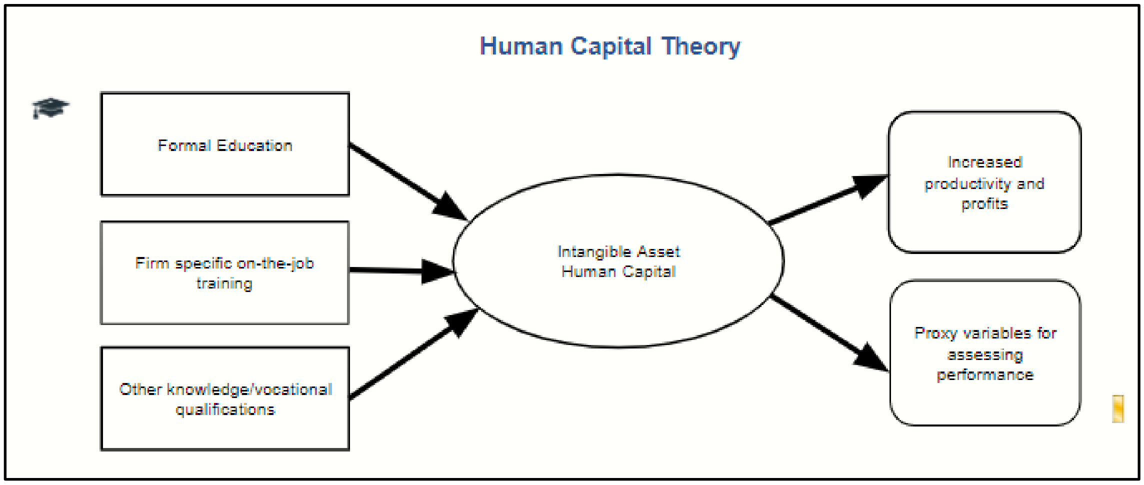


Figure 2-1. Human Capital Theory (Adapted from Oni & Kabia, 2012; Reed & Wolniak, 2005).

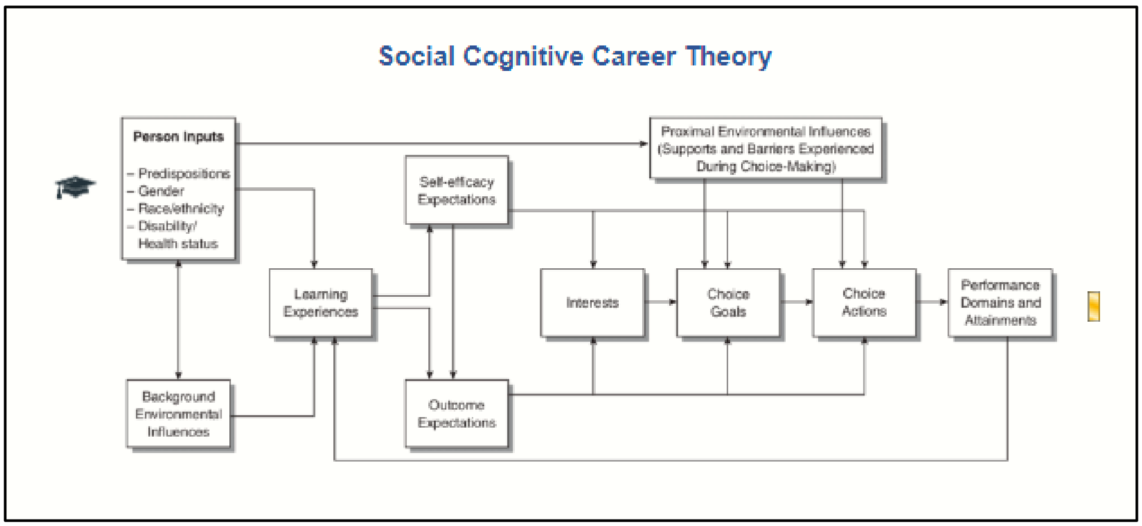


Figure 2-2. Social Cognitive Career Theory (Lent et al., 1994).

2.3.3 Pathways, Pipelines, and Ecosystem Paradigms

As stated above, the pathways, pipelines, and ecosystems paradigms also provided a metaphorical framework to structure this study (Lee, 2019). Instead of choosing the best of three paradigms, the journey officers take through their undergraduate experiences and into their space operations careers includes all three. Their journey mirrors an *ecosystem* to describe their undergraduate experience, a *pathway* through their commissioning source and onto active duty, a *pipeline* while in Undergraduate Space Training (UST), another *pathway* through their follow-on training toward operational certification, and another *ecosystem* to describe the early portion of their careers.

These theoretical frameworks and paradigms informed the conceptual framework for this study, how the research problem should be best explored, and the relationship between the different variables available (Grant & Osanloo, 2014). Figure 2-3 shows the conceptual framework developed for this study as an integration of HCT, SCCT, CT, and the paradigms incorporated with legacy USAF and new USSF constructs.

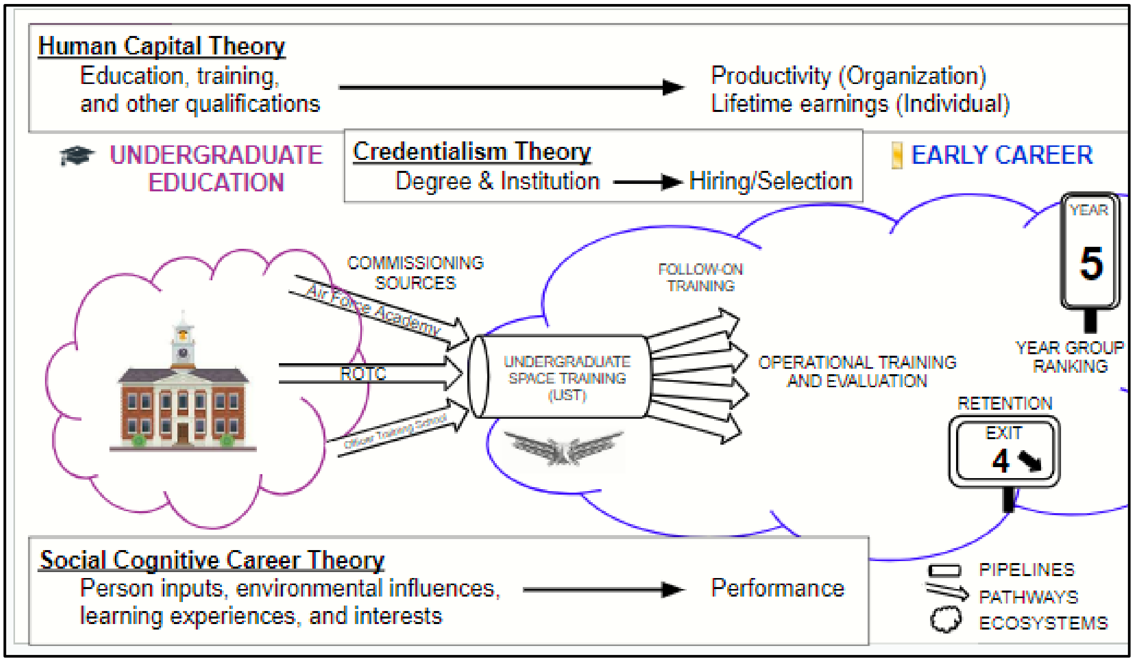


Figure 2-3. Conceptual Framework (Oni & Kabia, 2012; Reed & Wolniak, 2005, Lent et al., 1994, Collins, 2019).

The aforementioned studies involving the IT, sports management, and other professions also leveraged HCT and SCCT for their Theoretical Frameworks (Oni & Kabia, 2012; Donhardt, 2004; LeCrom, 2016). Using HCT, Oni and Kabia (2012) studied whether IT certifications and experience predict self-reported job performance and competency. Using SCCT, LeCrom (2016) researched what factors, e.g., GPA, test scores, and experience, contribute to success in graduate school and early career performance. While UST is not an accredited graduate program, its curriculum for newly commissioned officers lends itself to serve as an equivalent post-undergraduate academic program akin to the graduate school aspect of LeCrom's sports management study's framework.

Additionally, two other studies punctuated the need to go beyond HCT in studying factors related to post-graduate success. In a study of employability for civil engineers, the authors found extracurricular activities, e.g., student organizations, internships, and the role of educators, were critical in facilitating career preparation (Bae et al., 2022). In another unique, cross-cultural study, the authors investigated the applicability of SCCT's social cognitive variables for undergraduate engineering students and the fit to their interests and major choice (Kim & Seo, 2014). While the scope of the Kim and Seo study stopped short of identifying relationships to post-graduate performance, it highlighted key variables worthy of consideration as potential independent variables that may relate to performance after graduation. Some of these variables are available in the databases acquired for this study. However, limited access to other variables are beyond the scope and availability for this study and will be deferred for future research after this study establishes baseline findings from readily available data.

With this conceptual framework in mind, the next chapter describes the study's methods, to include the specific research questions, the detailed study design, the participants, the data sources and collection, and analysis approach. Chapter 3 also contains the quality considerations and limitations of this unique study.

CHAPTER THREE

METHODS

This chapter describes the research methods used for this study and includes the specific research questions, design, data collection, quality and ethical considerations, data analysis, delimitations and limitations. As introduced in Chapter 1, the central *research question* was further refined into associated subquestions to incorporate the conceptual framework and availability of data to support the study (Creswell & Creswell, 2014). Based on the review of studies outlined in the previous chapters, plus the availability and applicability of space operations data, this quantitative study used a *non-experimental, retrospective design* to provide both descriptive and relational outcomes in answering the research questions (Johnson, 2001).

Using a *non-experimental, retrospective* design, this chapter describes Creswell's (2019) five-step *data collection* process for these unique military participants, sources, and databases. It then addresses the associated *quality and ethical considerations* applicable to the study's quantitative methods with a focus on the validity, generalizability, reliability, and objectivity (Borrego et al., 2009). This chapter then continues with the first two steps of Creswell's (2019) four-step *data analysis* process, i.e., preparing the data and identifying the procedures, saving the last two steps for Chapter 4, i.e. reporting and interpreting the results. The chapter concludes with a summary of the study's *delimitations and limitations*. The key delimitations are the five-year timeframe from 2018-2022 and the focus on newly commissioned, active-duty space operations officers. Primary limitations include the lack of direct access to participants and gaps in available data sets.

3.1 Research Questions

With the conceptual framework in mind from Chapter 2 and the availability of data, this study will seek to answer the following specific research questions through identifying participants and data sources; collecting and analyzing data; and addressing quality and ethical considerations, delimitations, and limitations:

> Central RQ: To what extent do undergraduate experiences predict early career performance for legacy USAF and new USSF space operations officers?

This research question was further refined based on the availability of data and scope, i.e., delimitations, of the study:

> Refined Central RQ: To what extent does *readily available* undergraduate data relate to performance at *initial space operations training*?

This refined central research question was then subdivided into two associated sub-questions to (1) *confirm* the extent independent variables used in current practice by the military relate to performance in initial training and (2) *explore* the extent other readily independent variables relate to performance in training (Johnson, 2001). This approach would help identify if credentialism may be occurring and what other aspects of undergraduate experiences may better predict performance in training. The exploratory approach included important steps to consider other variables from Human Capital Theory (HCT) and Social Cognitive Career Theory (SCCT).

> RQ1a (Confirmatory): Do *commissioning source* and *major* selection rates meet the established independent selection rate requirements?

> RQ1b (Confirmatory): To what extent do *commissioning source* and *major* relate to performance at initial space operations training?

> RQ2 (Exploratory): To what extent do *other available undergraduate data* relate to performance at initial space operations training?

The available proxy variables that represented undergraduate experiences (i.e., independent variables) included *race, institution, gender, ethnicity, date of commission, GPA, officer aptitude test scores, prior military service, career field preferences, cadet ranking* and *training start date.* Available proxy variables that represented performance at initial space operations training included *UST final scores* and *number of failed block tests.*

3.2 Study Design

Creswell and Creswell (2014) offered several considerations for selecting research methods which led to selecting a quantitative design to answer the research questions above. Creswell and Creswell stated quantitative methods should be used "…if the problem calls for the identification of factors that influence an outcome…and understanding the best predictors of that outcome." With that in mind, this study used a *non-experimental, retrospective* research design to provide both descriptive and relational outcomes (Johnson, 2001). The secondary data were collected from existing USAF and USSF databases that included proxy variables for undergraduate experiences, i.e., independent variables, and early career performance at initial training, i.e., dependent variables.

3.3 Data Collection

The undergraduate experiences, represented by a collective set of readily available independent variables from USAF and USSF, include several proxy variables for HCT's *education, training,* and *other qualifications inputs* and SCCT's *person inputs, environmental influences, learning experiences,* and *interests inputs* (see Figures 2-1 and 2-2). Some, but not all of these available independent variables directly align to criteria used in past and current USAF and USSF selection processes. The readily available dependent variables used to represent professional performance include relevant proxy variables appropriate for USAF and USSF space operations officers and not the traditional HCT and SCCT performance variables. For example, HCT's *individual earnings* was not a useful discriminator as all new officers entering the military essentially earn the same salary. Instead, this study used *UST final scores* as space operators' first professional performance metric while on active duty.

Additional professional performance metrics were also requested to paint a more detailed picture of early career performance, i.e., follow-on training and operational evaluation scores, retention rates, and peer group rankings. The latter is a key professional performance metric previously assessed by a committee of senior space operations officers at the five-year point in junior officers' careers. Unfortunately, these requests were not always fulfilled due to system, resource, priority limitations, and other changes within USSF. These and other limitations will be specifically addressed at the end of this chapter.

This study used Creswell's (2019) five steps for data collection which included identifying the *participants*, *permissions*, the *types of information*, the *instruments*, and the *administrative processes* needed to determine data sources for collection.

3.3.1 Participants

The units of analysis for this study, i.e., *participants*, are newly commissioned active duty officers entering space operations as their first career field. The target population was *all* space operations officers that were newly commissioned prior to attending UST as their first assignment in fiscal year (FY) 2018 through 2022 (Creswell, 2019).

The sample size was a large percentage of the target population based on database availability and it numbered well above the 30 needed for a correlation study, $N = 471$ (Creswell, 2019). As this data collection occurred over a five-year span, any variations in available data based on database limitations and FY policy nuances were accounted for prior to, during, and after analysis. Although many other officers attended UST during this timeframe, only those officers entering space operations as their *first* assignment were considered in order to better control for those proxy variables representing undergraduate experiences. This mitigated the impact from other experiences that may influence early career performance.

3.3.2 Data Sources

Since this study was heavily dependent on data provided by the USAF and USSF, the availability of data determined the depth and breadth with which relationships could be made. In addition to the Internal Review Board (IRB) *permissions* needed for human subjects' research, the study sought specific *permissions* for collecting and protecting sensitive participant data using an Education Partnership Agreement (EPA) between the academic research institution and appropriate USAF and USSF organizations (AETC, 2022). While the EPA appropriately placed the onus for the majority of the workload on the researcher, key functions for data consolidation and transmission were performed by the USAF and USSF. Since the study used government-provided secondary data, no informed consent was required from participants. The EPA was updated once during the study to account for the establishment of USSF and re-organization of responsibilities from USAF organizations to the new USSF equivalents. While the data collected was mostly unaffected by this historic organizational change, there was one slight loss of fidelity in a key proxy dependent variable that is addressed below.

The *types of information* for data collection involved requesting data already resident in key USAF- and USSF-owned databases. This included, but was not limited to, the data used by the USAF, and now USSF, for both the selection process and the officers' documented performance while on active duty.

Table 3-1 lists the types of quantitative information that served as proxy variables for undergraduate experiences (independent variables) and performance measures derived from initial training (dependent variables). This resulted in proxy variables in several of Creswell's data categories: *factual* (gender, race, ethnicity, commissioning source, academic major, institution, wait time between commissioning and UST course start date, etc.), *attitudinal measures* (an affective scale of career field preferences by the participants, i.e., an *interest inventory*), *performance* (*aptitude:* Air Force Officer Qualification Test*, criterion-referenced:* undergraduate Grade Point Average and UST final scores, and *behavioral:* cadet ranking) (Creswell, 2019).

Table 3-1. Available Quantitative Data.

DATA FIELD	ROTC	USAFA	OTS
Social Security Number	AFPC	AFPC	AFRS
Commissioning Source	AFPC	AFPC	AFRS
Race	AFPC	USAFA	AFRS
Major	AFPC	AFPC	AFRS
School/Institution	AFPC	AFPC	AFPC
Gender	AFPC	USAFA	AFRS
Ethnicity	AFPC	USAFA	AFRS
Date of Commission (DOC)	AFPC	USAFA	AFPC
Grade Point Average	AFPC	USAFA	AFRS
AFOQT (Aptitude Test)	AFPC	USAFA	AFRS
Prior Service	AFPC	USAFA	AFRS
Career Field Preferences	AFPC	USAFA	AFRS
Cadet Ranking	AFPC	AFPC	OTS
UST Course Start Date	AETC/STARCOM	AETC/STARCOM	AETC/STARCOM
UST Final Score	AETC/STARCOM	AETC/STARCOM	AETC/STARCOM
Failed UST block tests	AETC/STARCOM	AETC/STARCOM	AETC/STARCOM

Table 3-1 also shows the source of the data based on the participants' commissioning source. The Air Force Personnel Center (AFPC), Air Force Recruiting Service (AFRS), United States Air Force Academy (USAFA), and Officer Training School (OTS) provided key data representing *undergraduate experiences* and associated experiences prior to graduating, commissioning, and attending initial training. USAF's Air Education and Training Command (AETC) and, starting in FY2022, USSF's Space Training and Readiness Command (STARCOM) provided early career *initial training data* to represent early career performance.

To ensure human subjects' protection, the personal identifiable information contained in the data sets was encrypted when transferred between organizations and stored in Box Secure folders. It was then sanitized after merging and conditioning prior to analysis. These USAF and USSF sources provided data sets, i.e., *instruments*, in the form of Microsoft Excel spreadsheets. Data shown in yellow in Table 3-1 were not made available by the owning organization. The *administrative processes* in collecting these data relied on extensive coordination via email, phone, and in-person meetings to request, receive, and continuously protect the encrypted spreadsheets via the Department of Defense Secure Access File Exchange website (Creswell, 2019).

These available data also correspond to key elements of Credentialism Theory, Human Capital Theory (HCT) and Social Cognitive Career Theory (SCCT), the theoretical frameworks used to develop the conceptual framework for this study. Table 3-2 depicts this mapping. Although not shown in the table, the combination of *major* and *commissioning source* also maps to current military selection practices and potential credentialism, i.e., the idea that the degree earned and associated education correspond to traits of the individual (Becker, 1992).

Table 3-2. Data Field to Theoretical Framework Mapping.

DATA FIELD	**HCT *(see Figure 2-1)***	**SCCT *(see Figure 2-2)***
Commissioning Source	On-the-Job Training	Environmental Influences
Race		Person Inputs
Major	Formal Education	Learning Experiences
School/Institution	Formal Education	Environmental Influences
Gender		Person Inputs
Ethnicity		Person Inputs
Date of Commission (DOC)		Environmental Influences
Grade Point Average	Formal Education	Learning Experiences
AFOQT (Aptitude Test)	Other Knowledge	Person Inputs
Prior Service	On-the-Job Training	Environmental Influences
Career Field Preferences		Interests
Cadet Ranking	On-the-Job Training	Learning Experiences
UST Course Start Date	Proxy Performance Variable	Environmental Influences
UST Final Score		Performance Attainments
Failed UST block tests		Performance Attainments

3.4 Quality and Ethical Considerations

With the study's emphasis on quantitative methods, quality considerations focused on the following evaluation criteria: *validity, generalizability, reliability,* and *objectivity* (Borrego et al., 2009). Of note, the officer selection processes for each commissioning source and the curriculum for UST had significant changes at the start of some FYs or even during a FY. Because of those changes, each significant change will be identified when describing the data sets, analysis, and results to capture each epoch appropriately. For example, officer selection processes were relatively static in FY 2018 and 2019 but changed significantly in 2020 with the establishment of USSF and have dynamically evolved in each subsequent year. Also, the UST curriculum went through a major overhaul for FY 2020, and again part way through FY 2022.

When considering *validity* to determine if the instruments measure what is intended to be measured, the study has high validity for the proxy variables associated with performance at UST. The training course has authoritative assessment tools and associated grades to show performance levels in that environment. However, the proxy values for undergraduate experiences may have some reduced validity as they may not measure all or the most applicable experiences that either fully represent the undergraduate experience or could predict performance at UST and beyond. They are, however, either actual or available variables used to select officers making them relevant for the study's RQs.

For the proxy variables representing undergraduate experiences, they are authoritative as represented by the official database for selected officers, i.e., participants. Two variables, *GPA* for ROTC officers and *career field preferences* for all officers, have reduced validity as they may not fully represent the final undergraduate GPA upon graduation or reveal potential interest in other career fields, respectively. Finally, while validity in the results is high for *UST final score*, performance in that training environment may or may not be highly related to other aspects of an officer's early career and may likely require further study. This was the main driver for the requests made for additional proxy variables, i.e., follow-on training and evaluation scores from STARCOM and SpOC.

Ideally, any future research for this population would also be able to collect retention data, i.e., how many officers serve beyond their initial four-year commitment, and the five-year or equivalent assessment scores previously given by a team of senior space operators. These two additional measurements would help further understand any relationships between undergraduate experiences and those important early career measurements. Kuncel's study (2004) provides some mitigation on this issue as it contradicted the notion that intelligence in professional environments is wholly different from intelligence in academic environments. This informed this study's use of undergraduate predictors of early career job performance *and* added validity of using performance at initial training, an academic environment, as a good representation of early career performance.

Since the sample size is a high percentage of the population size for the specific timeframe studied, both data sets have high *generalizability*, i.e., applicability to others in the population. There is also high *generalizability* for the results when measured against UST courses that have the same relative curriculum. As discussed at the beginning of this section, the UST curriculum has gone through minor changes and significant overhauls, so *generalizability* is directly proportional to the amount of change in the curriculum. Like the last statement above for validity, the results may also not be generalizable to other aspects of an officer's career beyond UST which would also require further longitudinal research involving early career performance data after UST completion. Also, while the results of this study may not have high *generalizability* to other professions, it does have high *transferability* in its methods and implications to other professions looking to study relationships between undergraduate experiences and professional performance.

Additionally, the results should be high with respect to *reliability* as repeatedly performing the same analysis process on similar quantitative data sets should yield the same results. Like generalizability, *reliability* is only high if UST course curriculum has not changed dramatically. To mitigate threats to *generalizability* and *reliability*, the study will use a *z*-score for *UST final scores* to normalize the independent variable across the three UST curricula that were present during the study's timeframe.

The final quality consideration for evaluation is *objectivity,* i.e., how well the researcher limits bias and interaction with participants. For most aspects of this study, *objectivity* was at a high level as the data sets to be analyzed came from existing databases and participants will have had no direct interaction with the researcher. The data is either self-reported information, confirmed by others, or grades determined by UST, all of whom had no previous knowledge of this study. One aspect of the study that could be threatened by researcher bias is the selection of proxy variables used to represent undergraduate experiences. To mitigate these threats to *objectivity*, the study will look at all available and common variables from the various commissioning sources.

3.5 Data Analysis

Analysis for this non-experimental, retrospective study (Johnson, 2001) will follow Creswell's (2019) four steps of analysis and will focus on similar correlation methods used in the quantitative studies outlined in Chapter 2. This chapter will cover Creswell's first two steps, *preparing the data* and *identifying the data analysis procedures*. Chapter 4 will cover the last two, *reporting* and *interpreting the results*.

3.5.1 Operational Definitions for Independent and Dependent Variables

After collection, the data were conditioned, merged, and sanitized. Each datum was then operationally defined with a score to ensure standardized measurements across the various databases in *preparation* for analysis (Creswell, 2019). Most values were single-item scored except for *UST final scores*, which are summed via unweighted averaging among block test scores.

The databases contained independent and dependent variables that were both continuous and categorical data. Category definitions were based on the number of unique entries to allow for meaningful analysis. An informative engineering educational study looked at similar undergraduate independent variables from a large database to help inform the scoring used in this study (Hatfield, 2022). See Table 3-3 for operational definitions of each variable, i.e., the scoring codebook.

For available independent variables, the participant's *social security number* was converted to an anonymous substitute identifier based on the participant's UST curriculum version and fiscal year of attendance. *Commissioning source* was categorized as ROTC, OTS, or USAFA. *Race w*as limited to white or non-white as sufficient numbers were not present in more distinct categories. See Appendix A for disaggregated data regarding *race*.

To categorize academic *majors*, this study used the Department of Education's Classification of Instructional Program (*CIP*) codes to standardize their presentation among the various descriptions used by academic institutions. These CIP codes were then categorized into one of the three Air Force-defined tiers used for selection (Department of Education, 2022; AFPC, AFOCD, 2018). These three tiers represent prioritized groups of majors with space, systems, and mathematics related majors in the first tier; other STEM majors in the second tier; and any other Bachelor of Science degree in the third tier. Of the many options available, the academic *institutions* were categorized according to the Carnegie Classification of Institutions (2021) as either selective or inclusive to leverage findings from Dalessio (1986) regarding impacts on job performance based on prestigiousness of the school attended.

Gender was limited to male or female as the USAF and USSF databases do not yet capture non-binary options. *Ethnicity* was limited to Hispanic or non-Hispanic as sufficient numbers were not present in more distinct categories. See Appendix A for disaggregated data regarding *ethnicity*. The *date of commission* and *UST course start date* were converted to the time difference between commissioning, i.e. undergraduate graduation, and the start of their UST course. This allowed for additional sanitization and reflected a more useful metric to analyze any relationship between *wait time,* i.e., the time between when undergraduate experiences end and training begins, i.e., professional performance.

Academic performance was represented by the undergraduate Grade Point Average (GPA) on a 4.0 scale. Of note, the GPA available in the data sets may not reflect the final undergraduate GPA for some commissioning sources as it is often collected one to three semesters prior to graduation to inform career field selection processes. *Officer aptitude* was represented by scores on the standardized Air Force Officer Qualification Test (AFOQT) given to all officer candidates. Of the five AFOQT composite scores available, Academic Aptitude was chosen as a composite representation of both Verbal and Quantitative knowledge and abilities, excluding the remaining two tied to non-space career field aptitude, i.e. Pilot and Navigator. *Prior military service* was captured to identify those with enlisted military experience in addition to their undergraduate experience. This additional experience before commissioning may relate to officer professional performance and is worthy of consideration in this military-related study. *Career field preference* was categorized according to the Air Force Specialty Code (AFSC), i.e., career field, preferences provided by officers on their "dream sheets". Since each commissioning source captured this information differently, this variable was defined as either first choice for space operations or not first choice.

Undergraduate military performance in each respective commissioning program was represented by the *cadet ranking* among their peers within their commissioning source. To normalize their values, local commander rankings were calculated program-wide by each commissioning program and then converted to percentiles based on overall ranking with the commissioning program, i.e., ROTC or USAFA. Since there is not an established, standardized ranking criteria used by all local commanders and commissioning programs, cadet rankings may be influenced by individual commander bias and may include influences from other independent variables. For example, a commander may rank their cadets partially based on their GPA. Commissioning programs may then calculate final ranking based on AFOQT scores and again on GPA. This potential multicollinearity among independent variables was accounted for by evaluating Variance Inflation Factors (VIFs), described below.

To operationalize dependent variables, the *UST final score* served as the proxy variable to represent professional performance in initial training. The *number of UST block test failures* was also initially collected as an additional performance metric to identify any potential relationship between undergraduate experience and negative performance indicators in training. However, the relatively low number of *block test failures,* $N = 17$, and gaps in available data after the transition from USAF- to USSF-provided UST data significantly lowered the validity of any analysis that would have been conducted.

Table 3-3. Operational Definitions for Independent and Dependent Variables (i.e., Scoring Codebook).

DATA FIELD	Type	Operational Definitions
Commissioning Source	Categorical	0 = ROTC; 1 = OTS; 2 = USAFA;
Race	Categorical	0 = White; 1 = Non-White
Major	Categorical	Convert to CIP codes then to AFOCD Tiers 1-3
School/Institution	Categorical	0 = Selective; 1 = Inclusive
Gender	Categorical	0 = Male; 1 = Female
Ethnicity	Categorical	0 = Non-Hispanic; 1 = Hispanic
Date of Commission (DOC)	Continuous	Re-calculated as Wait Time
Grade Point Average	Continuous	4.0-point scale
AFOQT (Aptitude Test)	Continuous	Percentage score
Prior Service	Categorical	0 = No; 1 = Yes
Career Field Preferences	Categorical	0 = 1st choice for space operations; 1 = not first choice
Cadet Ranking	Continuous	Percentile score by commissioning source
UST Course Start Date	Continuous	Re-calculated as Wait Time
UST Final Score	Continuous	Standardized by UST curriculum version
Failed UST block tests	Categorical	0 = no test failures; 1 = at least one test failure

3.5.2 Data Analysis Procedures

Data analysis procedures included descriptive processes to describe trends in the data prior to the inferential processes to draw conclusions about the relationships between the independent and dependent variables (Creswell, 2019). Since the data were collected from multiple sources across multiple FYs, each with potential differences in how the data were captured, care was taken to fully describe each unique data set. The study initially focused on descriptive analysis to show totals, central tendencies, variability, and relative standing in the data to provide context to the inferential analysis that followed

(Creswell, 2019). JMP was used as the statistical program for most analysis with Excel also employed when less complex analysis was needed.

After obtaining key descriptive statistics, the study then conducted multiple tests based on the specific research question, the conceptual frameworks and associated theories, and the types of variables involved (Mertler & Reinhard, 2017). When selecting independent variables for the models, a statistical level of significance of *p-value* < .05 was used to determine if a statistically significant relationship existed between independent variables and the dependent variable, *UST final score*.

The first research question focused on confirming the applicable USAF or USSF policy at the time with their emphasis on using *commissioning source* and *major* to make officer selections and its echoes of potential credentialism. To answer the first part of the first RQ, i.e., do *commissioning source* and *major* selection rates meet the established independent selection rate requirements?, the study first conducted a *chi-square goodness of fit test* and a *one population proportion z test* on *major* selection rates against AFOCD-defined tier percentages. The intent was to determine if selections based on *major* and *commissioning source* followed established military requirements prior to testing the extent those variables relate to participants' performance at initial space training. This was an important first step due to the singular reliance on the *major* credential in officer selection for space operations, especially in light of concerns with the U.S. defense sector's ability to maintain STEM capabilities (Harrington et al., 2014).

This study intended to conduct similar tests for *commissioning source* selections against PGL-defined requirements, however, those requirements were dynamic during the study's timeframe and stable hypothesized values were not available. Two snapshots were taken of *commissioning source* selections during the study's timeframe for illustrative purposes only. Next, a *chi-square test of independence* was conducted to determine if *major* and *commissioning source* were independent of each other during the selection process as an additional method for understanding how well the actual selection process met intended requirements.

To answer the second part of the first RQ, i.e., to what extent do *commissioning source* and *major* relate to performance at initial space operations training?, a *two-way ANOVA test* was conducted to test the relationship those two categorical independent variables had with *UST final score,* the proxy variable for early career performance at initial space training.

For the second research question, which involved a more exploratory approach, two different predictive modeling methods were first used, Partitioning and Bootstrap Forest, to reveal independent variables that were related to the dependent variable. These independent variables were then tested to develop an initial linear regression model. A stepwise process was then used to systemically add other variables to the model, in accordance with the conceptual framework and research questions, and test their statistical significance and relationship to the dependent variable. To check for multicollinearity, Variance Inflation Factors (VIFs) were evaluated among the selected independent variables (Ott & Longnecker, 2010).

To validate the proposed final linear regression model, the data set was randomly split into two subsets. Once split, predictive models were generated from both sets and the resultant coefficients of determination, R^2, were compared to validate relative similarity. This process was completed ten times to add further validity to this process (Draper & Smith, 1981).

Also, once a proposed final linear regression model was developed, the next step ensured assumptions were not violated. Specifically, were the residuals independent? Did the residuals have constant variance? And were the residuals normally distributed? (Ott & Longnecker, 2010).

Finally, R^2 and the effect sizes were evaluated to determine the *practical* or *meaningful* significance of the model, and therefore, more fully answered each research question. R^2 determined the amount of variability in the dependent variable captured by the independent variables in the model. The effect size determined how big the change in the dependent variable occurs from a change in a specific independent variable, holding all other variables constant (Ott & Longnecker, 2010).

Since USAF, and now USSF, policies may be assuming a relationship between a few undergraduate experience variables, e.g., technical majors, and future active duty performance, this statistical analysis was intended to confirm their approach or provide justification for follow-on study and related policy changes.

Results of the analysis will be reported in appropriate tables and figures in the following chapter to *represent* and *interpret* the relationships, if any, between undergraduate experience and professional performance.

3.6 Delimitations and Limitations

Several of the key delimitations and limitations are summarized here to describe the scope and constraints of the study. Two deliberate delimitations were selected to define the scope of this study. The timeframe, i.e., FY 2018-2022, was chosen to capture sufficient data across the three UST curricula versions and prior to the next major overhaul in initial training. The target population, i.e., newly commissioned space operators attending UST as their first assignment, was defined to ensure a relatively homogeneous data set of undergraduate experiences, mitigating impacts from variables not available for collection or applicable to this educationally focused study, i.e., from non-Air Force, Guard, Reserve, and *later* career space operators.

There were three main categories of limitations for this study: access to participants, access to additional data sets, and access to a subset of data in available data sets. With early career space operators spread across the globe in their operational assignments, it was beyond the resources available for this study and the authority of AETC and STARCOM, as EPA partners, to obtain contact information, permissions, and instruments beyond the readily available databases provided. This was the main driver for the quantitative versus mixed methodology of this study.

Due to significant system, personnel, and priority limitations in key USAF and USSF organizations, several applicable data sets were not made available despite extensive coordination and requests. Although these limitations are likely caused by the constrained resource environment and transitory nature of the military, most of them were likely intensified by three near-simultaneous, historic milestones occurring during the study's timeframe: COVID; the standup of USSF and associated re-organizations of previous USAF units into new USSF units; and significant dynamic updates to selection processes and training programs. More specifically, data samples were obtained for follow-on Spacepower Discipline training from STARCOM and for operational training and evaluation data from SpOC, however, they were insufficient in number to analyze as a part of this study. For similar reasons, several existing independent variables were not made available by USAFA and OTS that limited their inclusion in the analysis for participants commissioned through those pathways (see Table 3-1). Likewise, but on a smaller scale, the granularity of data in STARCOM-provided *UST final scores*, the key dependent variable in this study, was not as precise as the same data provided by AETC prior to the transfer of responsibilities.

Keeping these limitations in mind, the methods described in this chapter were used to fully analyze the available data to generate the results and implications described in the next two chapters. After providing the key descriptive statistics, Chapter 4 will provide the results of the respective chi-square, z, t, ANOVA and multiple regression tests associated with each research subquestion above. Chapter 5 will address the implications of those results to inform actions and further study in and outside of the military space operations profession.

CHAPTER FOUR

RESULTS

Using the available data aligned to the conceptual framework, this chapter provides the results of the data analysis process described in Chapter 3 to answer the following research questions:

> RQ1a (Confirmatory): Do *commissioning source* and *major* selection rates meet the established independent selection rate requirements?

> RQ1b (Confirmatory): To what extent do *commissioning source* and *major* relate to performance at initial space operations training?

> RQ2 (Exploratory): To what extent do *other available undergraduate data* relate to performance at initial space operations training?

The chapter will begin with an overview of key descriptive statistics for this unique, five-year data set. Each data field within the data set will then be mapped to their respective element of the theoretical, metaphorical, and conceptual frameworks in preparation for inferential analysis. Finally, this chapter will show the results of the applicable chi-square test, z or t test, ANOVA, and regression analysis for each research question above, including relevant model validation and assumption checking.

4.1 Descriptive Statistics

To answer the research questions above, descriptive statistics will first explain the trends in this unique data set regarding general tendencies, spread, and appropriate comparisons (Creswell 2019). The descriptive statistics will also outline the detailed scope and limitations of the data set to put any results into proper perspective.

Due to the scope of this study, i.e., newly commissioned active duty officers attending UST in FY2018-FY2022, and database limitations discussed in Chapter 3, only the applicable and available UST attendees during those years were included in the analysis. Although significant changes to selection processes began occurring as this study concluded, largely connected to the standup of USSF, these results represent a larger population of space operations officers from years previous to the study's timeframe. Mid-level and senior officers serving today are products of the legacy selection processes when they first entered active duty and attended UST. The figures and tables below provide the key summary data discussed.

Of the 776 UST attendees, 141 officers did not meet the criteria for inclusion as they did not attend UST as a *newly* commissioned *active duty* officer, this study's target population. This excluded group included cross-trainees from other career fields, Air National Guard and Air Force Reserve officers, and sister-service officers from other branches. These subsets would introduce additional experiences and variables that could not be identified and analyzed to answer the research questions for this study. Of the remaining 635 officers, sufficient data were not available for 164 officers due a variety of factors, i.e., they were commissioned outside of the study's timeframe but attended UST during the study's timeframe; the officers' commissioning source could not be identified to enable data collection from the owning organization; or the commissioning source data were available, but the owning organization did not provide undergraduate data. One likely scenario to describe this last category could be the timing of when ROTC and USAFA cadets identify their career field preferences and are selected for their first assignment. If they are first selected for flying duty while an undergraduate cadet but were subsequently reassigned to space operations prior to entering active duty, typically due to a medical disqualification, their undergraduate data were not readily available for inclusion in this study.

This resulted in $N = 471$ officers being included in the study, see Figure 4-1. These 471 officers were subdivided by their commissioning source to properly account for data gaps not provided by their owning organization. Some of these gaps apply to the entire data set from a single commissioning source, see Table 3-1 above, or to a smaller subset of their officers. Of note, ROTC provided the most comprehensive data on their officers. ROTC accounted for $N_{ROTC} = 223$, or 47% of the total participants with at least 97% available data on their officers for all variables except *ethnicity* (only 76%). USAFA accounted for $N_{USAFA} = 138$, or 29% of the total participants with 100% available data for seven variables, but no data for the other eight. Finally, OTS accounted for $N_{OTS} = 110$, or 23% of the total participants with varying levels of available data, i.e., no data for *cadet ranking*, 58% for *major*, but 87% or higher for most other variables.

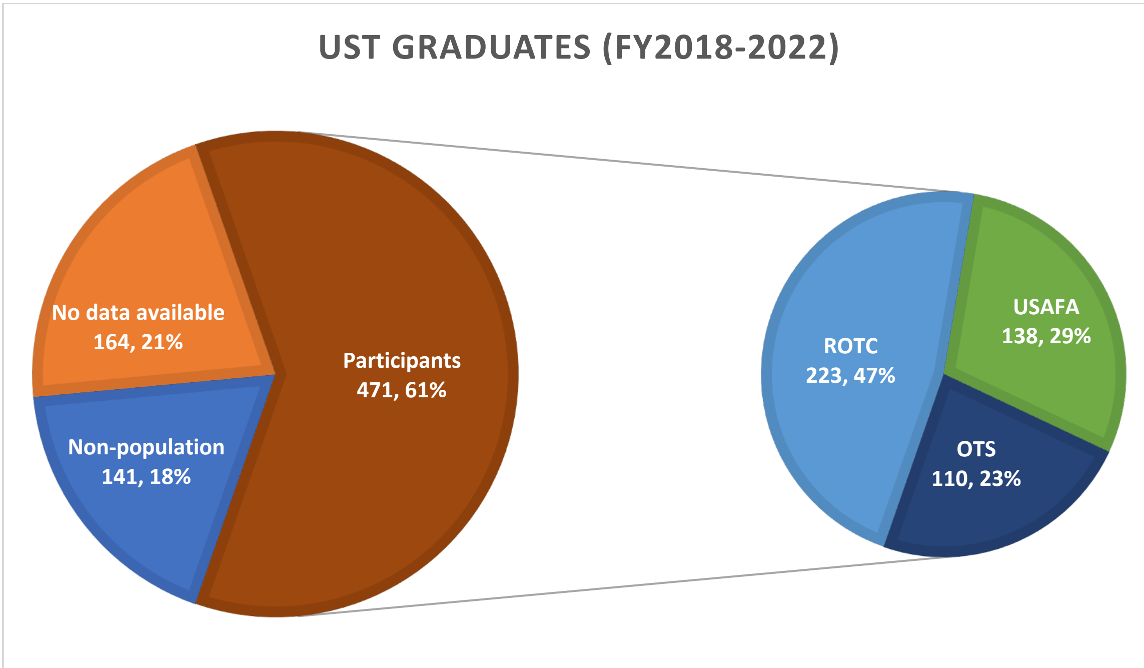


Figure 4-1. UST Graduates as Study Participants, by Commissioning Source.

Table 4-1 provides the total data availability for all participants, plus a breakdown by commissioning source. The percentage listed is based on the $N = 471$ sample size of inclusive participants for this study. Of note, each data field was available for at least 59% of participants (see Ethnicity as the minimum case).

Table 4-1. Data Availability for All Participants

DATA FIELD	ROTC	OTS	USAFA	Total
Social Security Number	100%	100%	100%	**100%**
Commissioning Source	100%	100%	100%	**100%**
Race	97%	96%	0%	**68%**
Major	99%	58%	100%	**90%**
School/Institution	98%	75%	100%	**93%**
Gender	100%	100%	0%	**71%**
Ethnicity	76%	100%	0%	**59%**
Date of Commission (DOC)	100%	96%	100%	**99%**
Grade Point Average	99%	87%	0%	**67%**
AFOQT (Aptitude Test)	99%	98%	0%	**70%**
Prior Service	99%	100%	0%	**70%**
Career Field Preferences	99%	100%	0%	**70%**
Cadet Ranking	99%	0%	100%	**76%**
UST Course Start Date	100%	96%	100%	**99%**
UST Final Score	100%	100%	100%	**100%**

Additionally, it is important to identify which of the three UST curriculum versions each officer completed to properly standardize the dependent variable used in this study, see Figure 4-2. While all versions of the curriculum met the same intent, i.e., provide initial training for military space operations officers, the curriculum had two significant updates during the study's timeframe to meet evolving USAF and USSF requirements. *Legacy UST* was implemented in 2015, prior to the study's timeframe, and included 76 training days at the *Secret* classification level. This curriculum version primarily assessed officer performance using multiple choice tests (533 TRS, 2022).

The second version, *UST Next 1.0*, was implemented by the USAF in October 2019 and increased the number of training days to 110 and classification level to *Top Secret/Sensitive Compartmented Information (TS/SCI)*. This version assessed officer performance using multiple choice tests, essays, and scenario-based instruments. Finally, *UST Next 1.1*¸was implemented by the USSF in February 2021 and kept the 110 training days at the *TS/SCI* classification level, but was redesigned to "allow modular academic blocks, improve flow of academics, more in-depth academic opportunities, [operations] field trips, and introduce new space warfighters to the warfighting domains" (533 TRS, 2022). For this study, N_{Legacy} = 167 officers (35% of total participants) graduated from *Legacy UST,* $N_{1.0}$ = 190 (40%) graduated from *UST Next 1.0*, and $N_{1.1}$ = 114 (24%) graduated from *UST Next 1.1*.

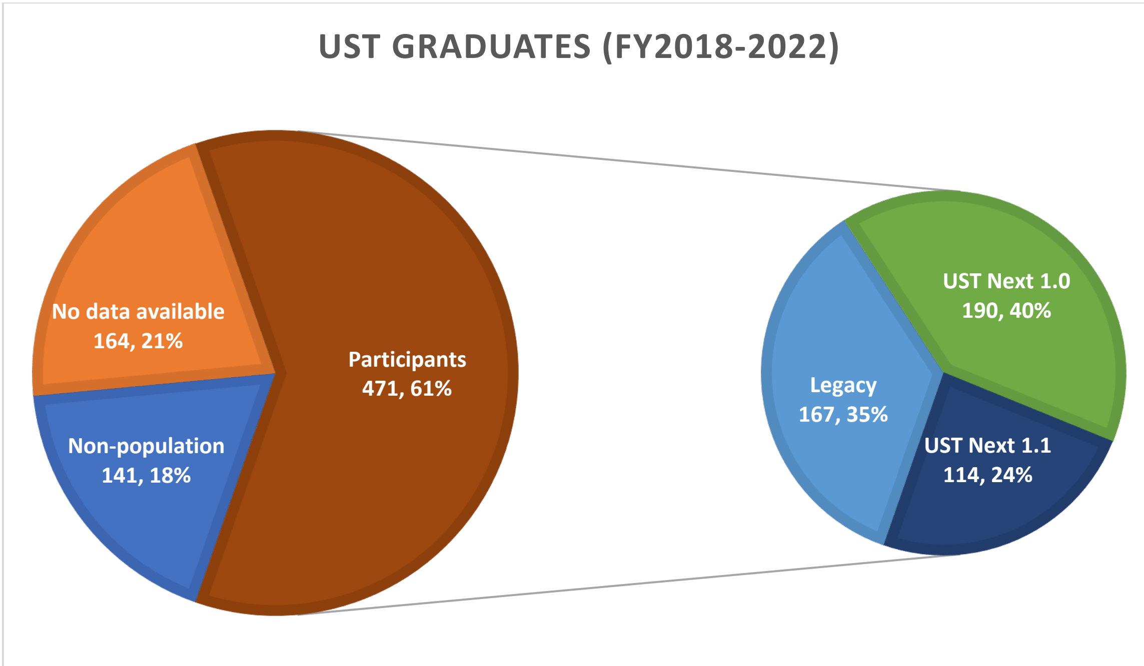


Figure 4-2. UST Graduates as Study Participants, by UST Curriculum Version.

Since the curriculum had significant changes between versions, the dependent variable, *UST final score*, was converted to a *z*-score to standardize this important variable prior to analysis. The mean and standard deviation for each UST version was calculated as follows: M_{Legacy} = 94.04 on a scale of 0-100 (*SD*: 3.611)*,* $M_{1.0}$ = 96.44 (*SD*: 2.192)*, and* $M_{1.1}$ = 94.80 (*SD*: 2.106). There were no recorded UST course failures or full withdrawals of any UST attendee, however, one officer did withdraw from the course for personal reasons but returned to graduate from a future course.

Prior to data analysis and in support of the research questions, other descriptive statistics were calculated to provide an overview of participants' undergraduate experiences for each independent variable. See Table 4-2. Each categorical variable shows the observed frequency by operational code along with the percentage of the total observed for that variable. Each continuous variable shows the calculated mean and standard deviation across all participants. The *Total* column shows the observed frequency for that variable among all participants in the study along with its associated percentage of the total number of participants, $N = 471$. As shown in the table and mentioned above, the owning organizations for the undergraduate experience data did not provide all data for their participants. Despite those gaps, at least two-thirds of total participants were included for each independent variable. Unfortunately, the absence of data for USAFA participants in eight of the fifteen variables limits the implications that can be made for that particular commissioning source.

Table 4-2. Descriptive Statistics for Independent and Dependent Variables.

DATA FIELD	Type	Operational Definitions	"0"	%	"1"	%	"2"	%
Commissioning Source	Categorical	0 = ROTC; 1 = OTS; 2 = USAFA;	223	47%	110	23%	138	29%
Race	Categorical	0 = White; 1 = Non-White	254	79%	68	21%		
Major	Categorical	Convert to CIP codes then to AFOCD Tiers 1-3	124	29%	85	20%	214	51%
School/Institution	Categorical	0 = Selective; 1 = Inclusive	371	85%	68	15%		
Gender	Categorical	0 = Male; 1 = Female	251	75%	82	25%		
Ethnicity	Categorical	0 = Non-Hispanic; 1 = Hispanic	242	86%	38	14%		
Date of Commission (DOC)	Continuous	Re-calculated as Wait Time	M = 208.013		SD = 147.466			
Grade Point Average	Continuous	4.0-point scale	M = 3.330		SD = 0.415			
AFOQT (Aptitude Test)	Continuous	Percentage score	M = 62.396		SD = 25.356			
Prior Service	Categorical	0 = No; 1 = Yes	265	80%	66	20%		
Career Field Preferences	Categorical	0 = 1st choice for space operations; 1 = not first choice	173	52%	158	48%		
Cadet Ranking	Continuous	Percentile score by commissioning source	M = 0.487		SD = 0.259			
UST Course Start Date	Continuous	Re-calculated as Wait Time	See Wait Time under DOC above (*)					
UST Final Score	Continuous	Standardized by UST curriculum version	See breakdown in above paragraph					
Failed UST block tests	Categorical	0 = no test failures; 1 = at least one test failure	360	93%	17	4%		

For *gender* and *race*, these five-year totals were then compared to USAF officer demographics at the time, across all career fields. No other data fields were readily available for comparison. The Department of Defense (DoD) began reporting demographic data for USSF in 2022, so this study used the center point of the study's timeframe (2020) and USAF data as a more appropriate initial measure for comparison. Comparing data from Table 4-2 and the DoD's reported data, this study's space operations officer participants somewhat aligned with USAF percentages in 2020. *Gender* for the study was 25% female versus 22% female for all USAF officers. *Race* was 21% non-white for the study versus 22% non-white for all USAF officers.

Of note, this study focused on newly commissioned officers, i.e., second lieutenants, whereas the USAF data from the DoD was for *all* officers in 2020. When comparing this study's data with available 2022 USAF and USSF data for *junior* officers, i.e., second lieutenants through captains, *gender* was 25% female for the study versus 26% female for USAF junior officers and 22% female for USSF junior officers. *Race* was 21% non-white for the study versus 25% non-white for USAF junior officers and 29% non-white for USSF junior officers. Trend data were not yet available for USSF, however, trend data for USAF from 2005 through 2022 indicated positive trends with increased percentages for both female and non-white officers (DoD, 2022).

4.2 Alignment with Theoretical, Metaphorical, and Conceptual Frameworks

To ensure alignment with the conceptual framework, see Figure 2-3 in Section 2.3.3, these variables were mapped to elements of the applicable theoretical framework, see Table 3-2, and metaphorical engineering education paradigm, e.g., pathway, pipeline, and ecosystem. This informed selection of the appropriate variables to answer each research question in accordance with the conceptual framework. Specifically, *UST final score* and any associated *failed UST block tests* served as the proxy dependent variables for this study. They represented the initial space training *pipeline* that all participants completed at the onset of their careers. Those variables also served as the proxy variables for *assessing individual performance* within Human Capital Theory (HCT) and *performance attainments* within Social Cognitive Career Theory (SCCT). All other proxy variables represented participants' undergraduate experience and served as the independent variables for each question and analysis. These variables represented elements of the educational *ecosystem*, commissioning *pathways*, and all three theoretical frameworks used for this study (e.g., HCT, SCCT, and Credentialism Theory).

More specifically, receiving an officer commission from one of the three c*ommissioning sources* and an undergraduate degree in a specific *major* were the credentials USAF and USSF primarily used to make career field selections for space operations. The participant's *commissioning source* provided them with HCT's *on-the-job training* as they prepared for a military career and their *major* represented the completion of their specific HCT *formal education*. These two variables also correspond to elements of SCCT as well. Each *commissioning source* had its own *environmental influence* on the participants as they completed their unique version of officer training, and their *major* defined a specific set of academic *learning experiences*.

Other available variables also aligned to HCT's *formal education* and *on-the-job training,* plus SCCT's *learning experiences* and *environmental influences* within the undergraduate *ecosystem.* Each *institution* uniquely defined its degree requirements as part of a participant's *formal education* while also offering a unique *environmental influence* from its campus setting or online community. *GPA* represented a common measure of success for their *formal education* and *learning experiences.* Similarly, *cadet ranking* served as a measure of success for their military-specific *on-the-job training* and *learning experiences*. A participant's enlisted *prior service* in the military identified them as having additional *on-the-job training* and *environmental influences* which could impact early career performance once commissioned as a new officer. One other potential *environmental influence* was represented by the *wait time* between completing their undergraduate experience and starting their initial space training.

As discussed in Chapter 2, SCCT has additional elements not accounted for in HCT that may help predict performance, namely *person inputs* and *interests.* Key demographic data captured by the military helped define some of these person inputs, specifically *race, ethnicity,* and *gender.* These variables could also be considered *environmental influences,* or even part of HCT's *other knowledge* as well. *Officer aptitude* was important *other knowledge* as it represented any natural talent or ability that may influence measures of success in the educational *ecosystem*, *commissioning source* *pathway*, or initial space training *pipeline*. Finally, *career field preferences* served as a proxy for the level of *interest* a participant had in space operations, a key motivational element of SCCT.

With this alignment and mapping completed, the analysis used applicable variables to answer each research question in accordance with the conceptual framework.

4.3 Confirmatory Analysis for Research Question #1

The next step analyzed the data to answer the two parts of the first research question:

> RQ1a (Confirmatory): Do *commissioning source* and *major* selection rates meet the established independent selection rate requirements?

> RQ1b (Confirmatory): To what extent do *commissioning source* and *major* relate to performance at initial space operations training?

These questions closely aligned to *credentialism theory* within the conceptual framework, see Figure 2-3 in Section 2.3.3.

The selection process for USAF and USSF officers at the time focused on two documents and their associated independent variables: the Program Guidance Letter (PGL) for *commissioning source* requirements and the Air Force Officer Classification

Directory (AFOCD) for entry education requirements, specifically academic *major*, by tier. The PGL is a "living document used by accession stakeholders as a planning tool" and the requirements by *commissioning source* can change from year-to-year and even within a fiscal year "as budgets are unknown and continually adjusted" (Headquarters USAF, PGL, 2019). On the other hand, the AFOCD remains mostly unchanged during any fiscal year and does not often change from year-to-year. For 2019, the AFOCD established entry education requirements with a 40% or more *mandatory* requirement for Tier 1, space-related technical majors*;* a 40% or more *mandatory* requirement for Tier 2, other technical majors; and a less than 20% *permitted* requirement for Tier 3, any other Bachelor of Science major (AFPC, AFOCD, 2018).

4.3.1 Commissioning Source Selection Rates

Since the *commissioning source* requirements*,* i.e., PGL*,* were not static, even within a given year, detailed analysis against these changing requirements would be difficult to validate without a hypothesized value for the analysis. However, as exemplars for this study, two PGL snapshots were taken in the middle of the study's timeframe to assess the extent selected officers met the requirements for those two snapshots. To further exacerbate the issue, the PGL requirements were set by fiscal year, i.e., an October 1 start, however, the USAF selection process at the time was conducted by calendar year, i.e., a January 1 start. In 2021, USAF aligned their selection process to the fiscal year. Figure 4-3 shows this two-year snapshot comparison. Data were adjusted from calendar year to fiscal year to better align with the associated PGL requirements.

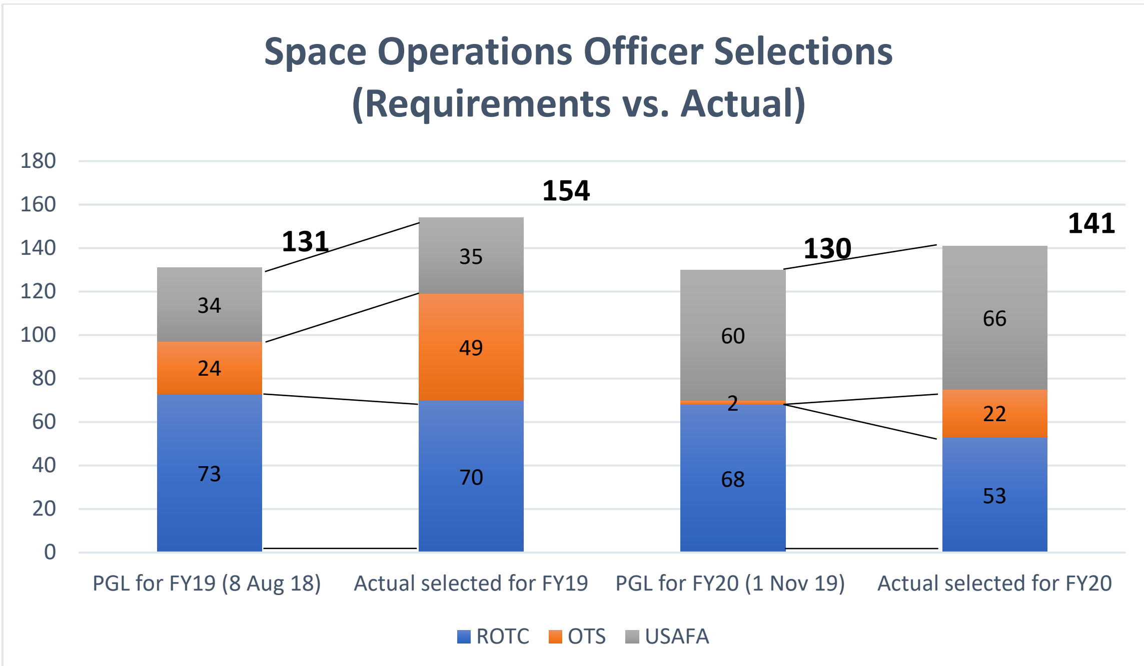


Figure 4-3. Commissioning Source Selections for FY2019 and FY2020.

4.3.2 Major Selection Rates

The *major* requirements for officer selection into space operations changed between 2018 and 2023 and year-by-year requirements were not made available by USSF (AFPC, AFOCD, 2018 & 2023). For the year of available requirements within the study timeframe, i.e., FY2019, a chi-square test of goodness-of-fit was performed to determine whether *major* proportional requirements were met for that year. For FY2019 commissioned officers, selection by *major* did not meet overall requirements for the population, X^2 (2, N = 127) = 97.49, $p < .001$. A one proportion z test was then performed to compare each *major* tier selection rate with FY2019 AFOCD requirements, N = 127. All three tiers did not meet requirements. The Tier 1 *major* selection rate of 30.7% was not significantly above the 40% or more mandatory requirement, z = -2.14, p = .98. The Tier 2 *major* selection rate of 15.0% was not significantly above the 40% or more mandatory requirement, z = -5.76, p = 1.00. The Tier 3 *major* selection rate of 54.3% was not significantly below the 20% or less mandatory requirement, z = 9.67, p = 1.00.

It is not clear what may have caused this significant shortfall in meeting requirements. However, it is worth noting that an updated AFOCD, put in place *after* the study timeframe, more closely matched the reality of those selected *during* the study's earlier timeframe. The 2023 AFOCD set entry education requirements with a 25% or more *mandatory* requirement for Tier 1, space-related technical majors; a 25% or more *desired* requirement for Tier 2, other technical majors; and a less than 50% *permitted* requirement for Tier 3, any other major. Also of note, is the removal of the Bachelor of

Science requirement for the Tier 3 category, allowing "any degree" in that tier (AFPC, AFOCD, 2023).

These new *major* selection requirements were retroactively applied to the study timeframe and a chi-square test of goodness-of-fit was performed to determine whether *major* proportional requirements were met using the updated 2023 *major* requirements. For FY2018-2022 commissioned officers, selection by *major* did not meet overall requirements for the population, X^2 (2, N = 423) = 7.25, p = .027. A one proportion z test was then performed to compare each *major* tier selection rate with FY2023 AFOCD requirements, N = 423. Under this scenario, i.e., retroactively applying FY2023 requirements to study timeframe, only Tier 1 major selection rate met requirements. The Tier 1 *major* selection rate of 29.3% was significantly above the 25% or more mandatory requirement, $z = 2.05$, p = .02. The Tier 2 *major* selection rate of 20.1% was not significantly above the 25% or more mandatory requirement, z = -2.33, p = .99. The Tier 3 *major* selection rate of 50.6% was not significantly below the 50% or less mandatory requirement, z = 0.24, p = .60.

4.3.3 Commissioning Source and Major Combined Effects on UST Final Score

With the USAF and USSF reliance on *commissioning source* and *major* for officer selection, a chi-square test of independence was performed to examine the relationship between *commissioning source* and *major* during officer selection. This test was conducted to determine if *major* and *commissioning source* were independent of each other during the selection process as an additional method for understanding the extent the established selection process may have had on performance at initial space training. The relationship between these variables was significant, X^2 (2, N = 423) = 36.85, p < .01. The test revealed a likely lack of independence between *commissioning source* and *major.* Tier 1 majors were more likely to be selected from OTS with a 28% higher selection rate, Tier 2 from ROTC with a 44% higher rate, and Tier 3 from USAFA with a 36% higher rate.

To answer the second part of the first research question, a two-way ANOVA was performed to analyze the relationship of *commissioning source* and *major* with *UST final score*. The two-way ANOVA revealed that there was an overall statistically significant difference in mean *UST final scores*, F(8, 414) = 4.54, p < .001. The main effect of *commissioning source* was not significant, F(2, 414) = 0.52, p = .59. The main effect of *major* yielded an F ratio of F(2, 414) = 8.35, p < .001, indicating the mean *UST final score* was significantly different among *major* tiers. Further analysis using a t test on the mean differences among the *major* tiers revealed UST final score was higher for Tier 1 *majors* (M = 0.20, SD = 0.93, N = 124) and Tier 2 *majors* (M = .19, SD = 0.86, N = 85) than for Tier 3 *majors* (M = -0.33, SD = 1.03, N = 214). The difference in the mean *UST final score* among Tier 1 and Tier 2 *majors* was not significant, t(414) = 0.03, p = .98. The difference between mean *UST final score* among Tier 1 and Tier 3 *majors* was significant, t(414) = 3.71, p < .01. The difference between mean *UST final score* among Tier 2 and Tier 3 *majors* was significant, t(414) = 2.71, p < .01. The *interaction* was not statistically significant, $F(4, 414) = 0.67$, $p = .61$. This ANOVA explains 6% of the variability in *UST final scores*, with an adjusted $R^2 = .06$.

Since the dependent variable was standardized using a z-score, the model coefficients, i.e., effect sizes, were recalculated to better reflect their practical or meaningful significance on *UST final* scores at initial space training. Since each standardized *UST final score* was dependent on the applicable curriculum version, the version with the largest standard deviation, $SD_{Legacy} = 3.611$, was used to calculate a best-case practical significance. Using that standard deviation, participants with technical *majors* in Tier 1 and Tier 2, had a slightly higher mean unstandardized *UST final score*, 0.7 percentage points above the overall mean, and participants with a Tier 3 non-technical *major* had a slightly lower mean unstandardized *UST final score*, 1.2 percentage points below the overall mean.

To summarize and confirm the answer to the first part of the first research question, i.e., do *commissioning source* and *major* selection rates meet the established independent selection rate requirements?, USAF and USAF did not meet the required *commissioning source* and *major* selection rates for the years analyzed using available references. Additionally, *commissioning source* and *major* were not independent factors in making career field selections as each *commissioning source* had a higher percentage from a certain *major* tier.

To summarize and confirm the answer to the second part of the first research question, i.e., to what extent do *commissioning source* and *major* relate to performance at initial space operations training?, *commissioning source* had no relationship and *major* had a weak relationship to performance at initial space operations training. Furthermore, the practical or meaningful significance between technical and non-technical *majors* only represented a 1.9 percentage point mean difference in a best-case unstandardized *UST final score.* Additionally, *commissioning source* and *major* were not independent factors in making career field selections as each *commissioning source* had a higher percentage from a certain *major* tier. Finally, USAF and USAF did not meet the required *commissioning source* and *major* selection rates for the years analyzed using available references.

4.4 Exploratory Analysis for Research Question #2

Having addressed the current, credentialism-like policies via the first research question, which resulted in a weak relationship with *major* only, the next step explored and analyzed the data to answer the second research question.

> RQ2 (Exploratory): To what extent do *other available undergraduate data* relate to performance at initial space operations training?

This question analyzed how the elements of *Human Capital Theory* and *Social Cognitive Career Theory* may predict early career performance.

4.4.1 Predictive Modeling and Forward-Selection Stepwise Regression

With ten other readily available independent variables to consider, two predictive modeling methods were employed to identify potential independent variables for inclusion in a predictive linear regression model. These variables mirrored the same or similar variables identified during the literature review and mapped to elements of this study's conceptual framework. Using recursive Partitioning predictive modeling, four dependent variables emerged (in order): *officer aptitude, major, GPA, and cadet ranking.* Using Bootstrap Forest predictive modeling, the top five dependent variables that emerged included (in order): *cadet ranking, officer aptitude, wait time, major,* and *GPA*. See Appendix B for additional details.

Four independent variables were found in both predictive modeling processes: *officer aptitude, major, GPA,* and *cadet ranking.* Three of these four independent variables were not provided by two of the owning organizations: USAFA did not provide *officer aptitude* test scores and *GPA* for its participants and OTS did not provide *cadet ranking* for its participants. Considering these limitations, the initial predictive linear regression model for RQ2 included *major,* from RQ1b and the predictive modeling process above, and *GPA*, from the predictive modeling process and literature review. Despite not having *GPA* data from USAFA participants, *GPA* serves as a recognized proxy variable for academic success in a participant's undergraduate experience and it was often used as an independent variable in many of the professional research efforts reviewed for this study, see Table 2-1.

Using dummy variables for categorical *majors*, this initial model assessed the relationship of Tier 1 *majors* (X1), Tier 2 *majors* (X2), and *GPA* (X3) on *UST final scores* (Y), $N = 279$. Tier 3 *majors* served as the intercept in the model. The overall test for this model was significant, $F(3, 275) = 14.06$, $p < .001$, indicating at least one independent variable has a significant relationship with *UST final scores*. This model explains 15% of the variability in *UST final scores*, with an adjusted $R^2 = .15$. The *major* tiers were significant predictors, $t_{Tier\ 1}(275) = 2.68$, $p_{Tier\ 1} < .01$, and $t_{Tier2}(275) = 2.11$, $p_{Tier\ 2} < .05$, indicating a positive relationship with mean *UST final scores* for technical *majors* over non-technical Tier 3 *majors*. *GPA* was also a significant predictor, $t(275) = 5.10$, $p < .001$, indicating a positive relationship with *UST final scores*. The regression equation was $Y = -2.40 + 0.21X1 + 0.17X2 + 0.72X3$, where Tier 1 *majors* increased mean standardized *UST finals scores* by 0.21 over Tier 3 *majors*, Tier 2 *majors* increased mean standardized *UST finals scores* by 0.17 over Tier 3 *majors*, and each additional point in GPA increased standardized *UST finals scores* by 0.72.

With this initial predictive linear regression model, the remaining independent variables were deliberately added to the model using a forward-selection model building approach. Variables were added based on their applicability to the theoretical and conceptual frameworks, availability, and statistical significance. *Officer aptitude* was added next as it was one of the top four variables identified from the predictive modeling process. While not specific to *officer aptitude*, as measured by the Air Force Officer Qualification Test, other aptitude tests were often used as an independent variable in several of the professional research efforts reviewed for this study, see Table 2-1.

This next step added *officer aptitude* (X4) to assess its relationship with Tier 1 *majors* (X1), Tier 2 *majors* (X2), and *GPA* (X3) on *UST final scores* (Y), $N = 278$. Tier 3 majors remained the intercept in the model. The number of participants changed in each stepwise iteration due to the aforementioned gaps in the data set. The overall test for this model was significant, $F(4, 273) = 28.00$, $p < .001$, indicating at least one independent variable has a significant relationship with *UST final scores*. This model explains 28% of the variability in *UST final scores*, with an adjusted $R^2 = .28$. In this model, differences in means among *major* tiers were no longer significant predictors, $t_{Tier\ 1}(273) = 0.69$, $p_{Tier\ 1} = .49$, and $t_{Tier2}(273) = 1.56$, $p_{Tier\ 2} = .12$. *GPA* remained a significant predictor, $t(273) = 4.12$, $p < .001$, indicating a positive relationship with *UST final scores*. *Officer aptitude* was a significant predictor, $t(273) = 7.04$, $p < .001$, indicating a positive relationship with *UST final scores*. Since *major* was no longer a significant predictor it was removed from the model.

The model was re-analyzed without *major* to assess the relationship of *GPA* (X1) and *officer aptitude* (X2) on *UST final scores* (Y), $N = 316$. The overall test for this model was significant, $F(2, 313) = 56.97$, $p < .001$, indicating at least one independent variable has a significant relationship with *UST final scores*. This model explains 26% of the variability in *UST final scores*, with an adjusted $R^2 = .26$. In this model, *GPA* remained a significant predictor, $t(313) = 3.45$, $p < .001$, indicating a positive relationship with *UST final scores*. *Officer aptitude* remained a significant predictor, $t(313) = 9.70$, $p < .001$, indicating a positive relationship with *UST final scores*. The regression equation was $Y = -2.36 + 0.39X1 + 0.02X2$, where each additional point in GPA increased standardized *UST finals scores* by 0.39 and each additional point in the *officer aptitude* test score increased standardized *UST finals scores* by 0.02.

Other readily available variables representing undergraduate experience in the conceptual framework were then added and assessed for their relationship with *UST final score* (Y). *GPA* (X1) and *officer aptitude* (X2) were included in all models and each new variable (X3) was added individually to determine if it was significant. In each iteration, the model was overall significant, $p < .001$, and *GPA* and *officer aptitude* remained individually significant, $p < .01$ and $p < .001$, respectively. However, the first five new variables that were individually added and assessed were not significant, and therefore, were removed from the model before each next step. See Table 4-3.

Table 4-3. Analysis Results for Cadet Ranking, Institution, Prior Service, Wait Time, and Career Field Preferences.

Independent Variable (X3)	Conceptual Framework mapping from HCT (Table 3-2)	Conceptual Framework mapping from SCCT (Table 3-2)	Sample Size (*N*)	Overall Test Statistic (*F*[3, *N*-4])	Overall Model Significance (*p*)	Adjusted R^2	Individual Test Statistic ($t[N-4]$)	Individual Significance (*p*)
Cadet ranking	On-the-job Training	Learning Experiences	220	29.93	< .001	.28	1.44	.15
Institution	Formal Education	Environmental influences	289	35.64	< .001	.27	-1.68	.09
Prior service	On-the-job Training	Environmental influences	316	38.44	< .001	.26	-1.13	.26
Wait time		Environmental influences	312	36.70	< .001	.26	-0.08	.94
Career field preferences		Interests	316	39.12	< .001	.27	1.66	.10

Finally, as part of the forward-selection process, *race, ethnicity,* and *gender* were individually, paired, and then collectively selected as the last remaining available variables as key *person inputs* from SCCT. Similarly to the first five variables assessed above, the model was overall significant in all iterations, $p < .001$. *GPA* and *officer aptitude* also remained individually significant, $p < .01$ and $p < .001$, respectively. Table 4-4 shows the resulting analysis as each variable or set of variables was added to the model with *GPA* (X1), *officer aptitude* (X2) and *UST final score* (Y).

Table 4-4. Analysis Results for Race, Ethnicity, and Gender.

Independent Variable(s)	Race	Ethnicity	Gender	Overall Significance (p < .001 in all cases)	Adjusted R^2
Race	t(307) = 2.06 p = .04			N = 311 F(3, 307) = 41.50	.28
Ethnicity		t(295) = 1.13 p = .26		N = 299 F(3, 295) = 37.64	.27
Gender			t(312) = 0.38 p = .71	N = 316 F(3, 312) = 37.93	.26
Race and Ethnicity	t(292) = 1.76 p = .08	t(292) = 0.87 p = .38		N = 297 F(4, 292) = 29.12	.28
Race and Gender	t(306) = 2.06 p = .04		t(306) = -0.01 p = .99	N = 311 F(4, 306) = 31.02	.28
Ethnicity and Gender		t(294) = 1.13 p = .26	t(294) = 0.05 p = .96	N = 299 F(4, 294) = 28.13	.27
Race, Ethnicity, and Gender	t(291) = 1.76 p = .08	t(291) = 0.87 p = ..38	t(291) = -0.07 p = .94	N = 297 F(5, 291) = 23.22	.27

From this analysis, only *race* was found to be significant and was included in the proposed final model for validation. *Ethnicity* and *gender* were removed from the model. As indicated in the first row of Table 4-4, this proposed final model assessed the relationship of *GPA* (X1), *officer aptitude* (X2), and *race* (X3) on *UST final scores* (Y), $N = 311$. This proposed final model was overall significant, $F(3, 307) = 41.50$, $p < .001$, indicating at least one independent variable has a significant relationship with *UST final scores*. This model explains 28% of the variability in *UST final scores*, with an adjusted $R^2 = .28$. In this model, *GPA* remained a significant predictor, $t(307) = 3.77$, $p < .001$, indicating a positive relationship with *UST final scores*. *Officer aptitude* remained a significant predictor, $t(307) = 9.49$, $p < .001$, indicating a positive relationship with *UST final scores*. *Race* was a significant predictor, $t(307) = 2.06$, $p = .04$, indicating a positive relationship with *UST final scores* for non-white participants.

This resulted in a *proposed* final regression model for validation, $Y = -2.45 + 0.43X1 + 0.02X2 + 0.12X3 + \varepsilon$, where each additional point in GPA increased standardized *UST final score* by 0.43, each additional point in the *officer aptitude* test score increased standardized *UST final score* by 0.02, and non-white participants increased standardized *UST final score* by .12.

4.4.2 Regression Model Validation

To validate this *proposed* final regression model, the data set was randomly split into two subsets: a training set and a validation set. Once split, predictive linear regression models were estimated from the training set and the resultant coefficient of determination, R^2, was compared to the R^2 from the predicted dependent variable in the validation set. This process was completed ten times to add further validity to the process (Draper & Smith, 1981). From this process, R^2 was calculated with a range of .23 to .33 among all the subsets (M = .28, SD = 0.04, N = *20*), approximating the adjusted R^2 of the proposed final regression model, R^2 = .28. The difference between each R^2 pair was calculated with a range of -.10 to .13 ($M_{\text{absolute values}}$ = .05, SD = 0.04, N = *10*).

4.4.3 Regression Model Assumptions

Finally, assumptions were then tested using residuals (ε) to validate the final predictive linear regression model, $Y = -2.54 + 0.43X1 + 0.02X2 + 0.12X3 + \varepsilon$. See Appendix C for details. With a sample size of 311 participants, the study ensured sufficient power to detect significant predictors of initial training performance, minimizing type II errors (Brooks & Barcikowski, 2012). Scatterplots of *GPA, officer aptitude,* and *race* against *UST final scores* revealed linear trends.

No outliers were identified as all standardized residuals were between -2.3 and 2.3, with 99% between -2.0 and 2.0. The quartile-quartile (Q-Q) plot confirmed the residuals' normality, and the residual plots confirmed equal variances. Finally, the Variance Inflation Factor (VIF) scores were well below 5, indicating no multicollinearity, VIF_{GPA} = 1.01, $VIF_{Aptitude}$ = 1.03, and VIF_{Race} = 1.02. All assumptions for the linear regression model were met.

4.4.4 Effect Size and Practical Significance

Since the dependent variable was standardized using a z-score, the model coefficients, i.e., effect sizes, were recalculated to better reflect their practical or meaningful significance on *UST final* scores at initial space training. Since each standardized *UST final score* was dependent on the applicable curriculum version, the version with the largest standard deviation, $SD_{Legacy} = 3.611$, was used to calculate a best-case practical significance. Using that standard deviation, each additional point in *GPA* increased a best-case, unstandardized *UST final score* by 1.55 percentage point. Each additional point in the *officer aptitude* test score increased a best-case, unstandardized *UST final score* by 0.07 percentage points. Non-white participants increased a best-case, unstandardized *UST final score* by 0.43 percentage points.

To summarize and confirm the answer to the second research question, i.e., to what extent do *other available undergraduate data* relate to performance at initial space operations training?, *GPA, officer aptitude,* and *race* had statistical significance in relationship to initial space training performance and accounted for 28% of the variance in *UST final scores.* While these variables were statistically significant in predicting *UST final scores,* they had low practical or meaningful significance. To illustrate this last point, if a non-white undergraduate student with a *GPA* one full point higher and *officer aptitude* test score 10 points higher than a white student, the model predicts they would improve their *UST final score* by 75% of one standard deviation. Practically, this equates to earning 2.68 percentage points more at initial space training, in a best-case scenario.

4.5 Results Summary

See Table 4-5 for a summary of the key results. In the context of the conceptual framework, there were many available variables from the undergraduate experience *ecosystem* and commissioning *pathways* to analyze with performance in the initial space training *pipeline.* Of those, only *major, GPA,* and *officer aptitude*, and *race* had statistical significance in their relationship to this early career milestone. Although statistically significant, their practical or meaningful significance was low, indicating other predictors need to be collected and/or the rigor of initial space training increased to further challenge new space operations officers.

Table 4-5. Summary of Key Results

DATA FIELD	KEY RESULTS
Commissioning Source*	Not significant; no bias in selection or initial space training
Race	Statistically significant, not practically significant
Major*	Not significant during stepwise regression analysis
School/Institution	Not significant during stepwise regression analysis
Gender	Not significant; no bias in selection or initial space training
Ethnicity	Not significant; no bias in selection or initial space training
Date of Commission (DOC)	Not significant during stepwise regression analysis (Wait Time)
Grade Point Average	Statistically significant, not practically significant
AFOQT (Aptitude Test)	Statistically significant, not practically significant
Prior Service	Not significant during stepwise regression analysis
Career Field Preferences	Not significant during stepwise regression analysis
Cadet Ranking	Not significant during stepwise regression analysis
UST Course Start Date	Not significant during stepwise regression analysis (Wait Time)

Note:
*Commissioning Source *and* major *did not meet selection rate requirements for the years analyzed, nor were independent factors during the selection process as each major tier had a higher percentage of selection from a specific Commissioning Source*

Specifically, for both parts of RQ1 and its association with Credentialism Theory, each *commissioning source* had a non-independent, higher percentage selection rate for a particular *major* tier; and selection requirements for *commissioning source* and *major* were not met for the years analyzed. USAF and USSF selection requirements, with their focus on these credentials, may have unintended and unnecessary effects on the *pathways* to space operations. Additionally, academic *major* was statistically significant, but only had a weak relationship to performance in the initial space training *pipeline,* $R^2 = .07$. *Majors* also accounted for a less than two percentage point mean difference across the three tiers as measured by best-case, unstandardized *UST final scores.*

For RQ2 and its inclusion of additional variables from elements of Human Capital Theory and Social Cognitive Career Theory, only *GPA* (X1), *officer aptitude (*X2*),* and *race* (X3) were statistically significant in relationship to initial space training performance, i.e., standardized *UST final scores* (Y). In this final model, $Y = -2.54 + 0.43X1 + 0.02X2 + 0.12X3 + \varepsilon$, those independent variables accounted for 28% of the variance in *UST final scores* and had low practical or meaningful significance, i.e., a couple percentage points on *UST final scores* in a best-case scenario.

Keeping this analysis in mind, the results described in this chapter were used to develop the conclusions and implications described in the next chapter. Chapter 5 will outline these implications to inform recommendations for USSF, for other career fields within the military, and for the other professions interested in studying the relationship between undergraduate experiences and early career professional performance.

CHAPTER FIVE

CONCLUSIONS AND IMPLICATIONS

This study quantitatively analyzed the extent to which undergraduate experiences relate to early career performance for space operations officers, more specifically, their performance at initial space training which occurs after graduation and commissioning. Using a conceptual framework based on Credentialism Theory, Human Capital Theory, and Social Cognitive Career Theory, this study first confirmed how variables used in USAF and USSF selection processes relate to initial space training performance. Next, this study explored how other readily available variables relate to similar performance. The methodology used in this study also revealed other implications for USSF and other professions wishing to better understand the relationship between undergraduate experience and professional performance.

The three theoretical frameworks leveraged for this study worked well and were applicable to the research questions as they progressively informed the confirmatory analysis of current practice, i.e., RQ1, the exploratory analysis for potential relationships with other readily available variables, i.e. RQ2, and the implications outlined in this chapter for consideration and future study by USSF and others. Specifically, Credentialism Theory was a very useful framework for analyzing USAF's and USSF's selection processes during this study, i.e., the reliance on an officer commission and specific degrees of study to represent implied knowledge, skills, and other traits. Additionally, the various elements of Human Capital Theory and Social Cognitive Career

Theory helped identify other readily available variables for analysis as well as variables not readily available but recommended for future consideration.

In answering the first part of the first research question, i.e., do *commissioning source* and *major* selection rates meet the established independent selection rate requirements?, the study found USAF and USSF did not meet the required *commissioning source* and *major* selection rates for the years analyzed which suggests those requirements may not be achievable. The analysis also showed a lack of independence in the selection process between *major* and *commissioning source,* which suggests an unintended and undesired outcome by the USAF and USSF with respect to potential bias in how specific expertise, i.e., *majors*, enters the officer corps.

In answering the second part of the first research question, i.e., to what extent do *commissioning source* and *major* relate to performance at initial space operations training?, *commissioning source* had no relationship and *major* had a weak relationship. The first conclusion, i.e., no statistically significant relationship for *commissioning source*, suggests favorable results as it did not reveal a bias from the undergraduate experience or selection process based on an officer's commissioning program. While this might also suggest USSF should select space operations officers from the most cost or resource efficient commissioning program, there are other benefits to having diverse pathways toward commissioning that were beyond the scope of this study. The second conclusion, i.e., a weak relationship between *major* and performance at initial space training, along with its low practical significance, suggest the military's emphasis placed on technical degrees for space operations does not relate to significant performance differences during initial training and therefore, is not a factor for officers in their ability to excel in that environment and become a space operations officer. This assumes the initial space training meets USSF needs; however, this study suggests the rigor at initial space training should be increased to take fuller advantage of the undergraduate education officers receive.

In answering the second research question, i.e., to what extent do *other available undergraduate data* relate to performance at initial space operations training?, only *GPA, officer aptitude,* and *race,* had statistical significance. While they accounted for 28% of the variance in *UST final scores,* they had low practical significance for any meaningful difference in initial training performance indicating other variables may have a stronger relationship to early career performance. As stated in the paragraph above, this also suggests the rigor at initial space training should be increased to take fuller advantage of the undergraduate education officers receive. Having more rigor at initial space training might also highlight stronger relationships between factors from the undergraduate experience and performance at initial space training.

Race results deserved a deeper look as a potential unintended bias may be occurring in the selection process or at initial space training. According to the study's results, non-white participants had a positive statistically significant relationship with *UST final score.* As noted in Chapter 3, *race* categorical scoring *w*as limited to *white* or *non-white* as sufficient numbers were not present in more distinct categories. See Appendix A for disaggregated data regarding *race*. Although not standardized among the commissioning sources, officers who identified in part or exclusively as *Asian* comprised half of the non-white officers in the study, i.e., 34 out of 68 officers, or 50%. The next largest category was *Black/African-American* with 20 out of 68, or 29%. Finally, all other categories, including *Other*, comprised the remaining 14 out of 68, or 21%. With the low number of participants in any category and the confluence of *Native Hawaiian or other Pacific Islander* with *Asian* for ROTC participants, sufficient power was not present to detect significant predictors of initial training performance in any *race* subcategory beyond *non-white* (Brooks & Barcikowski, 2012). However, according to Liu and Xie (2016), the high percentage of *Asian* participants included in the non-white category likely influenced the positive relationship between *race* and *UST final scores* due the fact "Asian Americans achieve higher test scores and obtain better grades" relative to whites and other racial groups as a "model minority".

The methodology used in the study also led to several other conclusions and implications. The literature review, study coordination, and collection process revealed a strong desire by the USAF and USSF to understand how undergraduate experience relates to early career performance. However, there was a relative lack of prioritization and commitment of resources from USAF and USSF in fulfilling this desire. Additionally, the collection process revealed several issues with gaps in, accessibility to, and standardization of common data currently available to the owning USAF and USSF organizations.

Finally, the delimitations and limitations of this study also informed opportunities for future research, especially studies related to other USSF early career performance measures beyond initial training. Examples of these measures from the active duty *pathways* and *ecosystem* include follow-on Spacepower Discipline training after UST, operational training and evaluation, retention rates, and potential USSF Development Team scoring of performance records. Finally, more qualitative methods are needed to more fully answer related research questions. This is especially timely as USSF begins to incorporate qualitative interviews directly into their selection process. These qualitative methods should focus on elements of the theoretical frameworks used in this study, on both sides of graduation. Implications from these conclusions are outlined below.

5.1 Implications for USSF from Analysis Results

Based on the descriptive analysis and RQ conclusions, USSF should consider three options for future selection process changes. First, STARCOM should add more *technical and academic rigor* to initial space training. Increasing the rigor will better leverage the technical degrees required by the AFOCD and also further challenge the young officers starting their space operations careers. The descriptive analysis, including the 100% graduation rate, high mean *UST final scores* with low standard deviations, and the extremely low number of individual block test failures, suggests there are opportunities to raise expectations for those attending initial space training and consequently, allow them to bring more knowledge and other training outcomes to their operational careers.

The USSF should eliminate specific *major* requirements in the AFOCD selection requirements or tie them to specific performance requirements as this study suggests *major* is not a factor in an officer's ability to become a space operations officer as measured by 100% completion rates and high scores at initial space training. This is further supported by the results of RQ1a and the demonstrated inability of the USSF and USSF to meet the selection requirements for the years analyzed. Certainly, technical *majors* may relate to higher performance *after* initial training, so additional research using other dependent proxy variables for early career performance should first be conducted to tie any additional USSF needs back to specific *major* requirements. See further discussion below on other measures of early career performance.

Finally, USSF should establish other requirements for making officer selections, specifically adding a space-focused portion of the AFOQT. Although RQ2 analysis resulted in three variables to consider based on their *statistical* significance, the high mean and tight spread of *UST final scores* limited any *meaningful* significance. Those three independent variables, e.g., *GPA, officer aptitude,* and *race,* plus others should continue to be analyzed as USSF makes changes to selection processes and STARCOM makes future changes to initial space training curriculum. USSF should also further study the extent that other quantitative and qualitative data, not included in this study, reveal undergraduate experience relationships to early career performance. Based on the literature review and theoretical frameworks used in this study, this collection could include pertinent items from psychological, interest, and biographical inventories (Dyer, 1987); SCCT-related scales (Kim & Seo, 2014); extra- and co-curricular experience (Bae, 2022); and aptitude tests (Kuncel et al., 2004). Regarding this last item, the noteworthy increase in R^2 and associated variability in *UST final scores* from the *officer aptitude* independent variable strongly suggests USSF should also consider a space-focused portion of the Air Force Officer Qualifying Test or new USSF-equivalent to mirror the *Pilot*, *Navigator*, and *Air Battle Manager* portions of the current AFOQT for those career fields.

There are several opportunities for USSF to collect any additional data, especially at existing *pathway* and *pipeline* milestones, e.g., adding new items to the USSF application process and capturing results from the new USSF interview selection process. Adding a survey or interview to the onboarding process at initial space training would also capture undergraduate experience data not currently collected.

5.2 Implications for USSF from Methodology

The methodology and collection phase for this study also revealed additional implications associated with *gaps in*, *accessibility to*, and *standardization of* data sets. Although the readily available data existed, multiple USAF and USSF owning organizations were unable to provide or continue to provide requested data. The enthusiasm within owning organizations for the study was almost always very high during initial coordination touchpoints, which continued during several initial transfers of collected data for some organizations. This was likely due to the interest in the research itself, plus the weight of the research effort being borne by the research institution in accordance with the EPA. Unfortunately, that enthusiasm and ability to provide data were not sustained in several organizations after initial coordination or throughout the collection process. From dialogue with those owning organizations, this was often due to a lack of priority, personnel, or system resources to fulfill the collection request.

USSF should add analytical resources and increase priority on future space operations education research as they take a “fresh approach” in “attracting, identifying, developing, and retaining a diverse workforce” (USSF, 2021). This should include leveraging the University Partnership Program and adding education research to the University Consortium topics list which is currently exclusively focused on *technology* development, with no refence to *professional* development or human subjects research (USSF, 2023).

5.2.1 Implications from Gaps in Data Sets

For those future studies, inclusion of the following readily available data would fill *gaps* identified in this study and help inform additional research: USAFA-provided data on the missing eight independent variables from this study, see Table 3-1; OTS-provided data on *officer candidate rankings*, equivalent to *cadet ranking* for the other two commissioning sources; and STARCOM-provided UST data that matches the fidelity of AETC-provided UST data collected prior to the USAF-to-USSF transition. More specifically on this last point, USAF, via AETC, provided individual block test scores, plus scores for all failed and retaken block tests, whereas USSF, via STARCOM, was only able to provide a rounded *UST final score* for graduates. This lowered the fidelity for the dependent variable used in this study and masked any failed block tests for the final *N* = 94, or 20% of participants. This also prevented additional analysis on individual blocks of instruction or on those participants who may have struggled during their initial training, identified by block test failures.

5.2.2 Implications from Accessibility to Data Sets

The lack of priority, personnel resources, and system resources also limited *accessibility* to relevant existing data beyond the UST *pipeline.* This prevented opportunities to analyze other proxy variables that represented early career performance and answer additional research questions regarding relationships between initial space training performance and later performance measures. STARCOM provided some initial data from the new Spacepower Discipline follow-on training courses, however, requests to receive additional data for analysis were not fulfilled. Another key proxy variable for early career performance also existed beyond initial and follow-on training. USSF's Space Operations Command (SpOC) collects operational training and evaluation data as each space operations officer seeks certification for their specific space system. Although both quantitative and qualitative data are collected on individual documents and used at the operational unit level, there is no central database that aggregates the data to enable detailed analysis. USSF should deliver a capability that captures currently collected data in a common database to inform future studies, e.g., an improved Patriot Excalibur-like capabilities used in Space Operations Command.

5.2.3 Implications from Lack of Standardization of Data Sets

USAF should standardize their data for race, ethnicity, major, career field preferences, and cadet rankings. The lack of *standardization* was noted when conditioning and merging similar data from the various owning organizations. Several common independent variables were represented by different values from different organizations and required additional conditioning prior to merging, sanitizing, and scoring the data. Besides the additional conditioning time needed to standardize the data, the differences in how data are represented and then scored could reduce the validity of the analysis. For example, OTS and ROTC both represent *race* with a single-letter code, however they use different codes and descriptors, e.g., OTS codes *White* with an *E* as one of 34 *race* categories, whereas ROTC codes *Caucasian* with a *C* as one of 6 *race* categories. To address the specific conclusion mentioned above related to *race*, USAF should provide appropriate distinction among race categories, specifically ensuring Pacific Islanders and Asian are not combined.

Additionally, OTS represents *ethnicity* data as either *Latino* or *Not Latino,* whereas ROTC uses 23 different codes for a diverse set of *ethnicity* options. For *major,* ROTC uses the four-character, USAF-specific degree code, whereas OTS and USAFA use a narrative descriptor. This could lead to reduced validity when converting *majors* to CIP codes prior to operationally scoring them by tier. For *career field preferences*, ROTC cadets submit their preferences with weighted values for each preference on a 100-point scale, whereas OTS officer candidates only provide preferences by ordinal number.

Finally, the process and calculations for *cadet rankings* are unclear within and across commissioning programs which may induce unintentional multicollinearity if rankings are heavily based on other independent variables, i.e., GPA, or lack a standardized criteria for commanders to use.

USAF, as the current owning organization for undergraduate experience data on behalf of USSF, should standardize how common data is represented across its various commissioning programs. While not a standardization concern, USSF and USAF should also consider how *gender* should be represented in the future as Department of Defense policies may evolve to include non-binary options.

5.2.4 Other Recommendations for Further Study

Beyond gaps, accessibility, and standardization implications, USSF should also consider other areas for *further study*. Although this study conducted "further analysis with more complex databases" than previous efforts (Stewart & Agrawal, 2021), USSF should conduct additional space operations education research that focuses on understanding the lack of independence results between *commissioning source* and *major* noted above, understanding how the undergraduate experience relates to officer retention, and understanding how the undergraduate experience relates to more comprehensive measures of early career performance beyond the training and evaluation metrics mentioned thus far. If the intent of having multiple pathways toward earning a commission provides favorable diversity in the officer corps, then USAF and USSF should take steps to ensure independence between *major* and *commissioning source* during the selection processes to avoid potential biases in how STEM and non-STEM related expertise is developed during the undergraduate experience.

Regarding other measures of early career performance, USSF should study junior officers selected for Weapons School using its performance metrics as dependent variables to identify any undergraduate experience relationship with that premiere early career opportunity. Also, up until 2021, USAF previously held Development Team (DT) conferences where a committee of senior space operations officers evaluated and scored junior officer records at the five-year career milestone. These scores informed personnel decisions and allowed the senior officers to offer specific feedback to the junior officers on how their performance compares to their peers. Although DT conferences continue for other requirements, they ceased scoring junior officer records a few years before the earliest participants in this study would have received their five-year score. The USSF Development Team should resurrect the scoring process for junior officers at an appropriate early career milestone to collect a more comprehensive measure of early career performance beyond the ones mentioned thus far. In addition to collecting a DT-like quantitative score, USSF should also collect qualitative data from the DT members *and* self-reported data from the junior officers to better inform any future research efforts and associated policy decisions. USSF should consider the elements of the theoretical frameworks used in this study when developing their additional data collection methods.

5.3 Broader Implications for Other Military Career Fields

Although this study was specific to the space operations career field, the structure and culture of the military allow for high *transferability* of the methodology used and implications identified here to other career fields. Other operational career fields in USAF, e.g., those involving rated flying duties, should directly apply the conceptual framework, and its supporting theoretical frameworks and paradigms, for equivalent education research involving their own officers. Those career fields often include similar initial training, e.g., Undergraduate Pilot Training, follow-on training, operational training and evaluation, Weapons School opportunities, retention metrics, and senior officer DT conferences. Non-operational career fields in the USAF, USSF, and other sister services should also leverage applicable elements of this study's conceptual framework, as many include their own form of initial and follow-on training, retention metrics, DTs, and other early career performance measures.

Implications stated above regarding gaps, accessibility, and standardization will have similar or direct implications for other USAF career fields, too, which would benefit from the changes in USAF's approach to data collection recommended here. The databases used to provide undergraduate experience data for this study are the same ones used to support selections from USAFA, ROTC, and OTS into other career fields.

5.4 Broader Implications for Other Professions

As evident in the literature review for this study, several frameworks, methodologies, and proxy variables have been previously used to identify relationships between undergraduate experiences and early career performance in other professions, too. Those outside of the military may have some limited *transferability* opportunities from this specific study, however, other professions should consider adapting the conceptual framework used here, substituting appropriate proxy variables in the undergraduate experience *ecosystem*, profession-specific *pathways* and *pipelines,* and performance measures unique to their early career *ecosystem*.

Research questions and associated elements of the study design should then be tailored to match selection or hiring processes and early career performance measures applicable to each profession. Considerations include altering both parts of RQ1 to focus on any *formally established* variables used in career selection by a specific profession. Examples may include requiring specific *majors* or other degree-specific requirements, i.e., *co-curricular experiences,* like internships; qualitative and quantitative results of *profession-specific licensure exams*, like nursing's National Council Licensure Examination (NCLEX); outcomes from any *standardized interview processes*, comparable to the direction USSF is heading; and other data collected to meet any stated professional requirements. As shown for RQ2, all elements of the theoretical frameworks used in this study should also be considered for inclusion in future studies to identify relationships and findings that would help recruiting, selection, training, and early career performance. Profession-wide collection processes may not be as readily available compared what was found in the military environment, so a more deliberate approach to study design and collection should be developed to replicate the available undergraduate data resident in current USAF and USSF processes.

Finally, implications identified for USSF above related to priority, resources, gaps, accessibility, and standardization likely have their own applicability to each profession. Researchers should also carefully consider these lessons learned when *studying undergraduate experience as predictors of early career performance* in other professions.

APPENDICES

Appendix A

Disaggregated Race and Ethnicity Descriptive Statistics

Table A-1. Race Descriptive Statistics

Race	ROTC (Legacy)	ROTC (Next 1.0)	ROTC (Next 1.1)	OTS (Legacy)	OTS (Next 1.0)	OTS (Next 1.1)	TOTAL
White or Caucasian	51	43	69	52	34	5	**254**
Asian, White				1			**1**
Asian	8	7	9	4	3		**31**
Native Hawaiian or other Pacific Islander	*	*	*	2			**2**
Black or African American	7	3	5	3	2		**20**
American Indian/Alaskan Native			1				**1**
Other	5	4	4				**13**
Unknown	2	1	4	3	1		**11**
Total	**73**	**58**	**92**	**65**	**40**	**5**	**333**
White	51	43	69	52	34	5	**254**
Non-White	20	14	19	10	5		**68**
Unknown	2	1	4	3	1		**11**

Notes:
ROTC uses 6 categories for race; OTS uses 34 categories
**ROTC combines Asian and Pacific Islander categories*

Table A-2. Ethnicity Descriptive Statistics

Ethnicity	ROTC (Legacy)	ROTC (Next 1.0)	ROTC (Next 1.1)	OTS (Legacy)	OTS (Next 1.0)	OTS (Next 1.1)	TOTAL
Not Latino				57	32	5	**94**
Latino*				8	8		**16**
Other Hispanic*	3	4					**7**
US/Can. Indian	3	6	10				**19**
Other Asian	1	2	2				**5**
Puerto Rican*	1						**1**
Filipino	3	1	2				**6**
Mexican*	4	1	6				**11**
Cuban*		1					**1**
Indian	2						**2**
Guamanian			1				**1**
Japanese			1				**1**
Korean	2	2					**4**
Latin American*		1	1				**2**
Vietnamese	1		1				**2**
Other	14	8	16				**38**
None	21	16	33				**70**
Unknown	18	16	19				**53**
Total	**73**	**58**	**92**	**65**	**40**	**5**	**333**
Hispanic	8	7	7	8	8		**38**
Not Hispanic	47	35	66	57	32	5	**242**
Unknown	18	16	19				**53**

Note:
ROTC uses 23 categories for race; OTS uses 2 categories
*Hispanic categories

Appendix B

Predictive Modeling in JMP

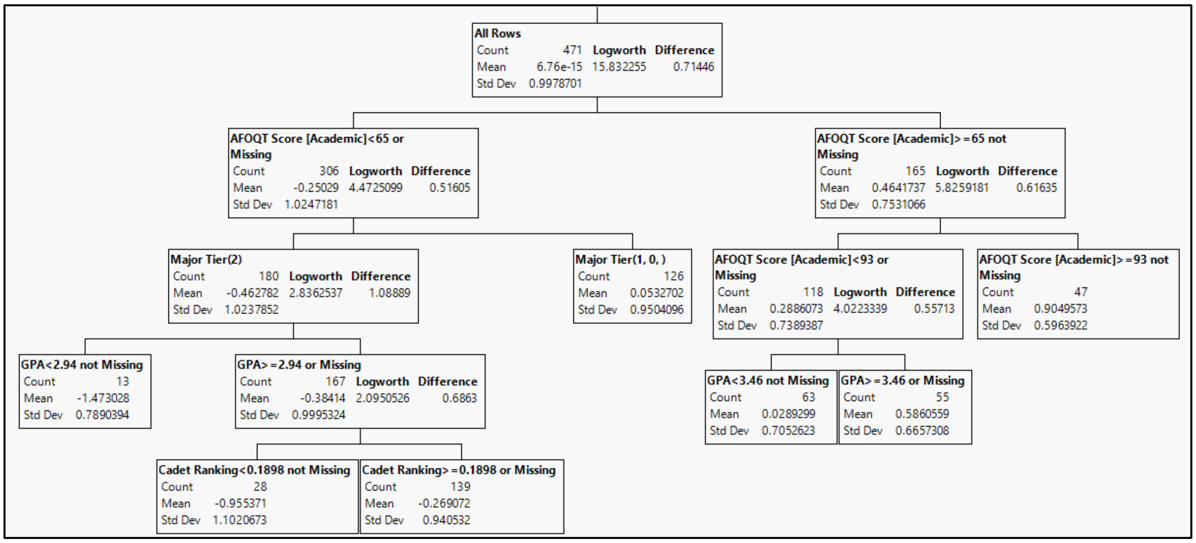
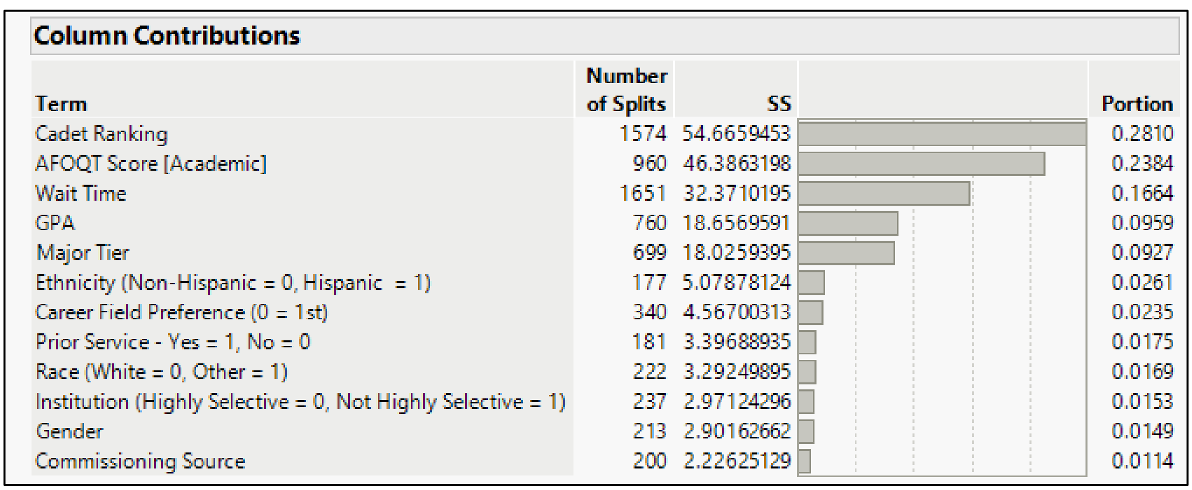


Figure B-1. Partition Predictive Model (Six Splits).



Column Contributions

Term	Number of Splits	SS	Portion
Cadet Ranking	1574	54.6659453	0.2810
AFOQT Score [Academic]	960	46.3863198	0.2384
Wait Time	1651	32.3710195	0.1664
GPA	760	18.6569591	0.0959
Major Tier	699	18.0259395	0.0927
Ethnicity (Non-Hispanic = 0, Hispanic = 1)	177	5.07878124	0.0261
Career Field Preference (0 = 1st)	340	4.56700313	0.0235
Prior Service - Yes = 1, No = 0	181	3.39688935	0.0175
Race (White = 0, Other = 1)	222	3.29249895	0.0169
Institution (Highly Selective = 0, Not Highly Selective = 1)	237	2.97124296	0.0153
Gender	213	2.90162662	0.0149
Commissioning Source	200	2.22625129	0.0114

Figure B-2. Bootstrap Forest Predictive Model.

Appendix C

Regression Model Assumptions

Brooks and Barcikowski (2012) suggest several conventional rules for determining sample size based on number of predictors, i.e., 15 or 30 subjects per independent variable, or predictor. For the final regression model in this study with three predictors, $N = 311$ far exceeded each conventional rule listed.

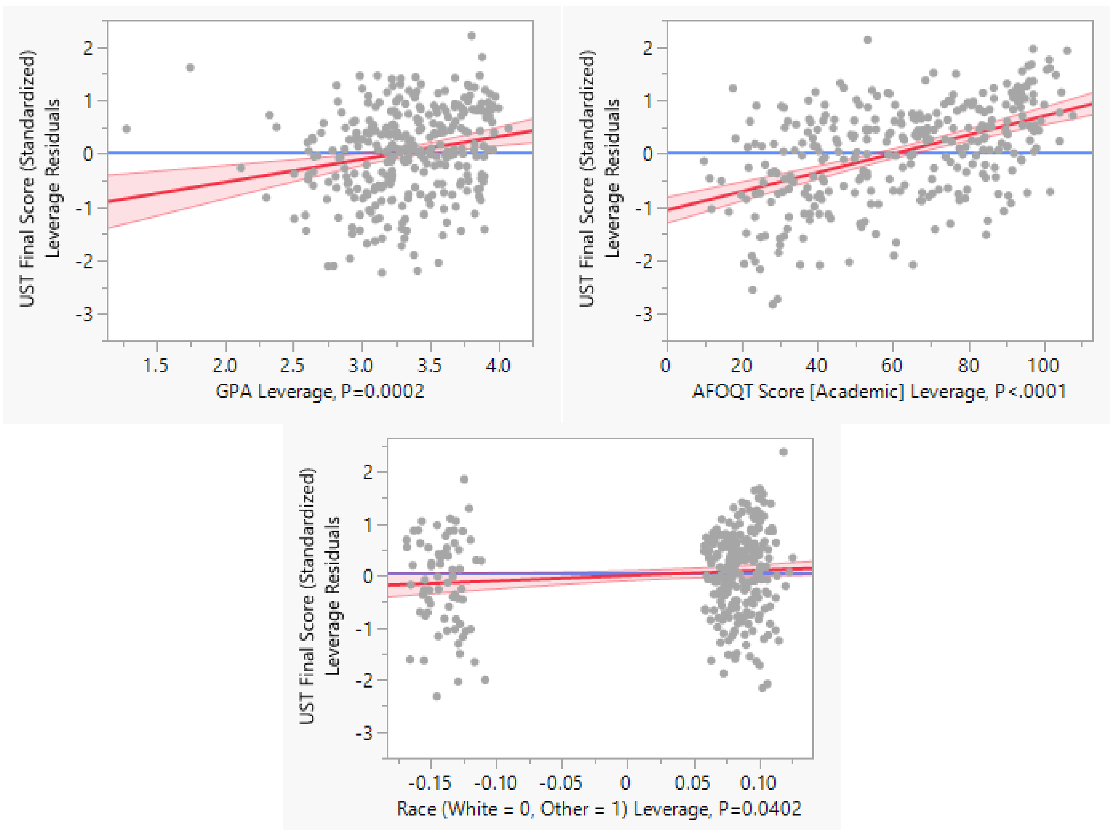


Figure C-1. Scatterplots of Independent Variables vs. Dependent Variable.

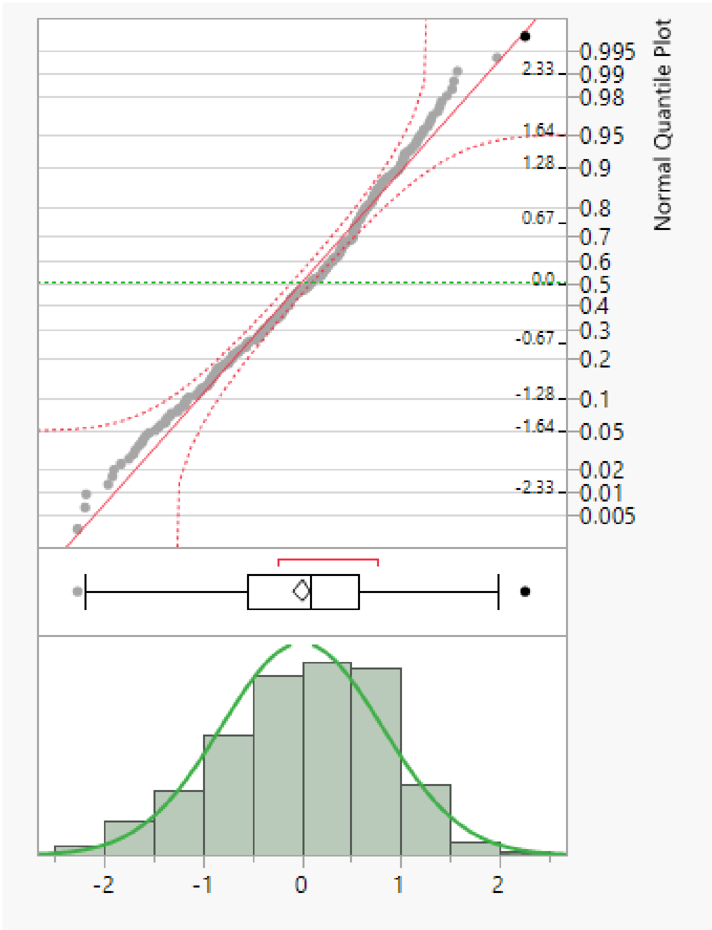


Figure C-2. Quartile-Quartile (Q-Q) Plot,

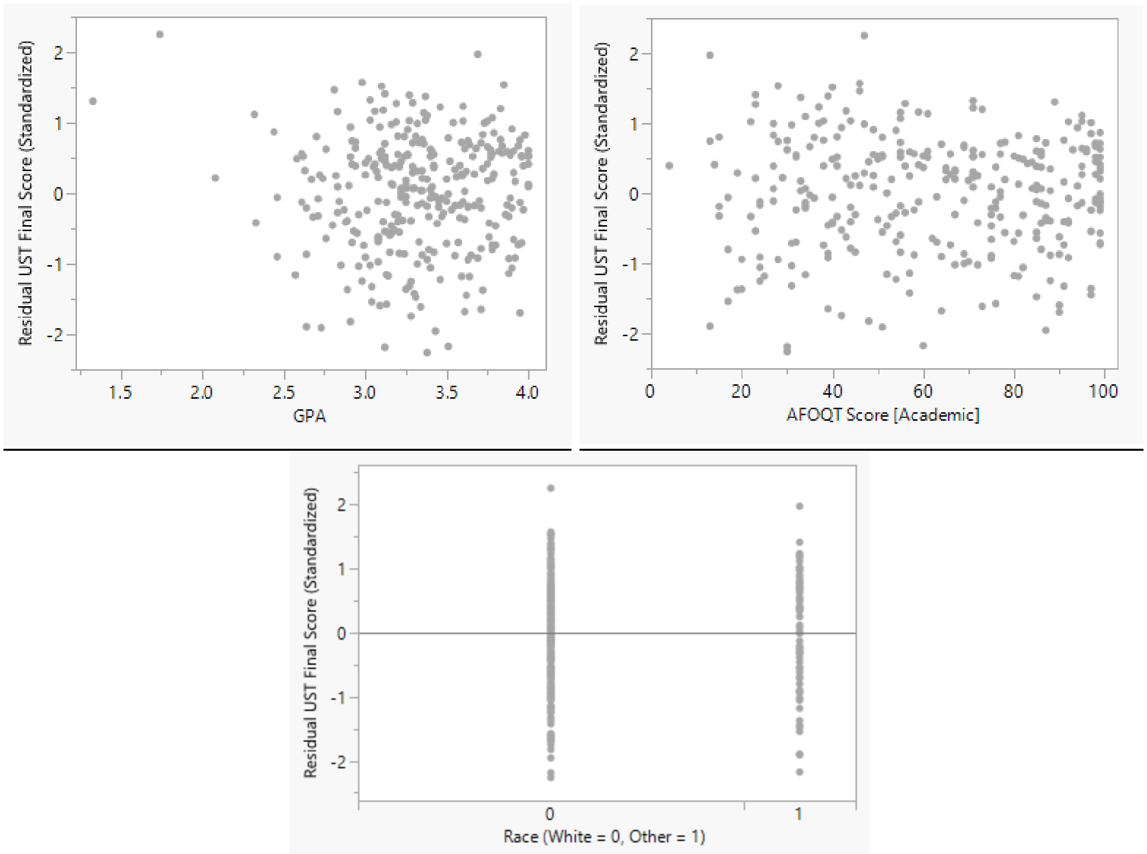


Figure C-3. Residuals vs. Independent Variables.

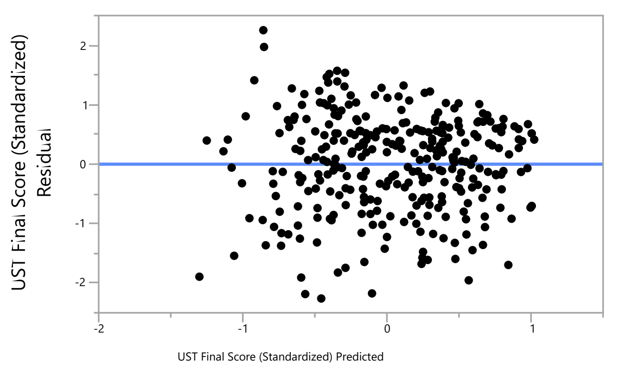


Figure C-4. Residuals vs. Predicted UST Final Scores.

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