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**THESIS**

**PREDICTING MIDSHIPMEN'S OUTCOMES  
AT THE UNITED STATES NAVAL ACADEMY**

by

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June 2021

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**PREDICTING MIDSHIPMEN'S OUTCOMES AT THE UNITED STATES  
NAVAL ACADEMY**

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Captain, United States Marine Corps  
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Submitted in partial fulfillment of the  
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## **ABSTRACT**

This research examines, describes, and analyzes factors that are associated with midshipmen's outcomes at the United States Naval Academy. Specifically, we identify factors that help predict which midshipmen will graduate in the top 10%, bottom 10%, or undergo attrition. The goal is to identify a list of factors which company officers and senior enlisted leaders can use to help develop midshipmen morally, mentally, and physically. We used logistic regression, classification trees, and random forests to seek the most effective prediction model for midshipmen's outcomes. The results of our logistic regression model accurately identify 71.4% of midshipman who are predicted to graduate in the top 10%, and 66.7% of midshipmen who are predicted to graduate in the bottom 10%. Additionally, whole person multiple, math SAT scores, participation in extracurricular activities, Myers-Briggs Type Indicator results, and mile times are key factors for predicting the top 10%. For the bottom 10%, the key factors are whole person multiple, math SAT scores, race/ethnicity, and prior enlistment. Due to a lack of specific attrition data, attrition models were unsuccessful. This study summarizes results, makes recommendations to the United States Naval Academy, and lists potential future work for Naval Postgraduate students.

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## EXECUTIVE SUMMARY

The United States Naval Academy (USNA) is a military service academy that graduates roughly 1,100 Navy and Marine Corps officers a year. In order to attend USNA, each candidate must submit an application. Within the application, the candidate must provide demographic information, high school performance, recommendation letters, ACT/SAT scores, candidate fitness assessment (CFA) scores, and medical information. From this information, the USNA admissions team evaluates each candidate as to whether the candidate should receive an appointment to the Naval Academy. The research objective of our study was to find the factors that help predict the midshipmen who will graduate in the top 10%, bottom 10%, or attrite based on the application submitted by each candidate.

Our study analyzed midshipmen applications from 2015 to 2019 to fit logistic regression models, classification tree models, and random forest models in order to predict the probability of a midshipmen graduating in the top 10%, bottom 10%, or undergoing attrition. Logistic regression models and random forest models outperformed the classification tree models in predicting the top 10% and bottom 10%. No attrition model was able to predict attrition well, which led to these models being removed from the analysis portion. This research identified factors within the application process that contribute to midshipmen graduating in the top 10% and bottom 10%.

The top 10% logistic regression model produced ten variables that were statistically significant in predicting the top 10%, and the bottom 10% produced eleven variables that were statistically significant in predicting the bottom 10%. Important predictors include:

- Whole Person Multiple: For both top 10% and bottom 10%, the whole person multiple is statistically significant. The higher the score candidates receive, the more competitive they are for an appointment. This research found that midshipmen who receive a higher whole person multiple have increased odds of graduating in the top 10% and decreased odds of graduating in the bottom 10%.

- Math SAT Score: For both top 10% and bottom 10%, the math SAT score is statistically significant. Midshipmen who score higher on the math SAT portion have higher odds of graduating in the top 10%, and midshipmen who score lower on the math SAT portion have higher odds of graduating in the bottom 10%.
- High School Athletic Extracurricular Activities (ECA): For both top 10% and bottom 10%, the participation in high school athletic ECAs is statistically significant, which is a score given by USNA admissions team. We found that midshipmen who receive higher athletic ECA scores have higher odds of not graduating in the top 10% and higher odds of graduating in the bottom 10%.
- Myers-Briggs Type Indicator (MBTI): The MBTI assigns one of 16 codes to each midshipman. The MBTI variable is statistically significant in predicting the top 10% of midshipmen only.
- Prior Enlistment: Whether or not a midshipman is prior enlisted is a statistically significant variable for the bottom 10% only. A midshipman who was prior enlisted is less likely to graduate in the bottom 10%.

This research provides the company officers (COs), senior enlisted leaders (SELs), and admissions team with a tool that can help with the potential outcomes of the incoming midshipmen. This tool can help COs and SELs to know which midshipmen may struggle academically and will enable the COs and SELs to ensure that these midshipmen get academic and physical assistance as early as possible. This research also provides the admissions team with factors to focus on when looking at future applications. Lastly, this research shows that the admissions team might include the MBTI into the application process, as it can help to predict whether or not a midshipman will graduate in the top 10%. For future studies, we encourage researchers to look at trends of USNA top 10% performers and bottom 10% performers at The Basic School and flight school.

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# I. INTRODUCTION

## A. BACKGROUND

At the United States Naval Academy (USNA), it is difficult to predict who will graduate at the top of their class, who will graduate at the bottom of their class, and who will not graduate. It is particularly difficult to predict this before the start of Induction Day (I-Day), which is the official start day for all incoming freshmen. Every year the admissions team at USNA processes over 15,000 applications, accepting roughly 8% of these candidates (*U.S. News & World Report* 2020). Of these candidates, roughly 90% of those admitted will graduate within four years. This is one of the reasons *U.S. News & World Report* ranked the Naval Academy its number two highest four-year graduation rate college (USNA 2020b).

Each candidate who receives a nomination to the Naval Academy represents an investment made by the government. As stated in the USNA admissions page, “the Navy pays 100% of the tuition, room and board, medical and dental care costs” (USNA 2020c). Additionally, each midshipman receives a scholarship upon receiving his or her appointment at USNA. Within each scholarship, midshipmen receive a monthly payment of \$1,087.80, with charges being deducted for laundry, barber, yearbook, and other services. This monthly paycheck received by the midshipmen increases each year (USNA 2020c). In essence, each candidate receives a full scholarship to the Naval Academy in exchange for five years of active-duty service upon graduation. Thus, the admissions team must do a thorough analysis of each candidate’s admissions package to ensure that it selects the candidates who have the most potential to help fulfill the Naval Academy’s mission. The mission of the Naval Academy is

to develop midshipmen morally, mentally, and physically, and to imbue them with the highest ideals of duty, honor, and loyalty in order to graduate leaders who are dedicated to a career of naval service and have potential for future development in mind and character to assume the highest responsibilities of command, citizenship, and government. (USNA 2020d, p. 1)

Our hypothesis for this study is that candidates who have the highest American College Test (ACT) / Scholastic Assessment Test (SAT) scores and perform better on the Candidate Fitness Assessment (CFA) have higher success at the Naval Academy. Additionally, we hypothesize that there is a relationship between success at USNA and participation in extra-curricular activities (ECAs), and between success at USNA and Myers-Brigg Type Indicator (MBTI) personality types.

## **B. PURPOSE OF STUDY**

The purpose of this thesis is to show common trends among the midshipmen who graduate in the top 10%, bottom 10% and the midshipmen who attrite, using information from their admission package and MBTI scores.

The goal of this thesis is to create a tool for the company officers (COs), senior enlisted leaders (SELs), and faculty to use to ensure these midshipmen take all the necessary steps to graduate and avoid probation. For example, COs and SELs can use this study to assign roommates for the freshmen midshipmen. Assigning as roommates a midshipman with high ACT/SAT score and a midshipman with low ACT/SAT score could enable the higher-scoring midshipman to assist a lower-scoring midshipman academically. Additionally, faculty might be able to use teaching methods that better suit midshipmen with a certain MBTI. The tool created by this thesis will also help the COs and SELs to proactively mentor at-risk midshipmen to ensure they do not fall behind academically, physically, or mentally.

## **C. RESEARCH QUESTIONS**

This thesis examines the following research questions:

1. Are there common trends in midshipmen who graduate in the top 10% of the class?
  - Can we accurately predict a midshipman graduating in the top 10% from his/her application?

2. Are there common trends in midshipmen who graduate in the bottom 10% of the class?
  - Can we accurately predict a midshipman graduating in the bottom 10% from his/her application?
3. Are there common trends in midshipmen who undergo attrition from USNA?
  - Can we accurately predict a midshipman undergoing attrition from his/her application?

#### **D. SCOPE AND METHODOLOGY**

This study seeks to identify and examine trends in the set of midshipmen making up the top 10%, bottom 10%, and undergoing attrition at the Naval Academy. The scope of this thesis covers midshipmen who started and graduated with the classes of 2015, 2016, 2017, 2018, and 2019. Each class size is roughly 1,200 midshipmen and each graduating class comprises between 1,000 and 1,100 midshipmen per year.

The methodologies in this study include logistic regression, classification trees, and random forests with the response variables being whether or not a midshipman graduated in the top 10% of his/her class, whether or not a midshipman graduated in the bottom 10% of his/her class, and whether or not a midshipman underwent attrition. For this thesis, the training set consists of classes 2015 to 2018, and the test set consists of the class of 2019.

#### **E. ORGANIZATION OF STUDY**

This study is broken down into five chapters. The second chapter consists of a literature review on the importance of the ACT/SAT on college grades and graduation, the impact of ECAs on academic performance and social success, the impact of physical fitness on academic success, and the relationship between the MBTI and academic performance and social success. The third chapter explains the data set and the research methodologies utilized. The fourth chapter presents the analysis of the data obtained on the classes of

2015, 2016, 2017, 2018, and 2019. The fifth chapter summarizes the conclusions from the research and offers recommendation and suggestions for further research.

## II. LITERATURE REVIEW

This chapter explores the research conducted to date on the relation of the ACT/SAT to undergraduate academic performance, the importance of physical fitness on academic success, the influence of extracurricular activities on academic performance, and the role personality traits play in academic performance.

### A. AMERICAN COLLEGE TEST AND SCHOLASTIC ASSESSMENT TEST

The ACT is “a career planning tool and curriculum-based standardized test that assesses a high school student’s readiness for college” (ACT 2020). The ACT is broken down into four categories: English, mathematics, reading, and science. The English section consists of 75 questions and tests the student’s ability in writing, language skills, and English. Consisting of 60 questions, the math section covers all math courses up until the 12<sup>th</sup> grade. The reading section consists of 40 questions and tests the student’s reading comprehension skills. Consisting of 40 questions, the science section tests the student’s ability to reason, analyze, and problem solve. There is also an optional writing section in the ACT that covers skills from high school-level English classes (ACT 2020).

The SAT is another standardized test that college admissions teams use in the admission process. The SAT tests the student’s knowledge and skills in writing, critical reading, and mathematics. The verbal portion consists of two sections: reading, and writing and language. The reading section of the SAT consists of 52 questions, and the writing and language section consists of 44 questions. The math portion is split into two sections: calculator and no calculator. The calculator section includes 35 questions, and the non-calculator sections includes 20 questions. The verbal and math portions on the SAT are reported on a scale from 200 to 800. Therefore, the math portions combine to receive a score between 200 and 800. Similarly, the verbal portions combine to receive a score between 200 and 800. By combining the math and verbal scores, the total score will fall between 400 and 1600 with a 1600 being a perfect score (SAT 2020).

To receive a nomination from the Naval Academy, a candidate must take either the SAT or ACT prior to submitting his or her admission package. The candidate may take

these tests as many times as desired in order to achieve the highest score possible. The Naval Academy will then consider the highest scores in each individual section for the candidate. When an ACT score is submitted in an admission package, it is converted into a SAT score for standardization (USNA 2020a).

Sackett et al. (2012) examines “the role of socioeconomic status in the relationships among college admissions-test scores, secondary school grades, and subsequent academic performance” (pg.1). This study looks at 143,606 students at 110 different colleges and universities. Through analyzing SAT scores, high school grades, socioeconomic status, the results of this study show that SAT scores are the strongest predictor of freshman grades.

With similar results in regard to freshman year grades, Kahn et al. (2002) use hierarchical regression analysis to predict freshman year grade point average (GPA). The regression analysis shows that the higher ACT/SAT scores correlate with higher freshman year GPA.

In another study, Hannon (2014) demonstrates that SAT scores are strong predictors for freshman GPAs. The regression analysis for this model shows that the SAT scores are highly predictive of freshman year GPAs, but that the SAT is less predictive for sophomore, junior, and senior GPAs.

Although these first three studies highlight the important correlations between ACT/SAT scores and freshman year GPAs, our study focuses on the correlations between SAT scores and whether a midshipman will graduate in the top 10%, bottom 10%, or attrite. These studies are still relevant because they show the predictive power of the ACT/SAT on academics. ACT/SAT scores provide useful information to the admissions team regarding how a candidate may do during plebe year. Plebe year at USNA is equivalent to other colleges'/universities' freshman year. With this information, the admissions team could inform the candidate's leadership on the candidate's potential plebe year academic performance.

Zwick and Sklar (2005) use high school grade point average, SAT scores, student ethnicity, and a student's first language to predict grades from freshman year and potential

to graduate college. This study shows that among Caucasian students, high school GPA is the strongest predictor for graduating college. On the other hand, SAT scores are better predictors for graduating college among Hispanic students. Although this study does not focus on the top 10%, bottom 10% or attrition, race/ethnicity is still a significant variable in predicting whether a midshipman graduates in the top 10% and bottom 10%. According to the chi-square test for independence, race/ethnicity is statistically significant in predicting whether a midshipman graduates in the top 10% and bottom 10%. The results of the chi-square test are discussed in Chapter IV.

While Schmitt et al. (2009) use cognitive and noncognitive predictors to predict the college student's academic performance after four years, their results do not consider ethnicity as Zwick and Sklar (2005) do. The cognitive predictors in Schmitt et al. (2009) include ACT/SAT scores, high school GPA, and an individual's life and background information. The noncognitive predictors include the situational judgment test and biodata measures. The biodata measures help an admissions team to collect information on an applicant's background and life history. Biodata measures include knowledge, learning, artistic appreciation, multicultural appreciation, leadership, responsibility, health, career orientation, adaptability, perseverance, and ethics. Through hierarchical logistical regression, Schmitt et al.'s study finds that ACT/SAT scores and high school GPA are the strongest variables for predicting college GPA throughout an individual's four years.

Stumpf and Stanley (2002) examine the "percentages of students graduating within six years and of students having a high school grade point average of at least 3.00" (p. 1042). According to this study, ACT scores at the 25<sup>th</sup> percentile, SAT math scores at the 25<sup>th</sup> percentile, and SAT verbal scores at the 75<sup>th</sup> percentile are the greatest predictors for students to graduate within six years from a college or university. However, it should be noted that a limitation of this study is the difference in graduation timelines, as the midshipmen at the Naval Academy must graduate in four years and do not receive the extra two years as mentioned in this study.

Schmitt et al. (2009), Zwick and Sklar (2005), and Stumpf and Stanley (2002) analyze ACT/SAT scores in order to predict a student's performance in college and whether or not he or she will graduate. Application of these three studies would be useful

in predicting whether a candidate will graduate or attrite, given the results of each study determining the importance of ACT/SAT scores. Analyses from these studies are applicable to our study because ACT/SAT scores are statistically significant in predicting the midshipmen who graduate in the top 10% and bottom 10%.

## **B. PHYSICAL FITNESS ASSESSMENTS**

Physical fitness is an important part of the curriculum at USNA, with mandatory fitness standards required of the midshipmen. At USNA, all midshipmen are required to take boxing, wrestling, swimming, personal conditioning, and martial arts. They also take a physical readiness test (PRT) twice a semester, which consists of push-ups, crunches, and a mile and a half run. Male midshipmen must run a mile and a half in under 10 minutes and 30 seconds, do at least 35 push-ups in 2 minutes, and do at least 65 crunches in 2 minutes. Female midshipmen must run a mile and a half in under 12 minutes and 40 seconds, do at least 20 push-ups in 2 minutes, and do at least 65 crunches in 2 minutes (USNA 2019). Physical education grades make up 16.78% of the military order of merit (MOM) (USNA 2017). If a midshipman fails the PRT three times at the Naval Academy, he or she will be referred to the Physical Education Board for possible separation. Midshipmen who fail “two official OPNAV standard PRTs within three years will automatically be referred for administrative separation from USNA in accordance with current USN Policy” (USNA 2019, pg. 8).

The CFA is a physical fitness assessment taken by candidates of USNA to ensure that the candidates meet the physical fitness requirements for acceptance. The assessment consists of six physical events, including the basketball throw, pull-ups, shuttle run, crunches, push-ups, and a one-mile run. A physical education instructor, coach, active duty commissioned officer, Blue and Gold officer, or Junior Reserve Officers’ Training Corps instructor must grade the candidate on the assessment. Once the first event begins, the candidate has 40 minutes to finish all six events (Table 1). The goal of the CFA is to ensure that the candidate has the “stamina and movement skills required to successfully complete the physical program and perform the duties required of commissioned officers in the uniformed services” (USNA 2020f).

Table 1. Candidate Fitness Assessment Testing Sequence. Source: USNA (2020g).

Events	Test Start Time	Testing Time	Rest	Total Elapsed Time
Basketball Throw	0:00	2 minutes	3 minutes	5:00
Pull-Ups	5:00	2 minutes	3 minutes	10:00
Shuttle Run	10:00	2 minutes	3 minutes	15:00
Crunches	15:00	2 minutes	3 minutes	20:00
Push-Ups	20:00	2 minutes	3 minutes	25:00
1-Mile Run	30:00	10 minutes	5 minutes*	40:00

*\* The 5-minute rest includes the transition time to the outdoor track. If the 1-mile run cannot be started by minute 30, an alternative arrangement for a running surface must be found.*

According to Bishop (2006), when a midshipman fails one or more physical readiness tests, he or she has a higher probability of attrition from the Naval Academy. This analysis shows that 31.1% of the midshipmen who undergo attrition have failed the PRT at least one time. In comparison, this analysis shows that 11.3% of the midshipmen who undergo attrition have never failed the PRT. Although our study does not focus solely on attrition as this one does, Bishop’s work is helpful in showing lack of physical fitness as a major contributor to the attrition rate at the Naval Academy. Our study looks at CFA results instead of PRT failures to see if they help in predicting midshipmen outcomes at the Naval Academy.

Fedewa and Ahn (2011) conducted a comprehensive meta-analysis covering 59 studies from 1947 to 2009 on the effects of physical activity and physical fitness on children’s academic achievement and cognitive outcomes. Through analyzing circuit training, resistance training, physical education programs, and aerobic exercises, they concluded that aerobic exercises have the greatest effect on academic achievement and cognitive outcomes. Moreover, they concluded that physical fitness is statistically significant in increasing math achievement. This is important in our study because math and physical fitness are important aspects of the Naval Academy curriculum. Additionally,

mile time and math SAT score are statistically significant in predicting top 10% and bottom 10% at the Naval Academy.

Hou et al. (2020) conducted a study on 316 medical and dental students enrolled at Tongji University in China to analyze physical fitness with “regular lifestyle” and the relation on academic performance. “Regular lifestyle” for the students is defined by high frequency library attendances and eating three meals per day at the cafeteria. From 2012 to 2014, physical fitness tests were taken by students each semester; the tests consisted of body mass index, vital capacity (the maximum volume of air that is expired after maximum inhalation), standing long jump, sit and reach, pull-ups, crunches, 50-meter run, 1000-meter run, and 800-meter run. This study indicates that the medical and dental students who score higher on the physical fitness test and have regular life habits have higher academic performance in comparison to students who do not score high on the physical fitness test and do not have regular life habits. With this study in mind, our study looks at performance on the CFA and how it affects academic performance. According to the two-sample t-test, the midshipmen who run faster on the mile, do more pushups, and do more crunches are more likely to graduate in the top 10% or not graduate in the bottom 10%. The results for the two-sample t-test are discussed in Chapter IV.

Chomitz et al. (2009) looks at the relationship between physical fitness and academic achievement in public schools in the northeastern United States. Academic achievement for this study is measured by how well the student performed on the Massachusetts Comprehensive Assessment System achievement tests in mathematics and English. As for the physical fitness, the study uses the number of physical fitness tests that each student passes during their physical education class. The conclusion of this study is that there is a statistically significant relationship between physical fitness and academic achievement.

Hsieh et al. (2018) examines junior high students over a three-year period in Taiwan to see the relationship in physical fitness and academic performance. The student’s physical fitness assessment consists of a 1600-meter run for males or 800-meter run for females, one-minute bent-leg curl ups, standing long jump, and a sit-and-reach test. The physical fitness assessment is given within the first four weeks of each academic year to

every junior high student. The Basic Competence Test for Junior High School Students measures the academic performance of every student at the end of their third year of junior high. This test ensures that the student is ready for high school. Hsieh et al. (2018) use data from 398,870 junior high school students who were all between the ages of 12 and 15. The result of this study shows that students with physical fitness scores in the top 25% in the first and third year perform better academically than the students who did not fall into the top 25%. The strongest predictor for academic performance is the time in the 1600-meter run and the 800-meter run.

Throughout these studies, there are common trends with physical fitness and academic performance. That is, students who are physically fit tend to have higher academic performance. The Naval Academy admissions team should be analyzing physical fitness for two reasons. First, the Naval Academy requires each student to be physically active. Second, physical fitness is an important aspect of physical and mental health. Our study expands on these analyses from above, but in regard to CFA results and whether or not a midshipman will graduate in the top 10%, bottom 10%, or attrite.

### **C. EXTRACURRICULAR ACTIVITIES**

Participation in ECAs in high school is important for candidates of the Naval Academy because participation in ECAs increases the likelihood of receiving an appointment. The admissions team at the Naval Academy separate ECAs into two categories; athletic and nonathletic. According to the Commandant of Midshipmen instruction, the Naval Academy puts emphasis on participation in ECAs because they teach individuals responsibility, social skills, and most importantly, they help develop leadership skills (USNA 2020g).

During a midshipman's time at the Naval Academy, participation in ECAs is not required, but it is encouraged. This is because ECAs provide leadership opportunities and empower midshipmen to be in charge of carrying out official functions for the Superintendent and the Commandant of Midshipmen (USNA 2020g), thereby supporting the mission of the institution. Participation in ECAs can also benefit a midshipman's overall order of merit (OOM). The OOM is how the Naval Academy ranks each

midshipman within their respected classes during their tenure at the Naval Academy. The OOM is a combination of academic order of merit and military order of merit.

Athletic performance and ECA participation make up 3.38% of the OOM for all midshipmen (USNA 2018). The athletic performance and ECA participation are portions of the individual's military order of merit. By participating in athletics and ECAs, midshipmen receive a mark from 1 to 4. In order to receive a mark of 1, a midshipman must participate in an intramural sport or junior varsity sport. A midshipman who receives a mark of 2 must letter in a club sport or be a team member of a varsity sport. To receive a mark of 3, a midshipman must letter in a varsity sport, or be an All-American in a club sport, or be a national team member. A midshipman who receives a mark of 4 is a team captain on a varsity sport or is an All-American national team member (USNA 1996).

Lastly, service assignment boards consider what ECAs a midshipman participates in during their time at the Naval Academy (USNA 2018). The service assignment board assigns the highest qualified midshipmen to fill the Navy and Marine Corps accession requirements. Participation in ECAs is highly encouraged, as it not only benefits grades, leadership abilities, and physical fitness, but it also may determine where a midshipman spends the next five years as a commissioned officer. Therefore, participation in ECAs goes beyond benefitting grades, as it opens up opportunities for individuals to be better leaders and increases social interactions with others.

The thesis of Zacherman (2010) examines the relationship between extracurricular activities and academic performance in 51,874 first year students and seniors in college from institutions throughout the United States. His study concludes that freshman and senior students who spend between 1 and 10 hours participating in extracurricular activities per week have higher GPAs on average than students who spend zero hours, or more than ten hours, per week participating in extracurricular activities. This study indicates that spending too much time in extracurricular activities may take time away from necessary schoolwork, which may negatively impact academic performance. Additionally, spending no time participating in ECAs due to working jobs or having other obligations may also negatively impact academic performance.

Knifsend and Graham (2012) examine high school students' participation in academic/leadership groups, arts activities, clubs, and sports and the relationship these students' participation have with academic engagement, GPAs, and sense of belonging at the school. This study also shows that students who participate in two of the activities have higher GPAs in the 11<sup>th</sup> grade, more academic engagement in the 12<sup>th</sup> grade, and have more sense of belonging to the school in both the 11<sup>th</sup> and 12<sup>th</sup> grade.

According to Trudeau and Shephard (2008), school-based physical activities have a positive association with academic performance, concentration, memory, and classroom behavior. Therefore, this study suggests that schools should have school-based physical activities built into their curriculum. This study also shows that taking away school-based physical activities and adding more academic work produces no measurable improvements in academic performance. Thus, schools should encourage the use of school-based physical activities, as it is good for the overall well-being of the student.

The studies noted above look at the importance of ECAs on academic performance. In our study, we look at each candidate's participation scores in high school athletic ECAs and scores in high school non-athletic ECAs. The goal for our study is to track trends in participation scores, and whether the candidate graduates in the top 10%, bottom 10%, or attrites from the Naval Academy. According to two sample *t*-tests, midshipmen who receive a higher score in non-athletic ECAs are more likely to graduate in top 10% or not graduate at the bottom 10%. Additionally, participation in ECAs is statistically significant in our study, and the results are discussed in Chapter IV.

#### **D. MYERS-BRIGGS TYPE INDICATOR**

In the 1920s, Carl G. Jung created the theories of psychological types, which posited that “what appears to be random in behavior is actually the result of differences in the way people prefer to use their mental capacities” (MBTI 2020a). Jung observed that people use their mental capacity to take in information and make decisions by either perceiving or judging. Additionally, he believed that people were energized by the external world or internal world, and this is where the terms extrovert and introvert came from. Although it was hard for individuals in that time period to understand his concepts and

ideas, Jung is now credited for the foundational work of the Myers-Brigg Personality Test that is widely used today (MBTI 2020b) .

In the 1940s, Isabel Briggs Myers and her mother, Katharine Briggs, created the MBTI in order to make Jung’s theories on psychological types more useful and understandable in people’s lives (MBTI 2020b). They created 16 different MBTI types constructed from four categories with two choices in each category. The first category is how the person is in the world. Each individual is either an Extrovert (E) or an Introvert (I). An extrovert is a person who enjoys being around people and is seen as outgoing. An introvert is a person who enjoys being alone and is seen as being reserved. The next category is the how the individual recognizes information. For this category, the person is either Sensing (S) or Intuition (N). Sensing describes a person who pays attention to the physical reality. Intuition describes a person who needs hands-on experience. The next category deals with decisions. For this category, the person is either Thinking (T) or Feeling (F). Thinking describes a person to whom logic is important; they need the basic truth in order to make decisions. Feeling is a person who is compassionate and makes decisions based on his or her emotions. The last category deals with structure and describes people as either Judging (J) or Perceiving (P). Judging describes people who like to make lists of things to do. Perceiving describes people who are looser and more casual; they typically keep plans to a minimum (MBTI 2020b). The breakdown of all 16 MBTI types is described in Table 2.

Table 2. Description of Myers-Briggs Results. Adapted from MBTI (2020c).

ISTJ	Quiet, serious, earn success by thoroughness and dependability. Practical, matter of fact, realistic, and responsible. Decide logically what should be done and work toward it steadily, regardless of distractions. Take pleasure in making everything orderly and organized - their work, their home, their life. Value traditions and loyalty.
ISFJ	Quiet, friendly, responsible, and conscientious. Committed and steady in meeting their obligations. Thorough, painstaking, and accurate. Loyal, considerate, notice and remember specifics about people who are important to them, concerned with how others feel. Strive to create an orderly and harmonious environment at work and at home.

INFJ	Seek meaning and connection in ideas, relationships, and material possessions. Want to understand what motivates people and are insightful about others. Conscientious and committed to their firm values. Develop a clear vision about how best to serve the common good. Organized and decisive in implementing their vision.
INTJ	Have original minds and great drive for implementing their ideas and achieving their goals. Quickly see patterns in external events and develop long-range explanatory perspectives. When committed, organize a job, and carry it through. Skeptical and independent, have high standards of competence and performance - for themselves and others.
ISTP	Tolerant and flexible, quiet observers until a problem appears, then act quickly to find workable solutions. Analyze what makes things work and readily get through large amounts of data to isolate the core of practical problems. Interested in cause and effect, organize facts using logical principles, value efficiency.
ISFP	Quiet, friendly, sensitive, and kind. Enjoy the present moment, what is going on around them. Like to have their own space and to work within their own time frame. Loyal and committed to their values and to people who are important to them. Dislike disagreements and conflicts, do not force their opinions or values on others.
INFP	Idealistic, loyal to their values and to people who are important to them. Want an external life that is congruent with their values. Curious, quick to see possibilities, can be catalysts for implementing ideas. Seek to understand people and to help them fulfill their potential. Adaptable, flexible, and accepting unless a value is threatened.
INTP	Seek to develop logical explanations for everything that interests them. Theoretical and abstract, interested more in ideas than in social interaction. Quiet, contained, flexible, and adaptable. Have unusual ability to focus in-depth to solve problems in their area of interest. Skeptical, sometimes critical, always analytical.
ESTP	Flexible and tolerant, they take a pragmatic approach focused on immediate results. Theories and conceptual explanations bore them - they want to act energetically to solve the problem. Focus on the here-and-now, spontaneous, enjoy each moment that they can be active with others. Enjoy material comforts and style. Learn best through doing.
ESFP	Outgoing, friendly, and accepting. Exuberant lovers of life, people, and material comforts. Enjoy working with others to make things happen. Bring common sense and a realistic approach to their work and make work fun. Flexible and spontaneous, adapt readily to new people and environments. Learn best by trying a new skill with other people.
ENFP	Warmly enthusiastic and imaginative. See life as full of possibilities. Make connections between events and information very quickly, and confidently proceed based on the patterns they see. Want a lot of affirmation from others, and readily give appreciation and support. Spontaneous and flexible, often rely on their ability to improvise and their verbal fluency.
ENTP	Quick, ingenious, stimulating, alert, and outspoken. Resourceful in solving new and challenging problems. Adept at generating conceptual possibilities and then analyzing them strategically. Good at reading other people. Bored by routine, will seldom do the same thing the same way, apt to turn to one new interest after another.
ESTJ	Practical, realistic, matter of fact. Decisive, quickly move to implement decisions. Organize projects and people to get things done, focus on getting results in the most efficient way possible. Take care of routine details. Have a clear set of logical standards, systematically follow them and want others to also. Forceful in implementing their plans.

ESFJ	Warmhearted, conscientious, and cooperative. Want harmony in their environment, work with determination to establish it. Like to work with others to complete tasks accurately and on time. Loyal, follow through even in small matters. Notice what others need in their day-by-day lives and try to provide it. Want to be appreciated for who they are and for what they contribute.
ENFJ	Warm, empathetic, responsive, and responsible. Highly attuned to the emotions, needs, and motivations of others. Find potential in everyone, want to help others fulfill their potential. May act as catalysts for individual and group growth. Loyal, responsive to praise and criticism. Sociable, facilitate others in a group, and provide inspiring leadership.
ENTJ	Frank, decisive, assume leadership readily. Quickly see illogical and inefficient procedures and policies, develop and implement comprehensive systems to solve organizational problems. Enjoy long-term planning and goal setting. Usually well informed, well read, enjoy expanding their knowledge and passing it on to others. Forceful in presenting their ideas.

During plebe year (freshmen year) at USNA, all midshipmen are required to take the MBTI. In the leadership class, Preparing to Lead, the midshipmen take a deeper look into their MBTI results in order to learn more about themselves as leaders. The goal of the class is to teach the fundamental tenets of leadership through theories and principles. This class is important for midshipmen, as it helps to develop them as leaders and begins to show them their personality types (USNA 2020e).

Borg and Stranahan (2002) look into how certain personality types, races, and genders outperform other students in upper-level economics courses. In this study, students who are Introverts on average outperform students who are Extroverts in the upper-level economic courses. Additionally, students who have the combination of Sensing/Judging trait do better, on average, than students who have the combination of Sensing/Perceiving trait. As for gender, male students with the combination of Sensing/Judging trait perform better, on average, than female students with the same combination. Finally, non-African American students who are Introverts, Judges, or a combination of Sensing/Judging perform significantly better than other students on average.

In the next study, Ware (2019) examines the relationship between Myers-Briggs Type Indicators and first-time North American Pharmacist Licensure Examination performances. The study concludes that the 134 students from South University School of Pharmacy students who are Introverts score an average of 9.5 points higher than students

who are Extroverts. Additionally, students who are Feelers score an average of 6.0 points higher than students who are Thinkers.

Kahn et al. (2002) look at 677 college freshmen to see how personalities affect first year of college performance. This study shows that students with Thinking personality traits have higher GPAs, on average, than students with Feeling personality traits. Additionally, this study looks at personality types of students who go on to their sophomore year of college. The conclusion on this portion is that students who are Extroverts and Sensing are more likely to attend college for their sophomore year than students that are Introverts and Intuition.

Burkins (2002) examines minority attrition at the Naval Academy based on personality types. This study shows that midshipmen with ENFP and INFP personality types are more likely to attrite from the Naval Academy than those with the other personality types. He attributes this to the belief that ENFP individuals are said to not like structure or routine, and INFP individuals are said not to handle stress well. This is a notable correlation, given that the Naval Academy is an institution built on structure, discipline, and stress. This analysis and the stressful environment of the Naval Academy make it plausible as to why these personality types graduate at a lower rate.

Burkins (2002) shows that minority midshipmen with ESTJ and INTJ personality types are more likely to be successful than midshipmen with the other 14 MBTI types at the Naval Academy. This is because individuals who are ESTJ prefer to get things done in the most efficient way, and individuals who are INTJ are driven to achieve personal goals. Both of these personality types should be successful at the Naval Academy because their personalities exhibit the traits necessary to successfully meet the expectations required of them.

Pashneh-Tala and Foster (2002) examine the use of personality measures in the admissions process at USNA. Pashneh-Tala and Foster's baseline model with the addition of MBTI is able to better predict overall attrition and voluntary attrition than the models without the MBTI variable. However, this new model is not a better predictor for academic or performance/conduct attrition. Although Pashneh-Tala and Foster's study looks solely

at attrition rates, results can be applicable to our study in analyzing attrition at the Naval Academy.

Layman et al. (2006) examines a new course in software engineering at North Carolina State University that teaches students practical tools and techniques they will face in the working sector. The study examines this new course from the perspective of the MBTI and learning styles of the students. The results of this study show that students who are Introverts tend to outperform Extroverts, Intuits tend to outperform Feelers, Thinkers tend to outperform Feelers, and Judgers tend to outperform Perceivers.

The above studies look at the importance of MBTI results on academic performance as well as attrition. According to the chi-square test for independence performed in our study, MBTI is a statistically significant variable in predicting whether or not midshipmen graduate in the top 10% or bottom 10%. Therefore, having the candidates take the MBTI before submitting an application to USNA is beneficial for predicting academic performance. Additionally, this helps the admissions team to provide more useful information to COs and SELs on the midshipman who are receiving appointments to USNA.

### **III. DATA SET AND METHODOLOGY**

#### **A. DESCRIPTION OF THE DATA**

The data set used for this study was provided by the United States Naval Academy Institutional Research Center. It covers the graduating classes of 2015 to 2019. The data encompasses each midshipman's demographic data, high school performance, personality data, candidate fitness assessment, and rankings given by USNA.

A total of 5,941 midshipmen are enrolled in the classes of 2015 to 2019. Of these 5,941 midshipmen, the male population is 76% (4,524) and the female population is 24% (1,417). The age of the midshipmen on the start of I-Day ranges from 17 to 24 years old. The midshipmen come from all over the United States including Guam, Puerto Rico, and the Virgin Islands. The top 10% of the classes totals 526 midshipmen and the bottom 10% totals 525 midshipmen. Of the 5,941 midshipmen, 649 midshipmen did not graduate, and the reason for attrition and when the attrition occurred are not included in the data for this study.

Missing data is prevalent throughout the data sets. 251 midshipmen do not have a high school class rank; 100 midshipmen do not have a high school class size, and 80 midshipmen do not have a high school standardized rank. Additionally, 137 midshipmen do not have MBTI results with five of those midshipmen in the top 10%, fourteen in the bottom 10%, and 84 of those midshipmen having undergone attrition. Because this data is important to the study and cannot be obtained, we remove these midshipmen from the study.

In the CFA data set, there are 626 midshipmen who elected to do arm hangs for time during the CFA instead of pull-ups. The arm hang column has a tremendous number of NAs, so we combine the column with pull-ups. In order to combine the columns, we make one second to nine seconds worth one pull-up, 10 to 19 seconds worth two pull-ups, 20 to 29 seconds worth three pull-ups, 30 to 39 seconds worth four pull-ups, 40 to 49 seconds worth 5 pullups, 50 to 59 seconds worth 6 pull-ups, 60 to 69 seconds worth 7 pull-

ups, 70 to 79 seconds worth 8 pull-ups, 80 to 89 seconds worth 9 pull-ups, and 90 to 99 seconds worth 10 pull-ups.

Next, we remove all outliers that appear to be errant data. There is a total of 50 outliers within the data set. The outliers are in the columns HS.Class.Rank, HS.Class.Size, Basketball.Throw, Crunches, Mile.Time, Pullup, Pushup, and Shuttle.Time. An example of one of the outliers is a midshipman who is reported to have thrown a basketball 9,999 feet. Due to this score not being physically possible, we remove outliers such as this from the data set in order to have a more realistic dataset.

For the final data set, there is a total of 5,452 midshipmen with a male and female breakdown of 4,156 (76%) males and 1,296 females (24%). The top 10% consists of 499 midshipmen, bottom 10% consists of 475 midshipmen, and those that did not graduate consists of 520 midshipmen.

## **B. VARIABLES**

In this study, there is a total of 27 variables with 24 being explanatory variables and three being response variables. The variables are broken down into categories: demographic variables, high school variables, Naval Academy variables, candidate fitness variables, and response variables.

### **1. Demographic Variables**

Table 3 shows the demographic variables each midshipman used during their application process. These variables range from the age on the day they started at the Naval Academy to whether or not their parents attended a military academy.

Table 3. Description of Demographic Variables.

<b>Variable Name</b>	<b>Type</b>	<b>Description</b>	<b>Range</b>
Age	Numerical	Age on I-Day	17 – 24
Gender	Binary	Gender of midshipman	0 = Female 1 = Male
Race	Categorical	Race/Ethnicity of midshipman	1 = White 2 = Black or African American 3 = Hispanic or Latino 4 = Asian

Variable Name	Type	Description	Range
			5 = American Indian/Alaska Native 6 = Native Hawaiian/Pacific Islander 7 = Two or more races 8 = Declined to respond
Feeder	Categorical	Avenue into the Academy	1 = Direct 2 = NAPS 3 = Foundation/Nuclear Power
Prior.Enlisted	Categorical	Branch of prior military service	0 = Not prior enlisted 1 = Navy 2 = Marine Corps
Parent.Military	Binary	Whether or not either parent served in the military	0 = No Military 1 = Yes Military
Parent.Academy.Graduate	Binary	Whether or not a parent attended a military academy	0 = No Academy Graduate 1 = Yes Academy Graduate
Education.Level	Categorical	Highest level of education	1 = High School 2 = NAPS 3 = Other (Foundation Prep School, College, Other Prep School)
Federal.Court.Regions	Categorical	Breakdown of home states	1 = ME, MA, NH, RI, PR 2 = VT, NY, CT, VI 3 = NJ, DE, PA 4 = WV, VA, MD, DC, NC, SC 5 = TX, LA, MS 6 = TN, KY, OH, MI 7 = WI, IL, IN 8 = ND, SD, MN, NE, IA, MO, AR 9 = AZ, ID, MT, NV, AK, CA, HI, OR, WA, GU 10 = UT, WY, CO, NM, KS, OK 11 = AL, GA, FL

## 2. High School Variables

Table 4 shows the high school variables that each midshipman provided to the Naval Academy admissions team within his or her application. These variables convey how students performed on their ACT/SAT, as well as how he or she did in high school.

Table 4. Description of High School Variables

Variable Name	Type	Description	Range
SAT.Math	Numerical	Highest score on the math portion	400-800
SAT.Verbal	Numerical	Highest score on the verbal portion	400-800
HS.Class.Rank	Numerical	High School class ranking	1-455
HS.Class.Size	Numerical	High School class size	1-2011

### 3. Naval Academy Variables

Table 5 shows the variables that the Naval Academy admissions team gave each midshipman based on his or her high school performance and participation in ECAs as well as the MBTI variable.

Table 5. Description of USNA Variables

Variable Name	Type	Description	Range
HS.Standardized.Rank	Numerical	Score assigned by USNA based on class size, class rank, GPA, teacher recommendations	137-720
Whole.Person.Multiple	Numerical	Score assigned by USNA based on entire application	48481 – 85430
HS.Athletic.ECA	Numerical	Score assigned by USNA for participation in high school sports	316-1516
HS.NonAthletic.ECA	Numerical	Score assigned by USNA for participation in high school non-sports related ECAs	348-1709
MBTI	Categorical	Results from MBTI	16 personality types. See Table 2

### 4. Candidate Fitness Assessment Variables

Table 6 shows the CFA variables, which are the raw scores of each midshipman's performances on the CFA, conducted prior to submitting their application.

Table 6. Description of Candidate Fitness Assessment Variables

Variable Name	Type	Description	Range
Basketball.Throw	Numerical	Distance basketball is thrown in feet	12-170
Crunches	Numerical	Total number of crunches in 2 minutes	26-200
Mile.Time	Numerical	Total time in seconds to run a mile	240-759
Pullup	Numerical	Total number of pullups in 2 minutes	0-65
Pushup	Numerical	Total number of pushups in 2 minutes	4-154
Shuttle.Time	Numerical	Total time in seconds to complete shuttle	3.9-15.8

## 5. Response Variables

Table 7 shows the response variables that this study used for the analysis. Both the top 10% and bottom 10% variables were created from the OOM from the midshipmen's senior year. The OOM is their graduation rank. The attrition variable was generated by whether or not the midshipman graduated, so no extra work went into this variable besides renaming it.

Table 7. Description of Response Variables

Variable Name	Type	Description	Value
Top.10	Binary	Did the midshipman graduate in the top 10%	0 = Not in top 10% 1 = In top 10%
Bottom.10	Binary	Did the midshipman graduate in the bottom 10%	0 = Not in bottom 10% 1 = In bottom 10%
Attrite	Binary	Did the midshipman graduate	0 = Did graduate 1 = Did not graduate

## C. METHODOLOGY

The models utilized for this data are logistic regression, classification trees, and random forests. Each of the three models uses a response variable that is binary, and the

response variables are membership in the top 10%, the bottom 10%, and undergoing attrition. The programming language used in this study for analyzing the logistic regression, classification trees, and random forest models is R. R is a computer language and environment that is used for statistical computing and for creating graphics (R 2021).

Before we fit any of the models in this study, we split the data into a training set and a test set. The training set is used to fit the model, and the test set is used to evaluate the model performance. The training set contains the classes of 2015 through 2018, while the test set contains the class of 2019. Lastly, we compare the different model outputs from the logistic regression, classification tree, and random forests to see which model has the best ability to predict our top 10%, bottom 10%, and attrition responses.

Logistic regression models are classification models that have “yes” or “no” response variables (James et al. 2013). The response variable is viewed as the probability of being “yes” conditioned on the associated predictor values. In this study specifically, we are interested in predicting whether a midshipman graduates in the top 10%, bottom 10%, or attrites on the basis of demographics, high school accomplishments, Naval Academy admission scores, and CFA results. With logistic regression, we use stepwise regression in order to find the best subset selection of explanatory variables. When using stepwise regression, we begin with a model containing all the explanatory variables of interest. The explanatory variables are added and removed as the Akaike information criterion (AIC) improves. The lower the AIC the better the predictors are for the model. Through stepwise regression, the variables that are left are the most significant variables and have the lowest AIC (James et al. 2013).

A classification tree is “used to predict a qualitative response rather than a quantitative one” (James et al. 2013). The classification tree models are easy to understand and interpret. The tree shows us visually how it decides whether or not a midshipman graduates in top 10%, bottom 10%, or attrites. Therefore, tree models offer explainability through the splits made on each branch. Additionally, tree model interactions are included automatically, and no variable transformation is necessary (James et al. 2013).

Random forest models are an extended application of classification trees. A random forest consists of a multitude of trees, where each tree is trained on a bootstrap sample from the original data, and every node split in each tree is based on a randomly drawn subset of available explanatory variables (James et al. 2013). Thus, we fit the classification tree before fitting the random forest model because this enables us to see if extending to a random forest improves our performance on predicting outcome at USNA (James et al. 2013).

Since the response “1” corresponds to “in the bottom 10%” and a response of “0” corresponds to “not in the bottom 10%,” To compare the three different models, we look at the confusion matrix outputs, receiver operating characteristic (ROC) curve, area under the curve (AUC), and variables of importance. The confusion matrix is a tool to help determine the performance of the classifier. From the confusion matrix outputs, the key metrics assessed are accuracy, specificity, sensitivity, positive predictive value (PPV), and negative predictive value (NPV) (James et al. 2013). In our study, the “positive” response corresponds to midshipmen not being in the top 10%, not being in the bottom 10%, and not undergoing attrition. The “negative” response corresponds to midshipmen being in the top 10%, being in the bottom 10%, and undergoing attrition. Accuracy tells us how many times we accurately predict where midshipmen graduate. Accuracy is defined as

$$\frac{\textit{True Positive} + \textit{True Negative}}{\textit{True Positive} + \textit{True Negative} + \textit{False Positive} + \textit{False Negative}} \quad (1)$$

Specificity tells us how many times our model accurately predicts that midshipmen graduate in the top 10%, bottom 10%, or attrite. Specificity is defined as

$$\frac{\textit{True Negative}}{\textit{True Negative} + \textit{False Positive}} \quad (2)$$

Sensitivity tells us how many times our model accurately predicts that midshipmen do not graduate in the top 10%, bottom 10% or attrite. Sensitivity is defined as

$$\frac{\textit{True Positive}}{\textit{True Positive} + \textit{False Negative}} \quad (3)$$

PPV tells us the probability of midshipmen not graduating in the top 10% or bottom 10% if the model predicts they are not going to graduate in the top 10% or bottom 10%. PPV is defined as

$$\frac{\textit{True Positive}}{\textit{True Positive}+\textit{False Positive}}. \quad (4)$$

NPV tells us the probability of midshipmen graduating in the top 10% or bottom 10% if the model predicts they are going to graduate in the top 10% or bottom 10%. NPV is defined as

$$\frac{\textit{True Negative}}{\textit{True Negative}+\textit{False Negative}}. \quad (5)$$

Lastly, we evaluate the ROC curve and AUC. The ROC curve and AUC show us the overall performance of the classifier summarized over all possible thresholds (James et al. 2013). If an AUC is equal to 0.5, the classifier performs no better than a coin flip. If the model has an AUC of 1, it can perfectly predict whether midshipmen graduate in the top 10%, bottom 10% or attrite. According to James et al. (2013), an AUC of 0.8 means the AUC is good for prediction.

## IV. DATA ANALYSIS

This chapter covers the exploratory analysis of the variables and the results of each model developed. Additionally, this chapter presents the Naval Academy admissions team with the variables that are important for predicting if midshipmen will graduate in the top 10%, bottom 10%, or attrite, based on admissions data. We start with the exploratory analysis of the variables.

### A. EXPLORATORY DATA ANALYSIS (EDA)

This section is broken down into four sections. The first section covers the chi-squared test for independence for the response variables Top.10, Bottom.10, and Attrite. The variables in each table are the categorical variables that are statistically significant to the response variable. The second section compares USNA MBTI results with the U.S. MBTI population results. The third section covers the two-sample  $t$ -test for all three response variables. The variables presented in each table are the continuous variables that are statistically significant to the response variable. Lastly, the fourth section covers the Whole Person Multiple as a single predictor for top 10%, bottom 10%, and attrite.

#### 1. Chi-Square Test

According to Devore (2016), the chi-squared test for independence helps evaluate whether when categorical variables are independent or dependent of each other. When categorical variables are associated with one another, there is a relationship between the variables. A relationship between the variables means that knowing the value of one of the variables assists in predicting the value of the other variable. The null hypothesis for the chi-squared test for independence states the two variables are independent, and the alternative hypothesis states the two variables are dependent.

The variables in Table 8 are statistically significant in predicting whether or not a midshipman graduates in the top 10%. Because all the variables have a  $p$ -value less than 0.05, we can reject the null hypothesis. By rejecting the null hypothesis, we are accepting the alternative hypothesis, which states that the variables are associated with each other.

Table 8. Top 10% Chi-Square Results

Variable	X-squared	df	p-value
Race	6634.2	7	< 2.2e-16
Feeder	133.4	2	< 2.2e-16
Prior.Enlisted	8.9	2	0.015
Parent.Academy.Graduate	6.2	1	0.013
Education.Level	119.6	2	< 2.2e-16
Federal.Court.Regions	21.9	10	0.016
MBTI	111.0	15	< 2.2e-16

The variables in Table 9 are statistically significant in predicting whether or not a midshipman graduates in the bottom 10%. Because all the variables have a *p*-value less than 0.05, the variables are associated with each other.

Table 9. Bottom 10% Chi-Square Results

Variable	X-squared	df	p-value
Gender	4.8	1	0.029
Race	353.9	7	< 2.2e-16
Feeder	481.0	2	< 2.2e-16
Education.Level	453.7	2	< 2.2e-16
Federal.Court.Regions	19.3	10	0.036
MBTI	77.0	15	2.4e-10

The variables in Table 10 are statistically significant in predicting whether or not a midshipman undergoes attrition. Because all the variables have a *p*-value less than 0.05, the variables are associated with each other.

Table 10. Attrition Chi-Square Results

Variable	X-squared	df	p-value
Race	22.2	7	0.003
Feeder	12.5	2	0.002
Education.Level	14.8	2	0.001
Parent.Academy.Graduate	5.5	1	0.019

## 2. Myers-Briggs Type Indicator

In this section, we compare the relative frequency of each MBTI type in the United States population with the USNA classes of 2015 to 2019. Table 11 and Figure 2 show the breakdown of the U.S. population and the midshipmen of the Naval Academy. According to the chi-square test for independence, the distribution of MBTI results for midshipmen is very different from the relative frequency of each MBTI type in the United States population. This is evident because the  $p$ -value for the chi-square test is nearly zero.

Table 11. U.S. Population and USNA MBTI Frequency

<u>Population</u>	<u>MBTI</u>	<u>USNA</u>
11.6%	ISTJ	19.1%
13.8%	ISFJ	4.0%
1.5%	INFJ	1.5%
2.1%	INTJ	4.2%
5.4%	ISTP	7.3%
8.8%	ISFP	2.5%
4.4%	INFP	2.9%
3.3%	INTP	4.5%
4.3%	ESTP	9.9%
8.5%	ESFP	4.0%
8.1%	ENFP	6.1%
3.2%	ENTP	5.6%
8.7%	ESTJ	16.7%
12.3%	ESFJ	4.4%
2.5%	ENFJ	2.6%
1.8%	ENTJ	4.8%

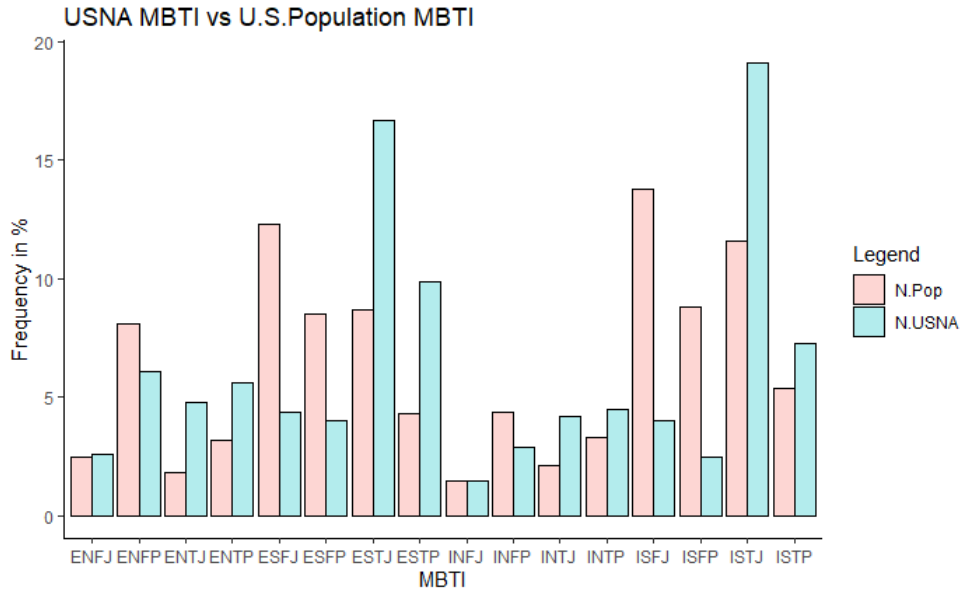


Figure 1. U.S. Population and USNA MBTI Results

### 3. Two Sample *t*-test

According to Devore (2016), the two sample *t*-test’s null hypothesis states that the mean of the two variables is equal. The alternative hypothesis states that the mean of the two variables is not equal. If the *p*-value is less than 0.05, the null hypothesis is rejected.

Table 12 shows the results of the continuous variables with the top 10% response variable. In this section, the response of “1” corresponds to “in the top 10%,” and a response of “0” corresponds to “not in the top 10%.” Because the *p*-value is less than  $2.2e-16$  for math SAT score, we can confidently reject the null hypothesis and conclude there is a significant difference in the mean math SAT score of midshipmen who graduate in the top 10% and mean math SAT score of midshipmen who do not. The midshipmen who graduate in the top 10% have a higher mean math SAT score than the midshipmen who do not, and this is evident from the positive *t*-statistic. Figure 2 shows the boxplot of math SAT score versus outcome. Because the *p*-value is less than  $2.2e-16$  for high school class rank, we can confidently reject the null hypothesis and conclude there is a significant difference in the mean high school class rank of midshipmen who graduate in the top 10% and the mean high school class rank of midshipmen who do not. The midshipmen who

graduate in the top 10% have a mean class rank that is lower than the midshipmen who do not, and this is evident from the negative t-statistic. Figure 3 shows a boxplot of high school class rank versus outcome.

Table 12. Top 10% 2-Sample t-test Results

<b><u>Variable</u></b>	<b><u>t</u></b>	<b><u>df</u></b>	<b><u>p-value</u></b>
Age	-9.3	685.5	< 2.2e-16
SAT.Math	29.9	687.3	< 2.2e-16
SAT.Verbal	24.3	711.3	< 2.2e-16
HS.Class.Rank	-19.0	911.4	< 2.2e-16
HS.Standardized.Rank	26.5	818.2	< 2.2e-16
Whole.Person.Multiple	34.4	805.9	< 2.2e-16
HS.NonAthletic.ECA	5.0	617.5	8.1e-07
Basketball.Throw	-2.9	622.1	0.004
Crunches	4.8	625.0	1.7e-06
Pushup	2.7	612.5	0.007
Mile.Time	-6.4	622.2	3.6e-10

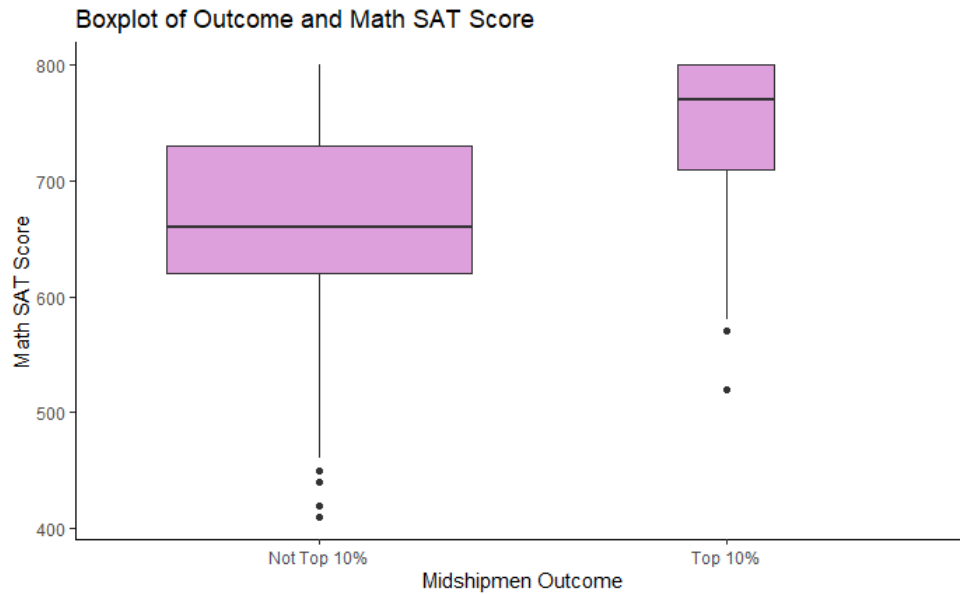


Figure 2. Top 10% versus Math SAT Score

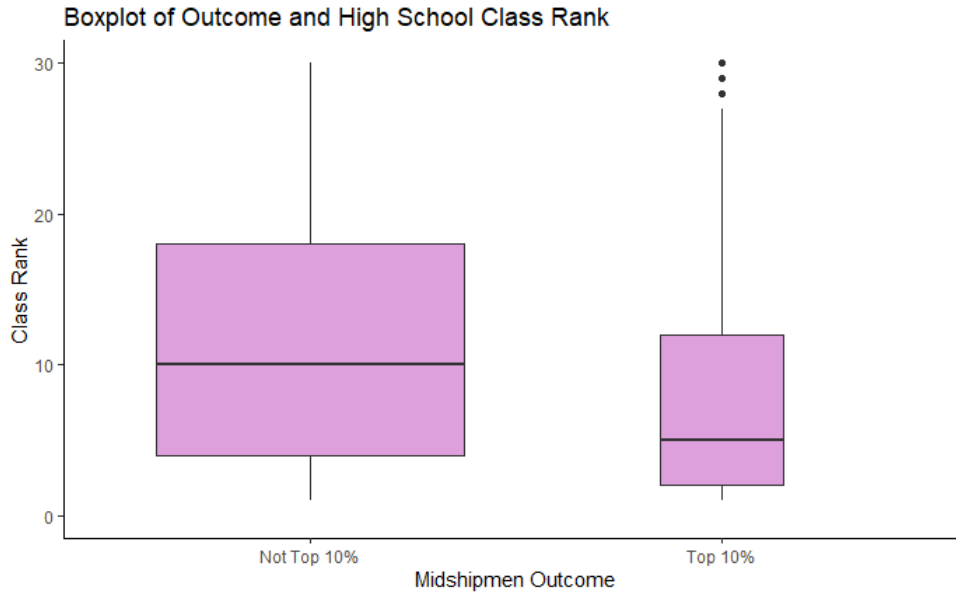


Figure 3. Top 10% versus High School Class Rank

Table 13 shows the results of the continuous variables with the bottom 10% response variable. In this section, the response of “1” corresponds to “not in the bottom 10%,” and a response of “0” corresponds to “in the bottom 10%.” Because the  $p$ -value is less than  $2.2e-16$  for whole person multiple, we can confidently reject the null hypothesis and conclude there is a significant difference in the mean whole person multiple of midshipmen who graduate in the bottom 10% and the mean whole person multiple of midshipmen who do not. The midshipmen who do not graduate in the bottom 10% have on average, higher mean whole person multiple than the midshipmen who do graduate in the bottom 10%, and this is evident from the  $t$ -statistic being positive. Figure 4 shows a boxplot of whole person multiple versus outcome. We can also confidently reject the null hypothesis and conclude there is a significant difference in the mean basketball throw in feet of midshipmen who graduate in the bottom 10% and the mean basketball throw in feet of midshipmen who do not. The midshipmen who do not graduate in the bottom 10% have a shorter mean basketball throw than the midshipmen who do graduate in the bottom 10%, and this is apparent from the negative  $t$ -statistic. Figure 5 shows the corresponding boxplot. It is important to remember the farther a midshipman throws the basketball the more likely

he or she is to graduate in the bottom 10%. Therefore, throwing the ball farther is associated with less favorable outcome.

Table 13. Bottom 10% 2-Sample t-test Results

<b><u>Variable</u></b>	<b><u>t</u></b>	<b><u>df</u></b>	<b><u>p-value</u></b>
Age	-9.8	554.0	< 2.2e-16
SAT.Math	24.6	593.3	< 2.2e-16
SAT.Verbal	21.7	572.0	< 2.2e-16
HS.Class.Rank	-10.7	516.0	< 2.2e-16
HS.Standardized.Rank	18.0	572.5	< 2.2e-16
Whole.Person.Multiple	27.0	587.3	< 2.2e-16
HS.NonAthletic.ECA	7.2	579.3	1.9e-12
Basketball.Throw	-4.1	541.0	5.0e-05
Crunches	3.5	545.3	0.001
Pushup	2.8	560.0	0.005
Mile.Time	-6.3	559.6	5.4e-10
Shuttle.Time	3.5	523.6	0.001

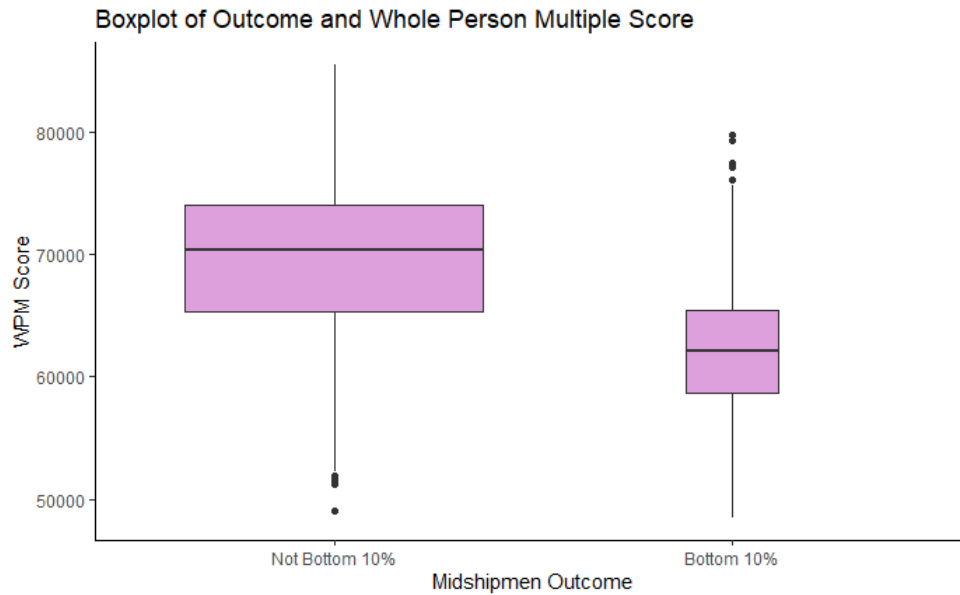


Figure 4. Bottom 10% versus Whole Person Multiple

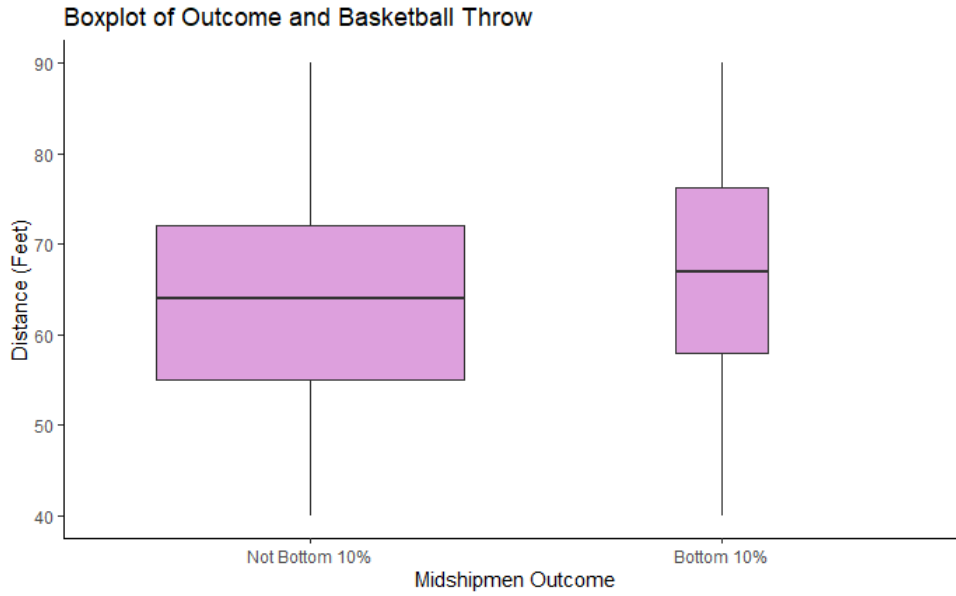


Figure 5. Bottom 10% versus Basketball Throw

Lastly, Table 14 shows the results of the continuous variables with the attrition response variable. In this section, the response of “1” corresponds to “attrition,” and a response of “0” corresponds to “graduation.” We conclude there is a significant difference in the mean verbal SAT score of midshipmen who attrite and the mean verbal SAT score of midshipmen who graduate. The midshipmen who graduate have a slightly higher mean verbal SAT score than the midshipmen who attrite, and this is evident from the t-statistic being positive. Figure 6 shows a boxplot of verbal SAT scores versus outcome. We also conclude there is a significant difference in the mean mile time in seconds of midshipmen who attrite and mean mile time in seconds of midshipmen who graduate. The midshipmen who graduate have a faster mean mile time than the midshipmen who attrite, and this is apparent from the t-statistic being negative. Figure 7 shows a boxplot of mile time in seconds versus outcome. It is important to remember the faster a midshipman runs the mile the less likely he or she is to undergo attrition. Running fast is therefore a positive predictor.

Table 14. Attrition 2-Sample t-test Results

<b>Variable</b>	<b>t</b>	<b>df</b>	<b>p-value</b>
Age	-2.0	611.7	0.04
SAT.Math	4.6	627.4	5.8e-06
SAT.Verbal	3.4	630.6	0.001
HS.Class.Rank	-2.5	601.4	0.014
HS.Class.Size	2.3	624.6	0.023
HS.Standardized.Rank	4.8	621.3	2.0e-06
Whole.Person.Multiple	7.7	624.8	6.3e-14
HS.Athletic.ECA	4.4	645.2	1.2e-05
HS.NonAthletic.ECA	3.9	672.3	9.9e-05
Crunches	2.3	628.0	0.020
Pushup	2.8	560.0	0.005
Mile.Time	-4.6	630.5	4.4e-06

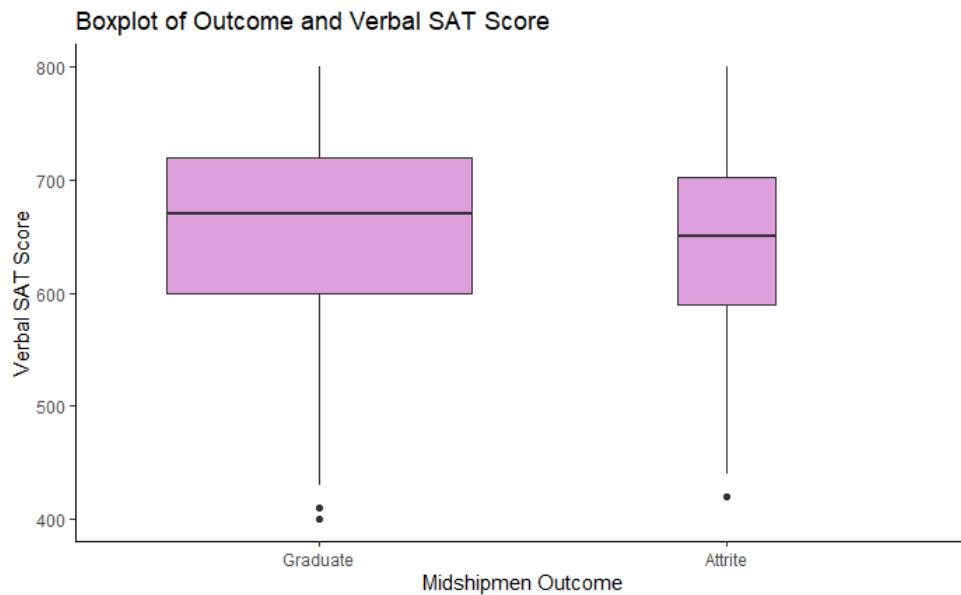


Figure 6. Attrition versus Verbal SAT Score

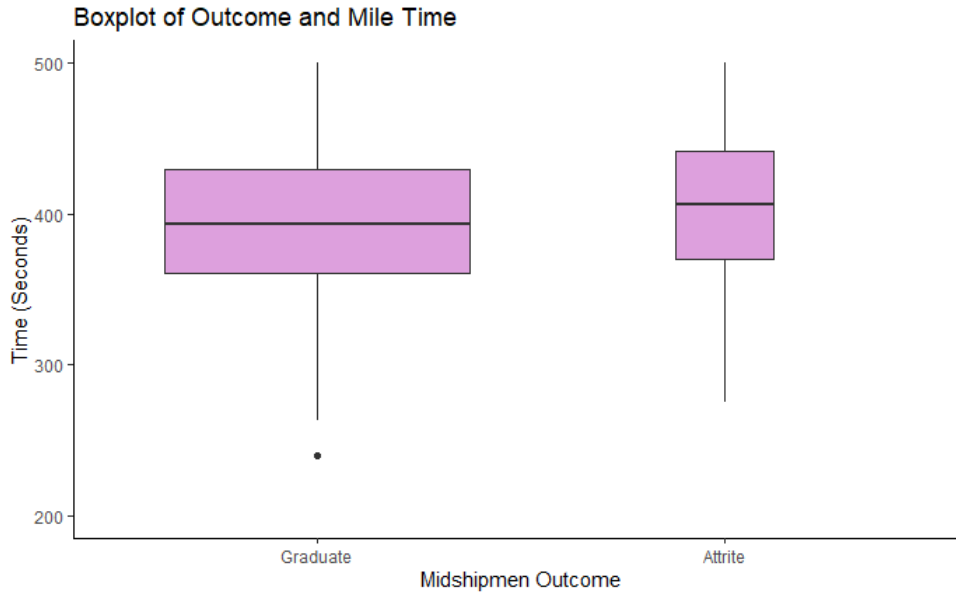


Figure 7. Attrition versus Mile Time

#### 4. Whole Person Multiple

The whole person multiple is a score given by the admissions team in order to compare and screen candidates seeking appointments to USNA. The score is a combination of qualitative and quantitative inputs; it helps the admissions team determine if candidates are qualified and competitive to receive an appointment to the Naval Academy (Phillips 2004). The whole person multiple is a statistically significant predictor for each of the three response variables.

Because the whole person multiple is such a strong predictor, we decided to run three logistic regression models to see how the variable performs by itself. Table 15 shows the results of all three logistic regression models' confusion matrices and AUCs. This multiple performs well in its ability to predict the top 10% and the bottom 10% but does not perform well in predicting attrition. In the next sections, we add more explanatory variables onto this initial model in order to improve the quality of our models.

Table 15. Whole Person Multiple Outputs

<b>Model</b>	<b>Accuracy</b>	<b>Sensitivity</b>	<b>Specificity</b>	<b>PPV</b>	<b>NPV</b>	<b>AUC</b>
<b>Top 10%</b>	0.90	0.99	0.06	0.91	0.46	0.80
<b>Bottom 10%</b>	0.91	0.99	0.04	0.91	0.47	0.81
<b>Attrition</b>	0.91	1.00	0.00	0.91	0.00	0.55

## **B. MODEL COMPARISON FOR TOP 10%**

The variables for the top 10% models are Top.10, Age, Gender, Race, Feeder, Prior.Enlisted, Parent.Military, Parent.Academy.Graduate, SAT.Math, SAT.Verbal, Education.Level, HS.Athletic.ECA, HS.NonAthletic.ECA, HS.Class.Rank, HS.Class.Size, Basketball.Throw, Crunches, Mile.Time, Pullup, Pushup, Shuttle.Time, Federal.Court.Regions, HS.Standardized.Rank, Whole.Person.Multiple, and MBTI.

### **1. Logistic Regression**

Table 16 shows the variables for the logistic regression model that predict the probability that midshipmen graduate in the top 10%. Through stepwise regression, the model for the top 10% reduces the overall model from 24 explanatory variables down to ten. An increase in math SAT scores, high school class size, and whole person multiple is associated with an increase in graduating in the top 10%, and the  $p$ -values indicate each variable is statistically significant. An increase in math SAT scores is associated with an increase in the log odds of top 10% by 0.00775 units. Midshipmen who score high on the SAT math portion and graduate from a large high school have a higher potential to graduate in the top 10%. We note that in many cases like class size and class rank the predictors are correlated. An increase in high school class rank, member of athletic and nonathletic ECAs, basketball throw, and mile time is associated with a decrease in graduating in the top 10%, and the  $p$ -values indicate the variables are statistically significant. An increase in mile time is associated with a decrease in the log odds of being in the top 10% by 0.00419 units.

Table 16. Top 10% Logistic Regression Output

Coefficients	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	-1.98e+01	1.70e+00	-11.63	< 2e-16 ***
Race2	-1.14e+00	1.02e+00	-1.12	0.2613
Race3	-2.37e-01	2.48e-01	-0.95	0.3405
Race4	-1.09e+00	3.22e-01	-3.39	0.0007 ***
Race5	-1.15e+01	2.99e+02	-0.04	0.9693
Race6	1.05e-01	1.15e+00	0.09	0.9271
Race7	-1.53e-01	2.37e-01	-0.65	0.5192
Race8	3.13e-01	4.67e-01	0.67	0.5024
SAT.Math	7.75e-03	1.25e-03	6.22	5.05e-10 ***
HS.Athletic.ECA	-2.01e-03	4.16e-04	-4.82	1.46e-06 ***
HS.NonAthletic.ECA	-1.21e-03	3.65e-04	-3.32	0.0009 ***
HS.Class.Rank	-9.87e-03	3.13e-03	-3.16	0.0016 **
HS.Class.Size	6.54e-04	2.94e-04	2.23	0.0260 *
Whole.Person.Multiple	2.29e-04	2.58e-05	8.88	< 2e-16 ***
MBTIENFP	-9.76e-01	5.24e-01	-1.86	0.0627 .
MBTIENTJ	1.31e-01	4.25e-01	0.31	0.7577
MBTIENTP	-9.24e-01	4.81e-01	-1.92	0.0541 .
MBTIESFJ	-6.22e-01	4.95e-01	-1.26	0.2087
MBTIESFP	-9.37e-01	5.75e-01	-1.63	0.1033
MBTIESTJ	-4.02e-01	3.89e-01	-1.03	0.3018
MBTIESTP	-7.20e-01	4.34e-01	-1.66	0.0972 .
MBTIINFJ	-4.96e-01	6.43e-01	-0.77	0.4401
MBTIINFP	-8.50e-01	6.05e-01	-1.41	0.1598
MBTIINTJ	6.77e-02	4.27e-01	0.16	0.8740
MBTIINTP	-6.80e-01	4.73e-01	-1.44	0.1504
MBTIISFJ	-3.97e-01	4.74e-01	-0.84	0.4031
MBTIISFP	-3.68e-01	5.74e-01	-0.64	0.5216
MBTIISTJ	-2.27e-02	3.82e-01	-0.06	0.9527
MBTIISTP	-5.75e-01	4.37e-01	-1.32	0.1886
Basketball.Throw	-8.66e-03	4.15e-03	-2.09	0.0368 *
Mile.Time	-4.19e-03	1.27e-03	-3.31	0.0009 ***

After creating the logistic regression model, we utilize the test set at a 50% cutoff to evaluate the logistic regression performance. Table 17 summarizes the results of the confusion matrix. This model predicts that 21 of the midshipmen in the test set will graduate in the top 10%. Of these midshipmen, 15 actually did graduate in the top 10% and 6 did not. Therefore, the NPV is 71% for this model. Additionally, this model predicts that

1,013 of the test set midshipmen did not graduate in the top 10%. Of these midshipmen, 87 graduate in the top 10% and 930 did not graduate in the top 10%. Thus, the PPV is 91% for this model. When focusing on the group we predict to be in the top 10%, we accurately predict 71% of the midshipmen who actually graduate in the top 10%, and in the group we predict not to be in the top 10%, only 9% are actually in the top 10%.

Table 17. Top 10% Logistic Regression Confusion Matrix at 50% Cutoff

<b>Prediction / Actual</b>	<b>No Top 10%</b>	<b>Yes Top 10%</b>
<b>No Top 10%</b>	930	87
<b>Yes Top 10%</b>	6	15

The important metrics derived from the logistic regression’s confusion matrix at the 50% cutoff are as follows:

- Accuracy: 0.91
- Sensitivity: 0.99
- Specificity: 0.15
- PPV: 0.91
- NPV: 0.71

For the above important metrics, an accuracy of 0.91 means we correctly predict whether or not a midshipman graduates in the top 10% at rate of 91%. A sensitivity of 0.99 means 99% of the time we correctly predict a midshipman does not graduate in the top 10%. A specificity of 0.15 means 15% of the time we correctly predict a midshipman to graduate in the top 10%. The PPV shows that if our model predicts a midshipman to not graduate in the top 10%, there is a 91% chance he or she does not graduate in the top 10%. The NPV shows that if our model predicts a midshipman to graduate in the top 10%, there is a 71% chance he or she does graduate in the top 10%.

After creating the logistic regression model, we also utilize the test set at a 29.8% cutoff to evaluate the logistic regression performance. We chose this cutoff because it separates the same number of midshipmen observed in the top 10% of the training set. Table 18 summarizes the results of this confusion matrix. When focusing on the group we predict to be in the top 10%, we accurately predict 41% of the midshipmen who actually graduate in the top 10%, and in the group we predict not to be in the top 10%, only 6% are actually in the top 10%.

Table 18. Top 10% Logistic Regression Confusion Matrix

<b>Prediction / Actual</b>	<b>No Top 10%</b>	<b>Yes Top 10%</b>
<b>No Top 10%</b>	883	64
<b>Yes Top 10%</b>	53	38

The important metrics derived from the logistic regression’s confusion matrix at the 29.8% cutoff are as follows:

- Accuracy: 0.88
- Sensitivity: 0.93
- Specificity: 0.42
- PPV: 0.94
- NPV: 0.41

## 2. Classification Tree

The optimal pruned tree for the top 10% is shown in Figure 8. This graph is a depiction of how the classification tree model predicts whether or not a midshipman graduate in the top 10%. Each node in Figure 8 shows the predicted class (not top 10% or top 10%), the predicted probability of graduating in the top 10%, and percentage of observations within the node. The four most important variables for the classification tree are Whole.Person.Multiple, SAT.Math, HS.Standarized.Rank, and MBTI. The

classification tree shows that only 3% of the midshipmen are predicted to graduate in the top 10% following the prunes of the tree.

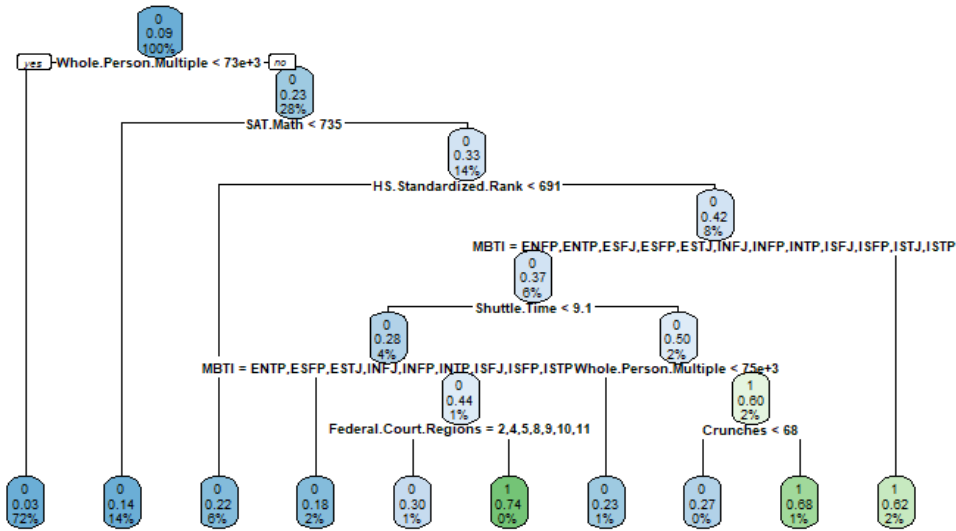


Figure 8. Top 10% Classification Tree Splits

Table 19 summarizes the results of the classification tree. The classification tree model predicts that 46 of the midshipmen in the test set graduate in the top 10%. Of these midshipmen, 25 actually did graduate in the top 10% and 21 did not. Therefore, the NPV is 54% for this model. Additionally, only 21 of the 936 midshipmen who did not graduate in the top 10% are incorrectly labeled. But, of the 102 midshipmen who graduate in the top 10%, 77 are missed by this model. While the overall error rate is low, the error rate among midshipmen who graduate in the top 10% is very high.

Table 19. Top 10% Classification Tree Confusion Matrix

Prediction / Actual	No Top 10%	Yes Top 10%
No Top 10%	915	77
Yes Top 10%	21	25

The important metrics derived from the classification tree’s confusion matrix at the 50% cutoff are as follows:

- Accuracy: 0.91
- Sensitivity: 0.98
- Specificity: 0.25
- PPV: 0.92
- NPV: 0.54

### 3. Random Forests

As Table 20 shows, the random forest model predicts that 17 of the midshipmen in the test set graduate in the top 10%. Of these midshipmen, 10 actually did graduate in the top 10% and 7 did not graduate in the top 10%. Hence, the NPV is 59% for this model. Furthermore, only 7 of the 936 midshipmen who did not graduate in the top 10% are incorrectly labeled. When focusing on the group we predict to be in the top 10%, we accurately predict 59% of the midshipmen who actually graduate in the top 10%, and in the group we predict not to be in the top 10%, only 9% are actually in the top 10%.

Table 20. Top 10% Random Forests Confusion Matrix

<b>Prediction / Actual</b>	<b>No Top 10%</b>	<b>Yes Top 10%</b>
<b>No Top 10%</b>	929	92
<b>Yes Top 10%</b>	7	10

The important metrics derived from the random forests' confusion matrix at the 50% cutoff are as follows:

- Accuracy: 0.91
- Sensitivity: 0.99
- Specificity: 0.10
- PPV: 0.91

- NPV: 0.59

#### 4. Comparing Models

Table 21 shows the results of the AUC for all three models. A model with an AUC of one perfectly predicts whether or not a midshipman graduate in the top 10%. According to Hosmer and Lemeshow (2000), an AUC of 0.5 suggests no discrimination, 0.7 to 0.8 is considered acceptable, 0.8 to 0.9 is considered excellent, and more than 0.9 is considered outstanding. Therefore, our classification tree is considered acceptable, and our logistic regression and random forests are considered excellent.

Table 21. Top 10% AUC Results

<b>Model</b>	<b>AUC</b>
<b>Logistic Regression</b>	0.85
<b>Classification Tree</b>	0.78
<b>Random Forest</b>	0.86

Table 22 shows the important metrics derived from the confusion matrices for all three models. With the focus on predicting midshipmen who graduate in the top 10%, our goal is to use the model that best predicts the midshipmen who do graduate in the top 10%. With that being said, the model with the highest NPV is the model of our choice. Because the NPV for the logistic regression is the highest, this model is considered better in predicting the top 10%.

Table 22. Top 10% Confusion Matrix Outputs

<b>Model</b>	<b>Accuracy</b>	<b>Sensitivity</b>	<b>Specificity</b>	<b>PPV</b>	<b>NPV</b>
<b>Logistic Regression</b>	0.91	0.99	0.15	0.91	0.71
<b>Classification Tree</b>	0.91	0.98	0.25	0.92	0.54
<b>Random Forests</b>	0.91	0.99	0.10	0.91	0.59

Figure 9 shows the ROC curve and the AUC for all three models. The ROC curve along with the AUC show the overall performance of the classifier summarized over all

possible thresholds (James et al. 2013). In order to have an effective model, the ROC curve needs to be as close as possible to the top left corner of the graph, and the bigger the AUC the better. As Figure 9 shows, both the logistic regression and the random forest models are closer to the top left corner than the classification tree model. Additionally, the logistic regression and random forest models have higher AUCs than the classification tree model.

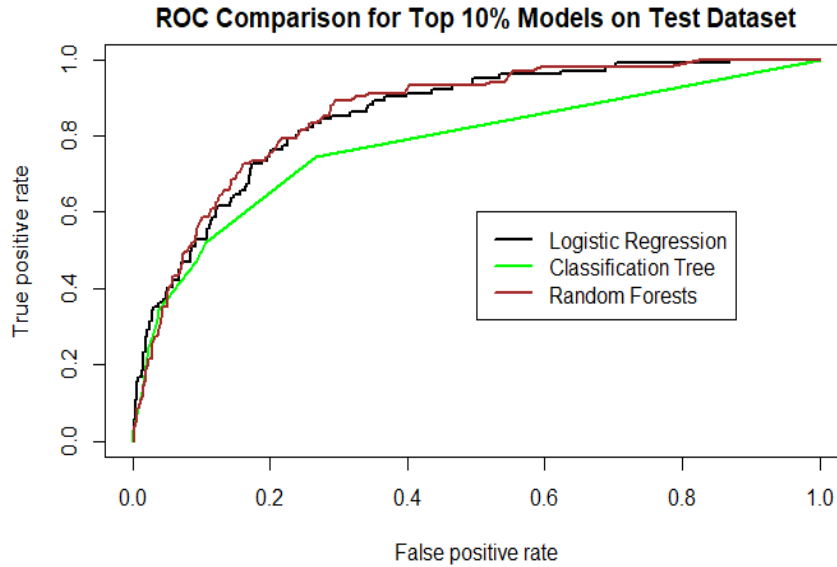


Figure 9. Top 10% ROC Results

### C. MODEL COMPARISON FOR BOTTOM 10%

The variables for the bottom 10% models are Bottom.10, Age, Gender, Race, Feeder, Prior.Enlisted, Parent.Military, Parent.Academy.Graduate, SAT.Math, SAT.Verbal, Education.Level, HS.Athletic.ECA, HS.NonAthletic.ECA, HS.Class.Rank, HS.Class.Size, Basketball.Throw, Crunches, Mile.Time, Pullup, Pushup, Shuttle.Time, Federal.Court.Regions, HS.Standardized.Rank, Whole.Person.Multiple, and MBTI.

#### 1. Logistic Regression

Table 23 shows the coefficient estimates for the logistic regression model that predicts the probability a midshipman graduates in the bottom 10%. The logistic regression model for the bottom 10% reduces the overall model from 24 explanatory variables down

to 11. Since the response “1” corresponds to “in the bottom 10%” and a response of “0” corresponds to “not in the bottom 10%,” positive estimates go with an increase in the log likelihood that a midshipman graduates at the bottom 10%. An increase in age, mile time, high school class rank, and high school athletic ECAs is associated with an increase in graduating in the bottom 10%, and the  $p$ -values indicate each variable is statistically significant. An increase in age is associated with an increase in the log odds of bottom 10% by 0.284 units. So, an older midshipman who does not rank high in his/her high school class and runs slowly on the CFA mile has a higher chance of graduating in the bottom 10%. An increase in math SAT score, verbal SAT score, whole person multiple, and high school class size is associated with a decrease in graduating in the bottom 10%, and the  $p$ -values indicate the variables are statistically significant. So, a midshipman who scores high on the math and verbal portions of the SAT is less likely to graduate in the bottom 10%. Additionally, a midshipman who receives a high whole person multiple and has a large high school class is less likely to graduate in the bottom 10%. In Table 23, going to Race2 from Race1 increases the log odds of graduating at the bottom 10%. This means African American midshipmen are more likely to graduate at the bottom 10% than Caucasian midshipmen. Furthermore, the remaining races/ethnicities are more likely to graduate in the bottom 10% than Caucasian midshipmen. Going to Prior.Enlisted1 from Prior.Enlisted0, decreases the log odds of graduating at the bottom 10%. Thus, prior enlisted Navy personnel are less likely to graduate in the bottom 10%.

Table 23. Bottom 10% Logistic Regression Output

Coefficients	Estimate	Std. Error	z value	Pr(> z )
(Intercept)	1.77e+00	2.14e+00	0.83	0.4073
Age	2.84e-01	8.72e-02	3.26	0.0011 **
Gender1	3.98e-01	1.72e-01	2.32	0.0204 *
Race2	1.06e+00	1.71e-01	6.23	4.58e-10 ***
Race3	5.62e-01	1.73e-01	3.25	0.0012 **
Race4	5.45e-01	2.73e-01	1.99	0.0460 *
Race5	2.21e+00	5.29e-01	4.17	3.06e-05 ***
Race6	8.05e-01	5.82e-01	1.38	0.1670
Race7	4.99e-01	2.16e-01	2.31	0.0209 *
Race8	-5.15e-01	7.92e-01	-0.65	0.5160

<b>Coefficients</b>	<b>Estimate</b>	<b>Std. Error</b>	<b>z value</b>	<b>Pr(&gt; z )</b>
Prior.Enlisted1	-1.45e+00	3.70e-01	-3.93	8.55e-05 ***
Prior.Enlisted2	-9.66e-01	5.96e-01	-1.62	0.1052
SAT.Math	-5.94e-03	1.29e-03	-4.62	3.92e-06 ***
SAT.Verbal	-2.28e-03	1.05e-03	-2.80	0.0294 *
HS.Athletic.ECA	8.01e-04	3.81e-04	2.10	0.0358 *
HS.Class.Rank	2.50e-03	1.18e-03	2.12	0.0342 *
HS.Class.Size	-7.69e-04	3.95e-04	-1.95	0.0515 .
Whole.Person.Multiple	-9.44e-05	1.78e-05	-5.32	1.05e-07 ***
Mile.Time	2.81e-03	1.19e-03	2.35	0.0188 *

After creating the logistic regression model for the bottom 10%, we utilize the test set at a 50% cutoff to evaluate the logistic regression performance. Table 24 summarizes the results of the confusion matrix. This model predicts that 21 of the midshipmen in the test set graduate in the bottom 10%. Of these midshipmen, 14 truly did graduate in the bottom 10% and seven did not. Therefore, the NPV is 67% for this model. Additionally, this model predicts that 1,017 of the midshipmen did not graduate in the bottom 10%. Of these midshipmen, 72 graduate in the bottom 10% and 945 did not graduate in the bottom 10%. Thus, the PPV is 93% for this model. When focusing on the group we predict to be in the bottom 10%, we accurately predict 67% of the midshipmen who actually graduate in the bottom 10%, and in the group, we predict not to be in the bottom 10%, only 7% are actually in the bottom 10%.

Table 24. Bottom 10% Logistic Regression Confusion Matrix

<b>Prediction / Actual</b>	<b>No Bottom 10%</b>	<b>Yes Bottom 10%</b>
<b>No Bottom 10%</b>	945	72
<b>Yes Bottom 10%</b>	7	14

The important metrics derived from the logistic regression's confusion matrix at the 50% cutoff are as follows:

- Accuracy: 0.92
- Sensitivity: 0.99

- Specificity: 0.16
- PPV: 0.93
- NPV: 0.67

For the above important metrics, an accuracy of 0.92 means we correctly predict whether or not a midshipman graduates in the bottom 10% at rate of 92%. A sensitivity of 0.99 means 99% of the time we correctly predict a midshipman does not graduate in the bottom 10%. A specificity of 0.16 means 16% of the time we correctly predict a midshipman to graduate in the bottom 10%. The PPV shows that if our model predicts a midshipman to not graduate in the bottom 10%, there is a 93% chance he or she does not graduate in the bottom 10%. The NPV shows that if our model predicts a midshipman to graduate in the bottom 10%, there is a 67% chance he or she does graduate in the bottom 10%.

After creating the logistic regression model for the bottom 10%, we also utilize the test set at a 27% cutoff to evaluate the logistic regression performance. This cutoff separates the same proportion of the training set that was observed to be in the bottom 10%. Table 25 summarizes the results of this confusion matrix. When focusing on the group we predict to be in the bottom 10%, we accurately predict 46% of the midshipmen who actually graduate in the bottom 10%, and in the group we predict not to be in the bottom 10%, only 5% are actually in the bottom 10%.

Table 25. Bottom 10% Logistic Regression Confusion Matrix

<b>Prediction / Actual</b>	<b>No Bottom 10%</b>	<b>Yes Bottom 10%</b>
<b>No Bottom 10%</b>	910	50
<b>Yes Bottom 10%</b>	42	36

The important metrics derived from the logistic regression’s confusion matrix at the 27% cutoff are as follows:

- Accuracy: 0.91

- Sensitivity: 0.96
- Specificity: 0.42
- PPV: 0.95
- NPV: 0.46

## 2. Classification Tree

The optimal pruned tree for the bottom 10% is shown in Figure 10. This graph shows how the classification tree model predicts whether or not a midshipman graduates in the bottom 10%. Each node shows the predicted class (not bottom 10% or bottom 10%), the predicted probability of graduating in the bottom 10%, and percentage of midshipmen within the node. The six most important variables for the classification tree are Whole.Person.Multiple, SAT.Math, Race, Feeder, HS.Athletic.ECA, and MBTI. The high school athletic ECA node shows that 1% of midshipmen graduate in bottom 10% when they receive a high school athletic score greater than 451. The classification tree shows that only 2% of the midshipmen graduate in the bottom 10% following the prunes of the tree.

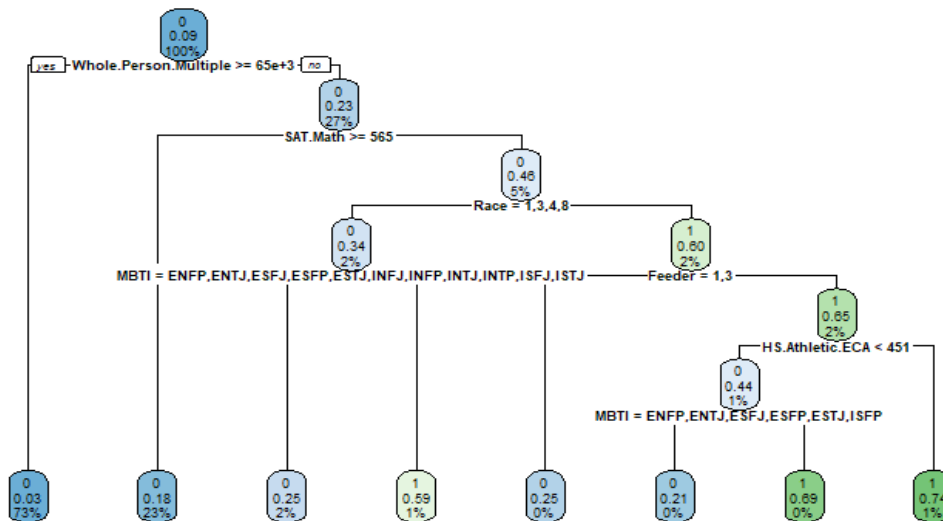


Figure 10. Bottom 10% Classification Tree Splits

Table 26 summarizes the results of the classification tree table. The classification tree model predicts that 27 of the midshipmen in the test set graduate in the bottom 10%. Of these midshipmen, 11 actually did graduate in the bottom 10% and 16 did not. Therefore, the NPV is 54% for this model. Additionally, only 16 of the 952 midshipmen who did not graduate in the bottom 10% are incorrectly labeled. But, of the 86 midshipmen who graduate in the bottom 10%, 75 are missed by this model. While the overall error rate is low, the error rate among midshipmen who graduate in the bottom 10% is high.

Table 26. Bottom 10% Classification Tree Confusion Matrix

<b>Prediction / Actual</b>	<b>No Bottom 10%</b>	<b>Yes Bottom 10%</b>
<b>No Bottom 10%</b>	936	75
<b>Yes Bottom 10%</b>	16	11

The important metrics derived from the classification tree's confusion matrix at the 50% cutoff are as follows:

- Accuracy: 0.91
- Sensitivity: 0.98
- Specificity: 0.13
- PPV: 0.93
- NPV: 0.41

### 3. Random Forests

Table 27 shows that the random forest model predicts that 17 of the midshipmen in the test set graduate in the bottom 10%. Of these midshipmen, nine actually did graduate in the bottom 10% and eight did not. Therefore, the NPV is 53% for this model. So, only 8 of the 952 midshipmen who did not graduate in the bottom 10% are incorrectly labeled. So, the overall error rate is low, but the error rate among midshipmen who graduate in the bottom 10% is high.

Table 27. Bottom 10% Random Forest Confusion Matrix

<b>Prediction / Actual</b>	<b>No Bottom 10%</b>	<b>Yes Bottom 10%</b>
<b>No Bottom 10%</b>	944	77
<b>Yes Bottom 10%</b>	8	9

The important metrics derived from the random forests' confusion matrix at the 50% cutoff are as follows:

- Accuracy: 0.92
- Sensitivity: 0.99
- Specificity: 0.10
- PPV: 0.93
- NPV: 0.53

#### 4. Comparing Models

Table 28 shows the results of the AUC for all three models. Both the random forest and the logistic regression models have AUCs above .8, which means these models are excellent at predicting whether or not a midshipman graduates towards the bottom of the class. Although the classification tree model is not as good as the other models, it is still considered an acceptable model because its AUC is above 0.7.

Table 28. Bottom 10% AUC Results

<b>Model</b>	<b>AUC</b>
<b>Logistic Regression</b>	0.84
<b>Classification Tree</b>	0.74
<b>Random Forests</b>	0.82

Table 29 shows the important metrics derived from the confusion matrices for all three models. With the focus on predicting midshipmen who graduate in the bottom 10%,

our goal is to use the model that best predicts the midshipmen who do graduate in the bottom 10%. With that being said, the model with the highest NPV is the model of our choice. Because the NPV for the logistic regression is higher, this model is considered better in predicting the bottom 10%.

Table 29. Bottom 10% Confusion Matrix Outputs

Model	Accuracy	Sensitivity	Specificity	PPV	NPV
<b>Logistic Regression</b>	0.92	0.99	0.16	0.93	0.67
<b>Classification Tree</b>	0.91	0.98	0.13	0.93	0.41
Model	Accuracy	Sensitivity	Specificity	PPV	NPV
<b>Random Forests</b>	0.92	0.99	0.10	0.93	0.53

According to Figure 11, both the logistic regression model and the random forest model are closer to the top left corner than the classification tree model. Also, the logistic regression model and random forest model have higher AUCs than the classification tree model. Although it is close, the logistic regression model outperforms the random forest model and the classification tree model.

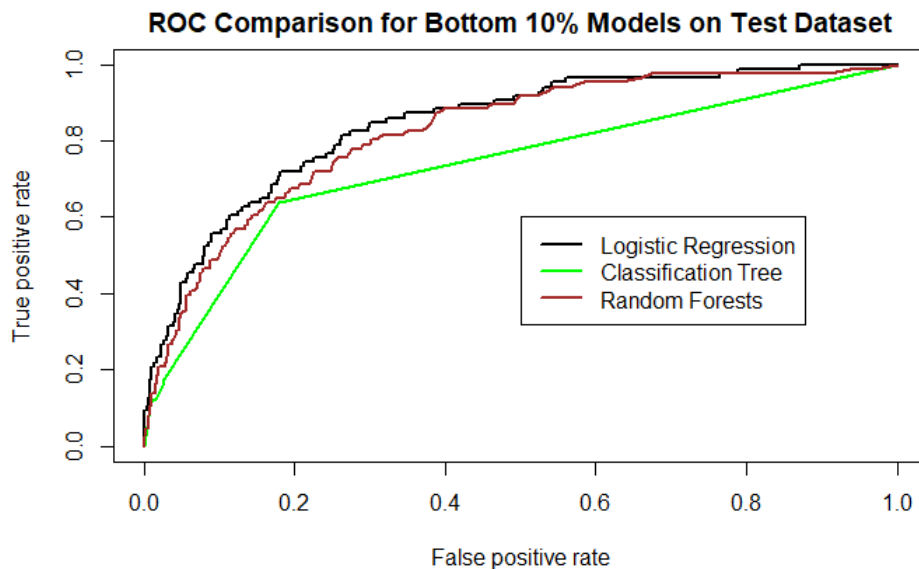


Figure 11. Bottom 10 ROC Results

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## V. CONCLUSIONS AND RECOMMENDATIONS

### A. SUMMARY

The purpose of this thesis was to identify factors and trends that can be used in predicting midshipmen who graduate in the top 10%, bottom 10%, or attrite from the Naval Academy. Identifying these factors and trends upon admissions will help the company officers, senior enlisted leaders, and faculty to identify midshipmen who might need extra military, academic, or physical instruction. Through our analysis, we identified that logistic regression and random forest models outperform classification trees for these problems. Because random forest models and logistic regression models had nearly the same predicting power, we conclude that it is best for the Naval Academy to use the logistic regression models because it is easier to determine how each variable affects whether the midshipmen graduate in the top 10% or bottom 10%.

Additionally, we found that we were not able to predict attrition with the variables that were given. We believe with the addition of some key attrition variables, the models that predict attrition before I-Day would have been more successful. The first key variable that would have helped is knowing how that midshipmen underwent attrition. For example, midshipman X underwent attrition for three consecutive failed physical fitness requirements. The second key variable that would have helped is knowing when that midshipmen underwent attrition. We believe that knowing the “when” and “how” for attrition, the models for attrition could have been improved.

Furthermore, the whole person multiple is a statistically significant variable for all three response variables. After adding the remaining 23 explanatory variables to the top 10% and bottom 10% logistic regression models, the predicting power for each model increased. Therefore, the Naval Academy admissions team should look into putting more weight into other variables to improve the whole person multiple and render it a better predictor of midshipmen’s outcomes.

Through our analysis, we identified ten variables that are statistically significant in predicting whether or not a midshipman graduates in the top 10% (Table 30). Because the

MBTI results are significant in predicting the top 10%, the Naval Academy might consider adding the MBTI to the application process. Additionally, COs and SELs might consider receiving these variables in Table 30 on each incoming plebe within their companies in order to have a better understanding on the plebe’s potential outcome.

Table 30. Top 10% Important Variables

<b>Variable</b>	<b>Df</b>	<b>Deviance</b>	<b>AIC</b>	<b>LRT</b>	<b>Pr(Chi)</b>
Race	7	1941.4	1989.4	17.7	0.0133 *
SAT.Math	1	1963.8	2023.8	40.1	2.4e-10 ***
HS.Athletic.ECA	1	1947.7	2007.7	24.0	9.5e-07 ***
HS.NonAthletic.ECA	1	1935.2	1995.2	11.5	0.0007 ***
HS.Class.Rank	1	1935.6	1995.6	11.9	0.0005***
HS.Class.Size	1	1928.5	1988.5	4.9	0.0272 *
Whole.Person.Multiple	1	2009.5	2069.5	85.9	< 2.2e-16 ***
MBTI	15	1956.4	1988.4	32.7	0.0051 **
Basketball.Throw	1	1928.0	1988.0	4.4	0.0361 *
Mile.Time	1	1934.9	1994.9	11.3	0.0008 ***

We also identified eleven variables that are statistically significant in predicting whether or not a midshipman graduates in the bottom 10% (Table 31). Because these variables are significant, the Naval Academy admissions team might consider allowing COs and SELs to review these variables in Table 31 for all incoming plebes in order for them to have a better understanding on the potential outcome for the midshipmen who will fall under their guidance.

Table 31. Bottom 10% Important Variables

<b>Variable</b>	<b>Df</b>	<b>Deviance</b>	<b>AIC</b>	<b>LRT</b>	<b>Pr(Chi)</b>
Age	1	2015.8	2051.8	10.6	0.0011 **
Gender	1	2010.7	2046.7	5.5	0.0186 *
Race	7	2058.7	2082.7	53.5	3.0e-09 ***
Prior.Enlisted	2	2022.1	2056.1	16.9	0.0002 ***
SAT.Math	1	2027.1	2063.1	21.9	2.9e-06 ***
SAT.Verbal	1	2010.0	2046.0	4.8	0.0287 *
HS.Athletic.ECA	1	2009.6	2045.6	4.4	0.0367 *
HS.Class.Rank	1	2009.6	2045.6	4.4	0.0352 *

<b>Variable</b>	<b>Df</b>	<b>Deviance</b>	<b>AIC</b>	<b>LRT</b>	<b>Pr(Chi)</b>
HS.Class.Size	1	2009.1	2045.1	3.9	0.0485 *
Whole.Person.Multiple	1	2034.2	2070.2	28.9	7.3e-08 ***
Mile.Time	1	2010.7	2046.7	5.5	0.0193 *

## **B. FUTURE WORK**

This study was only an initial look into the variables and trends in predicting the top 10% and bottom 10% of midshipmen before beginning their time at the Naval Academy. We believe there are several future works to be done to continue this study. For an individual who wishes to predict midshipmen who have the highest potential to undergo attrition before starting at the Naval Academy, we recommend receiving more data from the United States Naval Academy Institutional Research Center on how and when a midshipman undergoes attrition. Another future work we recommend is for an individual to analyze trends between Naval Academy performance and the Basic School performance. In order to accomplish this trend analysis, the individual will need to acquire additional data from the Basic School.

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