3-2002

# The Predictive Validity of the AFIT Graduate Engineering and Environmental (GEEM) Admission Requirements

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**THE PREDICTIVE VALIDITY OF THE AFIT GRADUATE ENGINEERING AND ENVIRONMENTAL MANAGEMENT (GEEM) ADMISSION REQUIREMENTS**

THESIS

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AFIT/GAQ/ENV/02M-16

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# The Predictive Validity of the AFIT Graduate Engineering and Environmental Management (GEEM) Admission Requirements

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Acquisition Management

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March 2002

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

AFIT/GAQ/ENV/02M-16

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Acknowledgements

In memory of those whose lives were taken from them on

September 11, 2001

May God give you His eternal Peace.

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## Introduction

Recognizing that a strong commitment to advanced technical and management education serves to maintain the capabilities and strength of the USAF (Van Scotter, 1993), the Air Force Institute of Technology (AFIT) Graduate School of Engineering and Management (GSEM) offers a range of full-time, eighteen-month, graduate-level scientific, engineering and management programs to military officers below the rank of Colonel (O-6) and Department of Defense (DoD) civilian employees. AFIT focuses on the USAF, the DoD, and the civilian research and development environment, striving to prepare students to "serve their country to the greatest degree possible" (AFIT GSEM Graduate Catalog, Academic Year 2001-2002, p. 3).

Within the GSEM, the Graduate Engineering and Environmental Management (GEEM) program focuses on graduating civil engineering officers and civilians that can "integrate engineering, science, and policy issues into a decision-making framework for optimum management of facility operations and environmental programs" (AFIT GSEM Graduate Catalog, Academic Year 2001-2002, p. 170). The USAF determines the size of entering GEEM classes according to the need for civil engineers and the availability of annual funds to finance the GEEM program. Upon graduation, GEEM students are assigned to civil engineering organizations across the Air Force.

The limited number of GEEM student slots compels the AFIT faculty to distinguish between applicants and select those most likely to successfully satisfy the graduation requirements: at least thirty-six quarter-hours of classes, maintaining at least a 3.00 (on a 4.00 scale) GGPA, and a twelve quarter-hour thesis study. To this end, the AFIT faculty and registrar rely on objective, quantitative admission data.

Applicants eligible for study in the GEEM program must have an earned baccalaureate degree from an accredited college or university in an appropriate discipline – most commonly civil, mechanical, or electrical engineering -- an overall undergraduate grade point average (UGPA) of at least 3.00, and Graduate Record Examination (GRE) General Test score of at least 500 on the verbal section and 600 on the quantitative section. In addition, the AFIT GEEM program uses the undergraduate math grade point average (UMGPA) as an indicator of the level of mathematical study and proficiency. The 3.00-standard applies to the UMGPA criterion, as well. Applicants must also have taken an undergraduate course in ordinary differential equations (ODE).

The existing body of research on the ability of the admission requirements to predict graduate school success presents inconsistent findings. Across studies, the predictive validity of both the GRE General Test and the UGPA have been shown to vary with academic discipline. Some studies report the existence of moderating effects of variables like age, gender, and time between undergraduate and graduate education on UGPA and GRE scores. Across studies, conceptualizations of graduate school success also vary. For example, the Educational Testing Service (ETS) validates scores on the GRE General Test against first-year graduate grade point average (FYGGPA). Other studies rely exclusively on cumulative GGPA or a dichotomous graduated versus did not graduate measures of graduate school performance. Other studies use composite measures of graduate school success. For example, Abedi (1991) used "the GGPA, the total number of credit hours attempted while in graduate school, and the type and number of degrees earned" (p. 154) to define graduate school success.

To counter the variability in the findings of individual studies, the 2000-2001 Guide to the Use of Scores, published by the ETS, encourages universities and academic departments to perform their own validity studies on the GRE and other admission requirements – i.e., UGPA. While controlling for age, gender, and the time between undergraduate and graduate education (TDELTA), this study seeks to determine the validity of the AFIT admission criteria as predictors of graduate school success, defined separately as: GGPA, AFIT thesis grade, FYGGPA, and Coursework GGPA.

From 1995 to 2002, the structure, content, and duration of the GEEM program was fairly stable, with a fairly homogenous population of students. Thus, to both maintain the homogeneity of the population (Keith, 1977) and to minimize "noisy data problems" that Schneider and Briel (1990, p.15) propose may produce lower correlation between GRE scores and graduate school success, this study focuses exclusively on GEEM students between the classes of 1995 through 2002.

This study seeks to answer the following questions:

1) Do any of the individual AFIT admission requirements – UGPA, GRE (verbal), GRE (quantitative), UMGPA – significantly predict a student's graduate school performance beyond the control variables – age, gender, and time between undergraduate and graduate education?
2) Do all of the AFIT admission requirements, together, significantly predict a student's graduate school performance beyond both the control variables and any individual admission requirement?

## Literature Review

An extensive body of research exists on the predictive validity of UGPA and GRE scores, the influences of age, gender, and time (in years) differences between undergraduate and graduate education, as well as, the various definitions of graduate school success. The literature review focuses on varied admissions requirements and processes that predict graduate school success. Research on the UGPA, GRE, age, gender, and TDELTA variables is presented along with a synopsis of definitions of graduate school success used throughout research. Finally, the AFIT admission and graduation requirements are presented as predictors and measures of success, respectively.

### *Admissions Processes*

Graduate institutions evaluate applicants for admission using any of a variety of admission processes, characterized by both composition and complexity. The admission requirements that compose an admission procedure are classified as either traditional or non-traditional. While both categories contain objective and subjective, quantitative and qualitative requirements, traditional measures are those requirements that are the most commonly used measures of undergraduate academic performance across universities – i.e., UGPA and GRE General Test score. The complexity of a procedure is classified relative to that of other admission processes. In this study, all admissions procedures are compared to a baseline process that relies strictly on unaltered, traditional variables – i.e., the UGPA and GRE General Test score to admit applicants. Any procedure that uses a combination of traditional and non-traditional admission requirements – i.e., UGPA, GRE General Test scores, and letters of recommendation -- or some altered form of a quantitative admission requirement – i.e., the last two years of the UGPA -- to admit applicants is considered, to varying degrees, more complex than the baseline procedure. The composition of the admission procedure, thus, drives the complexity of the admission process. In the following paragraphs, both traditional and non-traditional admission requirements will be explored in greater depth.

*Traditional Admission Requirements*. Traditional requirements include objective measures like the UGPA and the GRE General Test score, and subjective measures like letters of recommendation. Since most of the applicants to graduate school have an UGPA, Malone, Nelson and Nelson (2001) explain that it is a "very convenient," (p. 4) although range restricted, measure for admission decisions. To help further resolve differences between applicants clouded by the small range of UGPAs, many graduate institutions concurrently rely on the GRE. According to Norcross, Hyanch, and Terranova (1996), eighty-one percent of graduate psychology programs require GRE scores of applicants. The GRE provides graduate admissions with a standardized, common-scale measure of an applicant's verbal, quantitative, and analytical abilities.

*Non-Traditional Admission Requirements*. The category of non-traditional requirements contains a greater variety of less common, less-established measures than the traditional category. Enright and Gitomer (1989), for example, include interviews, writing samples, and research plans among non-traditional measures. Howard (1968) documents that the University of Cincinnati's used an applicant's UGPA from the junior and senior years of study to evaluate applicants with four-year cumulative UGPAs below graduate program requirements. The University of Cincinnati admissions committee suggested that the last two years of the undergraduate experience, theoretically, provided more insight into the applicant's ability to critically solve problems than do more traditional requirements. Stahmer (1968) reports that Harvard, Yale, and Columbia implemented specially-designed summer studies programs for academically "at-risk" applicants – those applicants with relatively low UGPA and GRE scores -- and made admissions decisions following the completion of this program upon such non-traditional requirements as "formal application, transcript of college work, statement of educational aims, writing samples, an interview, faculty recommendations, motivation, and desire" (Malone, Nelson, & Nelson, 2001:6).

*Traditional Versus Non-traditional Admission Requirements*. While studies performed by Case and Richardson (1990); Hagedorn and Nora (1996); and House, Gupta and Xiao (1997) imply that graduate institutions adopted non-traditional measures, oftentimes as supplements to traditional procedures, to improve upon the low predictive validity of traditional measures, research has not established that non-traditional measures are better predictors of graduate school success than traditional measures. For example, Stahmer (1968) reports large percentages of "at-risk" students – i.e., those applicants not meeting the stated admissions minimums -- admitted to graduate study under Harvard, Yale, and Columbia's non-traditional measures, graduated and pursued further graduate study. The success of students considered "at-risk" by traditional measures does not prove that the non-traditional measures used to admit them to the Harvard, Yale, and Columbia programs are necessarily better than the traditional measures that would have, most likely, rejected them. It simply shows that factors other than the traditional measures influence the prediction of applicant graduate school success. The Pennsylvania State University performed a study where students both above and below the minimum quantitative admission requirements were admitted for graduate study. No significant difference in GGPA between the two categories of students was found (Penn State University, Graduate School Bulletin, 1969, cited in Gunne and Leslie, 1972). Malone, Nelson and Nelson (2001) reported the graduation of seventy-five percent of the students admitted to the University of California at Los Angeles (UCLA) who did not meet the GPA and GRE admission requirements. Like the Harvard, Yale, and Columbia study (Stahmer, 1968), the graduation of these students from UCLA does not necessarily mean that non-traditional measures better predicted graduate school success over traditional measures.

All that can be inferred from the research is that non-traditional measures may be worse, just as good, or better able to predict graduate school performance. Considering that the composition of an admissions process drives the complexity, it follows that graduate institutions can evaluate applicants for admissions using any degree of complexity and achieve worse, equal or better results in admitting applicants.

*Engineering Management Program Selection Processes*. Typically, Graduate Engineering Management programs rely on traditional admissions processes, requiring a minimum UGPA and GRE General Test score. The 2001 Peterson's Graduate Programs in Engineering and Applied Sciences publishes the entrance requirements for eighty-two graduate schools that offer degrees in Engineering Management. The majority of graduate schools require a minimum UGPA (most commonly either 2.5 or 3.0) and the GRE (verbal) and GRE (quantitative) scores, either combined or considered separately. A few schools deviate from the traditional admissions process. For example, the Lamar University, College of Graduate Studies, College of Engineering, Department of

Industrial Engineering, Program in Engineering Management requires at least five years of related work experience. The Kansas State University, Graduate School, College of Engineering, Department of Industrial and Manufacturing Systems Engineering will only consider applicants with a bachelor of science degree in Mathematics, Engineering, or Physics. Dallas Baptist University requires the GMAT in lieu of the GRE General Test. The AFIT model, most closely, adheres to a more traditional process.

*AFIT Model for Predicting Graduate School Success*

Every graduate institution is limited in the number of students it can admit to any particular class. Whether using traditional, non-traditional, or a combination of both types of admissions requirements, the goal of graduate admissions is generally the same across institutions – to select those applicants with the knowledge, skills, and ability to perform well in a respective graduate program. Since the number of applicants often exceeds the number of positions available, every graduate institution is compelled to discriminate among all applicants and admit only a percentage of the entire applicant pool for graduate study. From an applicant's admissions data, graduate admissions make inferences about the applicant's potential to perform in graduate school. Those applicants with the greatest inferred potential for performance are admitted to the program before applicants with lesser potential.

The AFIT faculty and registrar rely on a combination of traditional – UGPA, GRE (verbal), and GRE (quantitative) -- and non-traditional variables – UMGPA – to evaluate applicants. In the context of the GEEM program, the AFIT seeks to admit only those applicants with the greatest inferred potential to successfully learn to "integrate engineering, science, and policy issues into a decision-making framework for optimum management of facility operations and environmental programs" (AFIT GSEM Graduate Catalog, Academic Year 2001-2002, p. 170). The UGPA demonstrates the student's ability to function in an academic environment by presenting a record of past academic achievement. AFIT does not give any formal consideration to any specific undergraduate institution. The UMGPA indicates the level of mathematical study as well as academic achievement in mathematics courses. The GRE assesses basic quantitative and verbal skills deemed requisite for success in the AFIT GEEM program by AFIT GEEM administrators.

The following sections present research on the predictive validity, strengths, and weaknesses of the AFIT GEEM admissions criteria.

*Undergraduate Grade point Average (UGPA).* Betts and Morell (1998) define the UGPA as a measure of a student's undergraduate academic success. Mathematically defined, the UGPA is a ratio of total quality points, the product of earned grade points and credit hours, to the total credit hours taken by the student. Virtually every undergraduate university and college in the United States calculates an UGPA for its students, with very little variance in methodology. Grade points, most commonly, range from 0.0 to 4.0, where an 'F' reflects a 0.0 and an 'A' is a 4.0. The undergraduate institution uses the UGPA for a variety of purposes, including the award of academic distinctions and the determination of graduation eligibility. Most undergraduate institutions require at least a 2.0 or 'C' UGPA for graduation. Graduate institutions, however, use the UGPA to make inferences about an applicant's ability to perform in graduate school, where graduate performance is measured in a variety of ways (-- i.e., first-year GGPA, cumulative GGPA, and graduation).

Researchers disagree on the ability of the UGPA to validly fill this role. UGPA validity studies examine specific academic departments or across academic departments and universities. In either case, no consensus on the predictive validity of the UGPA exists. For example, in a study of MBA graduates from a southeastern US business school, Ahmadi, Raiszadeh, and Helms (1997) found a strong positive correlation ($\underline{r}$ = .52) between UGPA and GGPA. In a regression-based study of graduate, criminal justice students at a southern US university, McKee, Mallory and Campbell (2001) found that the UGPA, alone, accounted for twenty-four percent of the variance in GGPA ($\underline{r}$ = .49). McKee, Mallory and Campbell (2001) also reported that GRE (verbal), GRE (quantitative), and GRE (analytical) scores predicted an additional sixteen percent of the variance in GGPA. Performing a stepwise multiple regression analysis on three groups of graduate students entering UCLA graduate schools in 1981, 1983, and 1985, Abedi (1991) found junior/senior UGPA to have "virtually no relationship with any of the measures of graduate academic success" (p. 160), defined as a composite measure consisting of "GGPA, the total number of credit hours attempted, and the type and number of degrees earned" (p. 154). Shelton (2001) explains that the UGPA accounts for "less than seven percent of the variance in first-year law school grades" (p. 1).

While research disagrees on the predictive validity of the UGPA, many researchers have proposed explanations for the inconsistencies. Goldberg and Alliger (1992:1026) and Malone, Nelson and Nelson (2001:4) explain that undergraduate grades exist within a tight range of values. As a result, differences in UGPA may not accurately reflect differences in the magnitude of student accomplishment. Malone, Nelson and Nelson (2001) explain that "it is not always clear what grades mean" (p. 4). The grade could be a measure of the student's course performance, performance compared to the student's peers, or a measure of the student's performance improvement since the beginning of the class (Malone, Nelson, and Nelson, 2001:4). Goldman and Slaughter (1976) and Morrison and Morrison (1995) blame a lack of standard practices used in assigning grades for dramatic grade variance within classes, across academic disciplines, and across different institutions. Malone, Nelson and Nelson (2001) further explain, "grade assignments are also sometimes influenced by student characteristics that have no relationship to academic performance – i.e., participation in class, argumentative behavior" (p. 5) (Singer 1964). Grade inflation may also prove to be a factor that compromises the predictive validity of the UGPA. Studying 134 colleges, Juola (1977) reports a mean average increase of M = 0.40 grade points from 1965 to 1973. Juola (1980) later expanded the study to include 180 undergraduate institutions and found a mean average increase of M = 0.43 grade points from 1960 to 1979. Levine (1994) surveyed 4900 college graduates from the classes of 1960 through 1993 and found a sixty-six percent increase in the number of A's given. The inflation of grades further restricts the already "narrow range" (Malone, Nelson, and Nelson; 2001:4) of undergraduate grades, further masking differences in student academic performance that help distinguish between applicants admitted and applicant rejected (Malone, Nelson, and Nelson; 2001:4).

In addition to independent studies, the Educational Testing Service (ETS) has published a table of average estimated correlation between UGPA and first-year graduate school grades in the 2000-2001 Guide to the Use of Scores GRE Manual. The ETS results tend to bring stability to the findings of the independent research. Across 1,038 academic departments and 12,013 examinees, the ETS reports an $r$ = .37 correlation between UGPA and FYGGPA. The ETS also reports correlation results for specific academic departments. For engineering programs, looking across eighty-seven departments and 1,066 examinees, the ETS published an $r$ = .38 correlation between UGPA and FYGGPA. The ETS reports similar findings among similarly sized samples in the Natural Sciences ($r$ = .37), Social Sciences ($r$ = .38), Humanities and Arts ($r$ = .37), Education ($r$ = .35), and Business ($r$ = .39).

A significant body of research also exists on the predictive validity of the UGPA in combination with other criteria. For example, Malone, Nelson, and Nelson (2001) found the UGPA to be a valid predictor of graduate school success, defined dichotomously as graduated or did not graduate, when multiplied by the score from the verbal section of the GRE. Malone, Nelson, and Nelson (2001) analyzed this combined variable in consideration of "Michael's (1983) findings that combinations of predictor variables yielded higher validity than single predictors" (p. 13). In the 2000-2001 Guide to the Use of Scores, the ETS published an average estimated correlation of the product of UGPA, GRE-V, GRE-Q, and GRE-A and FYGGPA of $r$ = .46, an improvement of $\Delta r$ = .09 over the correlation between UGPA and FYGGPA. For engineering students, the average estimated correlation of the product of UGPA, GRE (verbal), GRE (quantitative), and GRE (analytical) and FYGGPA was $r$ = .44, an $\Delta r$ = .06 improvement over the correlation between UGPA and FYGGPA.

Beyond combining the UGPA with other predictors, Schneider and Briel (1990) indicate that UGPA correlated with first-year GGPA in a similar manner as the GRE Subject Test score and first-year GGPA. The 2000-2001 ETS study generally supports this report. For engineering students, looking across twenty-one departments and 185 examinees, the correlation between UGPA and first-year GGPA is r = .39. Across the same sample, the ETS published an r = .41 correlation between first-year GGPA and the Engineering Subject Test. The similar correlation between UGPA and first-year GGPA and GRE Subject Test and first-year GGPA holds for most of the other academic departments. Chemistry and Economics, however, showed large differences -- Δr = .15 and Δr = .05, respectively -- between UGPA and first-year GGPA correlation and GRE Subject Test and first-year GGPA correlation.

From the preceding presentation of research on the predictive validity of the UGPA, it is clear that there is a great deal of variability among the focus and findings of individual studies. Such inconsistency only justifies the performance of more validation studies to determine the predictive validity of the UGPA within the specific context of the universities or academic departments that use the measure to evaluate applicants for admission.

*Graduate Record Examination (GRE) General Test.* Kuncel, Hezlett, and Ones (2001) state that the Graduate Record Examination was "developed in the 1940's" (p.162). Since 1966, the Graduate Record Examination (GRE) Board has been charged with improving the measure to "equalize higher education opportunities for all students, improve the practices, procedures, and quality of graduate education, and promote maximum utilization of human talents and financial resources" (ETS Guide to the Use of Scores, 2000-2001:5). The efforts of the GRE Board have most notably translated into the addition of the analytical section, beyond the original quantitative and verbal batteries, the implementation of the computer-adaptive test (CAT), and, most recently, the consideration of the addition of a writing sample. Yet, despite the modifications made to the GRE, “the results of this half century of research” on the GRE’s validity “have been inconsistent and controversial” (Kuncel, Hezlett, & Ones, 2001:163). This is proof that the GRE is still not a perfect measure and will continue to evolve in order to “serve the best interests of the entire graduate community” (ETS Guide to the Use of Scores, 2000-2001:5).

In the 2000-2001 Guide to the Use of Scores, the ETS claims that the Graduate Record Examination (GRE) General Test measures the graduate school applicant’s accumulated verbal, quantitative, and analytical skills on a common scale. Scores for each of the three components range from 200 to 800 points. The verbal component measures the applicant’s ability to analyze written passages as well as the relationship among sentences in the passage and the relationships among the words within the sentences. The quantitative section tests the ability to use basic mathematical concepts to solve quantitative problems. The analytical test examines the ability to both infer and deduce information from a given set of relationships -- i.e., analyzing arguments.

While verbal, quantitative, and analytical skills are measured using separate sections, there is a moderate-to-high overlap in the skills tested in each section. In the 2000-2001 Guide to the Use of Scores, the ETS reports average estimated correlation of $r = .45$ between the verbal and quantitative sections, $r = .66$ between the quantitative and analytical components, and $r = .60$ between the verbal and analytical components. Rock, Werts, and Grandy (1982) report correlations of $r = .64$ between verbal and quantitative sections, $r = .77$ between quantitative and analytical sections, and $r = .77$ between the verbal and analytical components.

According to Norcross, Hyanch and Terranova (1996), eighty-one percent of psychology graduate programs require applicants to sit for the GRE General Test. At test centers across the world, the Educational Testing Service (ETS) administers the computer-based adaptive GRE General Test throughout the year. The computer-adaptive test (CAT) model selects questions according to difficulty and examinee responses on past questions within the parameters of required question-type variety and content coverage. While few test centers still administer the original paper-based GRE General Test, the ETS reports that scores on the computer-adaptive tests are comparable to those on paper-based tests.

According to the ETS's 2000-2001 Guide to the Use of Scores, graduate institutions may appropriately use General Test scores "to admit graduate students, select graduate fellowship students for awards, select teaching or research assistants, or to perform graduate study counseling" (p. 8). The ETS does not consider the GRE to be suitable for other uses. Regardless of the suitability of the application, the ETS recommends that graduate institutions never use the General Test in isolation. General Test scores do not exactly and completely measure all the factors that influence the prediction of graduate school success. The ETS reports that the GRE General Test, alone, possesses only slight-to-moderate ability to predict first-year GGPA and tend to vary according to academic discipline. For example, while the first-year GGPA correlated positively with the verbal section ($r$ = .30), quantitative section ($r$ = .29), the analytical section ($r$ = .28) and the GRE General Test Total score ($r$ = .34) across 1,038 departments (12,013 examinees), the ETS reported that the predictive validity of the components varied according to academic department. For example, a study of eightysix education departments (901 examinees) produced an average estimated correlation of r = .31 (verbal), r = .30 (quantitative), r = .29 (analytical), and r = .36 (General Test total score). Yet, a study of eighty-seven (1,066 examinees) engineering departments produced an average estimated correlation of r = .27 (verbal), r = .22 (quantitative), r = .24 (analytical), and r = .30 (General Test total score) (ETS Guide to the Use of Scores, 2000-2001:24). Studies by Braun and Jones (1985), Thornell and McCoy (1985), and Morrison and Morrison (1995) report evidence of variability in the predictive validity of the GRE across academic disciplines. Thornell and McCoy (1985) report that across four academic disciplines – education, humanities, fine arts, and math/science – the validity coefficients of GRE (quantitative) and GGPA varies from r = .22 for fine arts to r = .37 for math/science. The validity coefficients for GRE (total score) and GGPA vary from r = .36 for fine arts to r = .48 for math/science. The validity coefficients of GRE (verbal) and GGPA vary from r = .42 for fine arts to r = .49 for education. Morrison and Morrison (1995) report weighted averages of observed effect sizes for GRE (quantitative) when GGPA was the measure of graduate school performance ranging from d = –.07 to d = 1.7. Morrison and Morrison (1995) also reported that the weighted average observed effect sizes for GRE (verbal) and GGPA varied from d = -.26 to d = 2.2. The weighted average observed effect sizes for GRE (total) and GGPA varied from d = -.1 to d = 1.3. Thus, the ETS recommends that graduate institutions use the GRE General Test as a "supplement" (p. 5) to other predictors of graduate school success, such as the UGPA and letters of recommendation. If graduate institutions plan on using the GRE for a suitable purpose, the ETS encourages individual universities and academic departments to conduct in-house validity studies of the GRE General Test (ETS Guide to the Use of Scores, 2000-2001:7).

The results of those in-house studies tend to vary with academic discipline and sometimes produce mixed results within disciplines. For example, while Wilson (1979) found median validity coefficients for first-year grades in psychology of $r = .18$ (verbal) and $r = .19$ (quantitative), House, Johnson, and Tolone (1987) found a correlation coefficient of $r = .15$ for GGPA in psychology. The 2000-2001 ETS Guide to the Use of Scores reports a $r = .29$ (verbal), $r = .29$ (quantitative), and $r = .28$ (analytical) correlation with first-year GPA in psychology. Goldberg and Alliger (1992) performed a meta-analysis of ten studies, focusing on graduate psychology students, and found "somewhat lower" (p. 1025) correlation values that those reported by the ETS: $r = .15$ (verbal) and $r = .14$ (quantitative). Burton & Turner (1983) report validity coefficients for first-year grades across all social sciences of $r = .26$ (verbal) and $r = .22$ (quantitative). However, Milner, McNeil, and King (1984) reported that the GRE was not a valid predictor of GGPA in a study of social work students. Dunlap (1979) corroborates the Milner, McNeil, and King (1984) finding, stating that the GRE was a "weak predictor" of graduate school performance. However, the 2000-2001 Guide to the Use of Scores, published by the ETS, reports average estimated correlations of the GRE General Test scores with graduate first-year GPA of $r = .33$ (verbal), $r = .32$ (quantitative), and $r = .30$ (analytical) for the social sciences. Morrison and Morrison (1995) performed a meta-analysis of twenty-two studies. They reported that the GRE demonstrated minimal predictive validity of GGPA, with a $r = .22$ quantitative validity coefficient and a $r = .28$ verbal validity coefficient.

One study, however, conducted by Kuncel, Hezlett, and Ones (2001), stands against the claim that the predictive validity of a comprehensive meta-analysis, examining 1,521 studies with 82,659 graduate students. They found all three components of the GRE General Test to be "generalizably valid predictors of GGPA, 1st-year GGPA, faculty ratings, comprehensive examination scores, citation counts, and, to a lesser extent, degree attainment" (Kuncel, Hezlett, & Ones, 2001:174). On their findings, Kuncel, Hezlett and Ones (2001) explain that "prior criticisms of the GRE's validity as situationally specific and useless are in error" (p. 176).

*Control Variables*. There are many factors that influence the student's UGPA, GRE score, and UMGPA. For example, age, gender, and the difference (in years) between undergraduate and graduate education (TDELTA) have been shown to influence the predictive validity of the UGPA and the GRE General Test. Matthews and Martin (1992) reported that age interacts with predictor variables to cause underpredictions for both older, low-to-moderate credentialed students – i.e, those over thirty years of age – and younger, high-credentialed students. House (1989) reports that GRE scores overpredicted the graduate school performance of younger students – those students under twenty-four years of age --- and underpredicted the graduate school performance of older students – those students over the age of twenty-five. On gender, Payne, Wells and Clarke (1971) found that females tend to be "more predictable than males" (p. 498). Computing multiple correlations from the combination of National Teacher Examination score (NTE-C), GRE-T (total of quantitative and verbal scores), and UGPA; Payne, Wells and Clarke (1971) achieved multiple R's of .34 ($\underline{N}$ = 61), .45 ($\underline{N}$ = 66), and .32 ($\underline{N}$ = 127) for males, females, and the total sample, respectively. House (1994) found the correlation between the total GRE score and GGPA was significantly stronger for women. House (1994) also found the correlation between the verbal GRE score and GGPA to be significantly stronger for women. However, the research on the influence of age, gender, and TDELTA on the predictive validity of UGPA and the GRE General Test does not present consistent findings across studies. For example, Malone, Nelson and Nelson (2001) concluded that both age and TDELTA had no predictive power after being eliminated from the regression model used in their study (p.11).

Whether or not age, gender, and TDELTA have true predictive power is not a problem that must be solved or theorized before research and analysis can begin. When seeking to validate admissions criteria, like the UGPA and the GRE General Test, for example, the researcher is most directly concerned with the predictive validity of these measures. If age, gender, and TDELTA exert any influence on the prediction of graduate school success using these or any other measures, then controlling for them provides the researcher with a way to measure the contributions of UGPA and the GRE General Test beyond the contributions of age, gender, and TDELTA. Controlling for these variables, despite whatever mixed findings may characterize the research, cannot harm the research effort. If age, gender, and TDELTA turn out to have, in fact, no predictive power of influence on other predictors, then controlling for them in a regression model will not hinder the predictive power of the other variables.

*Graduate School Success*

Malone, Nelson and Nelson (2001) explain that the definition of graduate school success is a "concept without precise definition," (p. 7). Researchers have most commonly defined graduate school success as either FYGGPA, GGPA, or dichotomously, as graduated versus did not graduate. Goldberg and Alliger (1992) list some less conventional definitions; including "graduate fellow success, comprehensive examination scores, faculty ratings, and grades in specific courses" (p. 1021).

However, both the common and uncommon definitions of graduate school success have demonstrated mixed relationships with selection criteria. Goldberg and Alliger (1992) found that the GRE, as a predictor of graduate school success, explained more variance in comprehensive examination scores, the measure of graduate school success, than any other predictor studies in their meta-analysis of ten studies. However, they warn that such a high validity may have been the product of a "circular relationship," where "a test score is being used to predict another test score" (p. 1024). The ETS reports that the GRE General Test, alone, possesses only slight-to-moderate ability to predict FYGGPA. Yet, the ETS found better results when the GRE General Test scores, the UGPA, and the GRE Subject Test score were all used as predictors of FYGGPA (ETS Guide to the Use of Scores, 2000-2001:24). Abedi (1991) found that UGPA was "virtually not related" (p. 160) to the composite measure of graduate school success, consistent of the number of credit hours taken, GGPA, and the type and number of degrees earned. Goldberg and Alliger (1992) found practically no predictive relationship between the GRE verbal and analytical sections and specific course grades. The GRE quantitative section proved slightly more predictive of course grades, but

Goldberg and Alliger (1992) believe a moderator variable to be effecting the relationship. Milner, McNeil and King (1984) reported that the GRE was not a valid predictor of GGPA in a study of social work students. In a study of MBA graduates from a southeastern US business school, Ahmadi, Raiszadeh and Helms (1997) found a strong positive correlation ($r = .52$) between UGPA and GGPA.

Goldberg and Alliger (1992) explain that researchers must first improve definitions of graduate school success before they can expect to make significant findings on the validity of the GRE. In fact, Goldberg and Alliger (1992) claim that the definitions must improve before making significant findings on any predictor of graduate school success. To improve graduate school success definitions for graduate psychology programs, Goldberg and Alliger (1992) advise researchers to focus on "what we are ultimately trying to predict, graduation and scientific productivity" (p.1026). For different graduate programs, however, the definition of success may emphasize different criteria depending on the goals of the program. Engineering and psychology programs have very different curriculums and, quite arguably, very different goals. If engineering does, in fact, so differ from psychology, then student success in each discipline should not be measured by the same standard.

*The Present Study*

This study examines the AFIT admission criteria as predictors of graduate school success and controls for age, gender, and time (in years) between undergraduate and graduate education. Since the completion of at least one undergraduate differential equations course is required for admission to the AFIT GEEM program, most every student ($N = 146$) in the GEEM database had taken such a course. Therefore, whether the student had taken a differential equations course (coded '1' if the student had taken a course and '0' if the student had not taken a course) was not controlled for in this study.

The AFIT Graduate Catalog for the Academic Year 2001-2002 defines graduate school success via two requirements for graduation: at least a 3.00 (on a 4.00 scale) GGPA and the completion of a thesis. However, while simply meeting these requirements may be sufficient for a student to be successful at AFIT, this study requires that graduate school success be defined more intricately; for nearly 100% of AFIT students graduate within the allotted eighteen months. Thus, this study distinguishes between relative levels of graduate student success, as measured by GGPA, Coursework GGPA and thesis grade. Students with higher GGPAs and thesis grades are deemed more successful than those with relatively lower GGPAs or and thesis grades.

Considering that the ETS uses the FYGGPA to validate the GRE examination, this study will consider FYGGPA as an alternative definition of graduate school success. Again, students with higher FYGGPAs are deemed more successful than those with relatively lower FYGGPAs.

## Methods

In studies that examine the predictive validity of admission requirements – i.e., UGPA, GRE General Test scores, etc. – bivariate correlation and multivariable regression analysis are the most common methodologies. This study employs both of those methodologies to investigate the predictive validity of the AFIT admission requirements.

This chapter opens with a summary description of the population used in this study and a discussion of the significant differences in dependent variable mean values according to gender, race, age, rank and undergraduate institution. The procedure used to collect the data and conduct a preliminary review for entry errors follows, focusing on the admissions requirements and measurements of graduate school success. This chapter closes with a description of the bivariate correlation and multivariable regression procedure.

### *Population and Procedures*

This study collected data on the 173 students that attended the AFIT GEEM program from 1995 to 2002, a period over which the structure, content and duration of the GEEM program was stable. Ninety-one percent of those students ($\underline{N}$ = 158) were US Air Force Officers. The remaining sixteen students were US Marine Corps Officers ($\underline{N}$ = 7), DoD Civilian employees ($\underline{N}$ = 8). For US military officers, student service rank ranged from second lieutenant and major. Military ranks have corresponding numbers – i.e., a second lieutenant is an O-1 (officer grade 1). The mean average of the numeric military ranks is $\underline{M}$ = 2.36, indicating that military officers in this population tend to be between the rank of first lieutenant and captain. The civilian pay-grades ranged from

GS-09 (Government Service 09) to GS-13 with a fairly even spread of employees across grades. The civilian pay-grades correspond to military officer ranks as follows:

**GS-09 = O-1, GS-11 = O-2, GS-12 = O-3, GS-13 = O-4**

The mean student age at entry to the AFIT GEEM program was M = 27.62 years (SD = 3.38). The youngest student was twenty-two years old at entry, and the oldest student was forty-eight years old at entry. GEEM students took a mean average M = 4.27 years (SD = 2.96) between undergraduate and graduate education. Eighty-seven percent of the population (N = 150) was male. Eighty-nine percent were Caucasian (N = 154). Eight were African-American, and eleven were classified as "other," which includes both Hispanics and Asians.

Data collected on the undergraduate institutions students attended revealed that twenty-seven percent of the students received their bachelor's degree from the US Air Force Academy (47 of the 173). The Texas A&M University posted the second greatest representation with five students. The three most common Bachelor of Science degrees among students were Civil Engineering (79 students), Mechanical Engineering (27 students), and Electrical Engineering (24 students). The remaining forty-three students possessed Bachelor of Science degrees in a variety of science and engineering fields. Tables of the undergraduate institutions attended and the degrees earned by AFIT GEEM students are contained in Appendices A and B, respectively.

All data were collected from student education records maintained by the AFIT registrar. Access to these files can be gained only by written permission of the director of the AFIT registrar. A copy of the letter requesting access to the AFIT academic records has been placed in Appendix C.

The academic files usually contained undergraduate transcript(s), a military service summary sheet, and the AFIT transcript. If one of these documents was absent from a student's file and a particular data point could not be determined from any other document in the student's record, then the data point was left blank. Thus, some data elements may have fewer data points than other data elements.

*Measures*

*Undergraduate Grade-Point Average (UGPA).* Undergraduate transcripts provided the student's cumulative academic performance at that particular institution. Mathematically defined, the UGPA is a ratio of total quality points, the product of earned grade points and credit hours, to the total credit hours taken by the student. Grade points were assigned consistent with AFIT's standard, where (AFIT GSEM Graduate Catalog, Academic Year 2001-2002, p. 22):

**A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, D = 1.0. F = 0.0.**

There were only a few deviations from this practice. For example, Worcester Polytechnical Institute (WPI) used a single letter grade to cover the typical B/C range. While an 'A' – Excellent – was labeled as 'DIST/AD,' the grade 'AC' was given to both a 'B' – Good – and a 'C' – Acceptable. Although the AFIT academic evaluator produced a UGPA for this student, the author did not find any procedure for converting the 'AC' grade into grade points. The UGPA could not be verified and was, therefore, not factored into the database for the WPI (N = 1) student.

In other cases, some students attended more than one undergraduate school before receive their bachelor's degree. In such cases, a composite UGPA, the ratio of the total quality points earned at all undergraduate institutions to the total credit hours earned across those undergraduate institutions, was calculated and subsequently used in the analysis.

*Undergraduate Math Grade-Point Average (UMGPA).* The UMGPA was calculated in the same manner as the composite UGPA, using the institute's published grading standard. The UMGPA was derived using any and all math-related classes published on a student's undergraduate transcript(s). Courses in Analytical Geometry, Analytical Geometry with Calculus, College Algebra, Trigonometry, Pre-Calculus, Integral Calculus, Differential Calculus, Ordinary Differential Equations, Applied Differential Equations, Probability and Statistics, as well as any course carrying the same department code as the aforementioned courses were factored into the UMGPA. The most common department codes were 'MTH.' And 'MA.'

*Graduate Record Examination (GRE) General Test Scores.* GRE General Test scores were collected from the official ETS report submitted to AFIT for each of the three components: verbal (GRE-V), quantitative (GRE-Q), and analytical (GRE-A). However, AFIT requires applicants to submit only the quantitative and verbal scores. If applicants reported their GRE scores to the AFIT admission office other than by the official ETS report, then the analytical scores were, most likely, not included. Of the 173 students in this study, eleven do not have analytical scores.

If more than one GRE score appeared in the student's record, the most recent test was used. In the event that no date was attached to the GRE scores, then the highest summed GRE score (verbal and quantitative components only) was used.

*Graduate Grade-Point Average (GGPA).* The GGPA was taken directly from the AFIT transcript. The GGPA was the cumulative grade point average after six-quarters of study at AFIT. The GGPA also includes the grade for the twelve hours of thesis study. The GGPA was used both with and without the influence of the thesis grade. A histogram of GGPA and Coursework GGPA values appears in Appendix D.1, Figures 1 and 2, respectively.

*Thesis grade*. The thesis grade was reported on the AFIT transcript in the sixth and final quarter of study. All AFIT theses represent twelve quarter-hours of credit. A histogram of thesis grade values appears in Appendix D.2, Figure 3.

*First-Year Graduate Grade-Point Average (FYGGPA).* The student's quarterly GGPAs were collected from the AFIT transcript. However, the hours and quality points that produced the quarterly GGPAs were not collected. Thus, when the FYGGPA was added to the study as a dependent variable, the data necessary to calculate a cumulative FYGGPA had not been collected. Therefore, the FYGGPA was calculated as the mean GGPA of the first four quarters of study at the AFIT. For future studies, however, it is recommended that the FYGGPA be the cumulative GGPA after the first four quarters of graduate study. A histogram of FYGGPA values appears in Appendix D.2, Figure 4.

*Review of Data*

While data were being collected, it was checked for entry errors against the original document. Once the database was complete, a cursory, visual inspection of the data was performed. The mean and variance of numeric data elements were used to perform a reality check on the data, looking for incorrectly entered data points that were influencing the two population parameters. Those variables that could not be averaged – i.e., race – were counted to both ensure that the number of data points collected did not exceed the total number of students in the population and that a sufficient number of data points were collected to satisfy central limit theorem assumptions.

Any data-entry mistakes discovered by these precautionary measures were corrected by consulting the academic record of that particular student. For example, the initial variance of TDELTA was about 99 years. TDELTA was calculated by taking the difference between the year the student started AFIT and the year the student graduated from the undergraduate program. An inspection of the data on TDELTA revealed that two data cells incorrectly contained the value '1994.' This error was unduly influencing the variance, and also, although less obvious, the mean of TDELTA. The student's academic files were reviewed for both the year the student entered AFIT and the year the student graduated from their undergraduate program. The correct years were entered into the database and the correct mean and variance were calculated.

*Regression Modeling*

SPSS 10.0 software was used to perform multivariable, linear, hierarchical regression analyses. For each dependent variable, GGPA, Coursework GGPA, thesis grade, and FYGGPA; three separate hierarchical analyses, with either two or three steps, were performed. The first step of each of the three analyses regressed only the control variables, age, gender, and time (T) between undergraduate and graduate education (TDELTA), against the dependent variable. Beyond the controls, the second step of each analysis measured a different predictor variable against the dependent variable. One analysis entered UGPA in the second step, measuring its ability to predict graduate school success beyond the control variables. The next analysis placed both GRE (verbal) and GRE (quantitative) in the second step. The final analysis placed UMGPA in the second step and all of the remaining predictors – UGPA, GRE (verbal), and GRE (quantitative) – in the third step.

SPSS 10.0 generated descriptive statistics for the data elements used in the analysis. In addition, a model summary, which contained the $R^2$ and the $\Delta R^2$ values for the regression, and coefficients table, which contained the standardized β coefficients, were produced. The software also produced a normal probability plot, a scatter plot of the standardized predicted residuals versus the standardized residuals, and VIF multicollinearity factors to check the assumptions of the General Linear Model (GLM). Finally, a Pearson correlation table was generated, using a $p = 0.05$ to evaluate significance of relationships.

Using the normal probability plot, scatter plot, and VIF multicollinearity factors, a quick check of the GLM assumptions was performed. Beyond the assumptions, significant Pearson correlations ($p < .05$) were used to identify bivariate predictive capability among the independent, dependent, and control variables. Significant $\Delta R^2$ ($p < .05$) and significant standardized β coefficients ($p < .05$) were used to identify statistically significant predictors of graduate school performance.

SPSS 10.0 software was also used to perform one-way ANOVA to explore significant differences in dependent variables according to age, gender, race, rank, and undergraduate institution.

## Results

### *Regression Assumptions*

Neter, Kutner, Nachtsheim, and Wasserman outline the assumptions of the General Linear Model (GLM). The residuals are assumed to be independent, normally distributed, and have a constant variance.

The GGPA, Coursework GGPA and FYGGPA regression models satisfied all of the GLM's assumptions. Scatter plots showed the standardized residuals for the GGPA, coursework GGPA and FYGGPA models to be homoscedastic. Normal probability plots demonstrated that the standardized residuals are normally distributed. For both models, VIF factors were examined to determine if multicollinearity exists between the variables. Neter, et al., advise that VIF factors greater than ten indicates significant multicollinearity among variables. However, for the GGPA, coursework GGPA and FYGGPA models, VIF factors did not exceed four. The highest VIF factors occurred between age and TDELTA, which seems reasonable considering the significant bivariate correlation between the two variables ($r = .77$, $p < .05$).

The thesis grade model, on the other hand, did not satisfy the homoscedasticity and normal error distribution assumptions, as demonstrated by a scatter plot and normal probability plot, respectively. The thesis grade model VIF factors, like those for the GGPA, coursework GGPA and FYGGPA models, did not exceed four. The highest VIF factors occurred between age and TDELTA.

*Descriptive Statistics*

In Table 4.1, mean, standard deviations, and correlations for the independent, dependent and control variables are presented.

Applicants eligible for study in the GEEM program must have an earned baccalaureate degree from an accredited college or university in an appropriate discipline – most commonly civil, mechanical, or electrical engineering – an overall undergraduate grade point average (UGPA) of at least 3.00, and Graduate Record Examination (GRE) General Test score of at least 500 on the verbal section and 600 on the quantitative section. In addition, the AFIT GEEM program uses the undergraduate math grade point average (UMGPA) as an indicator of the level of mathematical study and proficiency. The 3.00-standard applies to the UMGPA criterion, as well. Applicants must also have taken an undergraduate course in ordinary differential equations (ODE).

Considering the standard deviations about the mean values of the UGPA ($\underline{M}$ = 3.02, $\underline{SD}$ = 0.30), the UMGPA ($\underline{M}$ = 2.91, $\underline{SD}$ = 0.50), and the GRE (verbal) ($\underline{M}$ = 525.03, $\underline{SD}$ = 76.75); it was clear that AFIT admits students with grades or scores below that of the stated minimums. For example, a ninety-five percent confidence interval around the mean UGPA ranged from 2.53 to 3.52. Similar intervals were calculated around the means of UMGPA (from 2.09 to 3.74), and GRE (verbal) (from 398.39 to 651.67). The only variable that did not drop far below the AFIT-stated minimum was the GRE (quantitative) score ($\underline{M}$ = 689.26, $\underline{SD}$ = 55.60), which seemed reasonable considering that the AFIT GEEM program was an engineering-based program. A ninety-five percent confidence interval around the mean GRE (quantitative) ranged from 597.52 to 781.

The GGPA, coursework GGPA and FYGGPA had mean values of $M = 3.69$ ($SD = 0.16$), $M = 3.69$ ($SD = 0.17$) and $M = 3.67$ ($SD = .17$), respectively. A ninety-five percent confidence interval about the mean of GGPA ranged from 3.43 to 3.95. A ninety-five percent confidence interval about the mean of coursework GGPA ranged from 3.41 to 3.97. A ninety-five percent confidence interval about the mean of FYGGPA ranged from 3.39 to 3.95. There were significant correlations between GGPA and FYGGPA ($r = .93$, $p < .05$) and coursework GGPA and FYGGPA ($r = .97$ $p < .05$). Both the proximity of the means and the high correlation between these three dependent variables was not coincidental. The FYGGPA was merely a component of both the GGPA and the coursework GGPA. The FYGGPA was the average of the first four quarters of grades that contribute to both the GGPA and coursework GGPA.

There were significant correlations between GGPA and Age ($r = .14$, $p < .05$), TDELTA ($r = .18$, $p < .05$), UGPA ($r = .18$, $p < .05$), GRE (verbal) ($r = .25$, $p < .05$), and GRE (quantitative) ($r = .15$, $p < .05$). There were significant correlations between coursework GGPA and Age ($r = .24$, $p < .05$), TDELTA ($r = .23$, $p < .05$), UGPA ($r = .14$, $p < .05$), GRE (verbal) ($r = .30$, $p < .05$), and GRE (quantitative) ($r = .24$, $p < .05$). There were no significant correlations between any of the independent or control variables and thesis grade. Age ($r = .20$, $p < .05$), TDELTA ($r = .24$, $p < .05$), UGPA ($r = .17$, $p < .05$), GRE (verbal) ($r = .29$, $p < .05$), and GRE (quantitative) ($r = .20$, $p < .05$) and were all significantly correlated with FYGGPA.

There was a significant correlation between the GRE General Test verbal and quantitative sections ($r = .38$, $p < .05$). A significant correlation existed between the analytical section and the verbal section ($r = .38$, $p < .05$). A significant correlation existed between the quantitative and the analytical section ($r = 0.45$, $p < .05$). These results were lower than those reported in the 2000-2001 *Guide to the Use of Scores*, where the ETS found average estimated correlation of $r = .45$ between the verbal and quantitative sections, $r = .66$ between the quantitative and analytical components, and $r = .60$ between the verbal and analytical components. These results were comparable to the correlations reported by Sternberg and Williams (1997). Sternberg and Williams (1997) found correlations of $r = .26$ ($p < .01$) between verbal and quantitative sections, $r = .47$ ($p < .001$) between quantitative and analytical sections, and $r = .49$ ($p < .001$) between the verbal and analytical components. This study's results were lower than the correlations reported by Rock, Werts, and Grandy (1982). Rock, Werts, and Grandy (1982) found correlations of $r = .64$ between the verbal and quantitative sections, $r = .77$ between the quantitative and analytical sections, and $r = .77$ between the verbal and analytical components.

Table 4.1

Descriptive Statistics and the Lower Diagonal of Intercorrelations Among Study Variables

| | | | Intercorrelations | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Graduate School Success | | | | AFIT GEEM Selection Criteria | | | | | Control Variables | |
| Variable | M | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Success | | | | | | | | | | | | | |
| 1.GGPA | 3.69 | .16 | | | | | | | | | | | |
| 2.Thesis Grade | 3.72 | .31 | .64* | | | | | | | | | | |
| 3.First-year GGPA | 3.67 | .17 | .93* | .40* | | | | | | | | | |
| 4.Coursework GGPA | 3.69 | .17 | .79* | .39* | .97* | | | | | | | | |
| Selection Criteria | | | | | | | | | | | | | |
| 5.UGPA | 3.02 | .30 | .18* | .09 | .17* | .14* | | | | | | | |
| 6.GRE (V) | 525.03 | 76.75 | .25* | .02 | .29* | .30* | .16* | | | | | | |
| 7.GRE (Q) | 689.26 | 55.60 | .15* | -.02 | .20* | .24* | .22* | .38* | | | | | |
| 8.GRE (A) | 637.25 | 74.86 | .12 | -.03 | .17* | .20* | .12 | .38* | .46* | | | | |
| 9.UGPA (Math) | 2.91 | .50 | -.01 | -.05 | .02 | .01 | .61* | .08 | .17* | .08 | | | |
| Controls | | | | | | | | | | | | | |
| 10.Age | 27.62 | 3.38 | .14* | -.06 | .20* | .24* | .00 | .29* | -.01 | -.08 | .06 | | |
| 11.Gender[a] | .87 | .34 | -.03 | -.04 | -.07 | -.00 | .09 | -.05 | .12 | -.12 | .03 | .05 | |
| 12.Time between Undergraduate & Graduate Education | 4.27 | 2.96 | .18* | -.03 | .24* | .23* | -.27* | .25* | .04 | -.00 | -.16 | .77* | .03 |

Note. N ranges from 145 to 174. * $p < .05$.
a. Gender was binarily coded: 1 = Male, 0 = Female

*One-Way ANOVA*

In Table 4.2, significant differences in the mean values of each of the dependent variables was investigated according to gender, race, rank, and undergraduate institution using one-way ANOVA.

When one-way ANOVA was performed to investigate the significance of differences in mean dependent values according to gender, no significant differences were found for any of the four dependent variables.

When one-way ANOVA was performed to investigate the significance of differences in mean dependent values according to race, no significant differences were found for any of the four dependent variables.

When one-way ANOVA was performed to investigate the significance of differences in the mean dependent values according to rank, significant differences were found between the dependent variable means for first lieutenants and captains for GGPA ($\Delta M = -0.07$, $p < .05$), coursework GGPA ($\Delta M = -0.10$, $p < .05$), and FYGGPA ($\Delta M = -0.09$, $p < .05$) dependent variables except thesis grade.

When one-way ANOVA was performed to investigate the significance of differences in the mean dependent values according to whether or not the student attended a US Service Academy (USAFA: $N = 47$, USNA: $N = 2$), it was found that Service Academy graduate significantly had lower GGPA ($\Delta M = -0.06$, $p < .05$), coursework GGPA ($\Delta M = -0.06$, $p < .05$), and FYGGPA ($\Delta M = -0.07$, $p < .05$) than student who attended other undergraduate institutions.

Table 4.2

One-Way ANOVA Results for Demographic Variables (Gender, Race, Rank, and Undergraduate Institution) Against Measures of Success

| | Dependent Variables | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | GGPA | | Thesis Grade | | Coursework GGPA | | FYGGPA | |
| | M | SD | M | SD | M | SD | M | SD |
| Gender | | | | | | | | |
| Male | 3.69 | .16 | 3.71 | .31 | 3.69 | .15 | 3.66 | .17 |
| Female | 3.70 | .14 | 3.75 | .30 | 3.69 | .17 | 3.70 | .15 |
| ANOVA Results | F(1,151) = 0.17 | | F(1,149) = 0.29 | | F(1,150) = 0.00 | | F(1,147) = .079 | |
| Race | | | | | | | | |
| White | 3.69 | .16 | 3.72 | .30 | 3.69 | .17 | 3.67 | .17 |
| Black | 3.64 | .15 | 3.59 | .46 | 3.65 | .11 | 3.62 | .14 |
| Other | 3.70 | .15 | 3.79 | .22 | 3.68 | .15 | 3.66 | .17 |
| ANOVA Results | F(2,149) = 0.39 | | F(2,148) = 1.00 | | F(2,149) = 0.26 | | F(2,146) = 0.39 | |
| Rank | | | | | | | | |
| O-1 | 3.69 | .14 | 3.80 | .27 | 3.67 | .15 | 3.64 | .15 |
| O-2 | 3.65 | .15 | 3.70 | .27 | 3.64 | .16 | 3.63 | .17 |
| O-3 | 3.72 | .16 | 3.72 | .35 | 3.74 | .18 | 3.72 | .16 |
| O-4 | 3.81 | .15 | 3.67 | .35 | 3.84 | .13 | 3.83 | .14 |
| ANOVA Results | F(3,148) = 2.81* | | F(3,147) = 0.55 | | F(3,148) = 5.10* | | F(3,145) = 4.5* | |
| Undergraduate Institution | | | | | | | | |
| USAFA/USNA | 3.64 | .16 | 3.69 | .32 | 3.65 | .17 | 3.62 | .17 |
| Other Institutions | 3.70 | .15 | 3.73 | .30 | 3.71 | .17 | 3.69 | .17 |
| ANOVA Results | F(1,151) = 4.31* | | F(1,149) = 0.69 | | F(1,151) = 3.25 | | F(1,147) = 5.50* | |

Note. N varies according to missing data and group size. * $p < .05$

In Table 4.3, differences in the mean values of the admission requirements were investigated according to gender, race, rank, and undergraduate institution ('1' if from US Service Academy, '0' is otherwise) using one-way ANOVA.

When one-way ANOVA was performed to investigate the significance of differences in admission requirement mean values according to gender, no significant differences were found for any of the four admission requirements.

When one-way ANOVA was performed to investigate the significance of differences in mean admission requirement values according to race, no significant differences were found for any of the four admission requirements.

When one-way ANOVA was performed to investigate the significance of differences in the admission requirement mean values according to rank, significant differences were found between the admission requirement means for second lieutenants and captains for UGPA ($\Delta M = 0.26$, $p < .05$). Significant difference were found between second lieutenants and the other three, higher ranks for GRE (verbal) – between 0-1 and 0-2 ($\Delta M = -58.44$, $p < .05$), between 0-1 and 0-3 ($\Delta M = -67.90$, $p < .05$), and between 0-1 and 0-4 ($\Delta M = -119.61$, $p < .05$).

When one-way ANOVA was performed to investigate the significance of differences in the admission requirement mean values according to whether or not the student attended a US Service Academy (USAFA: $N = 47$, USNA: $N = 2$), it was found that Service Academy graduate significantly had lower UGPA ($\Delta M = -0.13$, $p < .05$), GRE (verbal) ($\Delta M = -48.60$, $p < .05$), and GRE (quantitative) ($\Delta M = -23.58$, $p < .05$) than student who attended other undergraduate institutions.

Table 4.3

One-Way ANOVA Results for Demographic Variables (Gender, Race, Rank, and Undergraduate Institution) Against Admission Requirements

| | Dependent Variables | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | UGPA | | GRE (verbal) | | GRE (quantitative) | | UMGPA | |
| | M | SD | M | SD | M | SD | M | SD |
| Gender | | | | | | | | |
| Male | 3.03 | .31 | 523.40 | 77.99 | 691.84 | 56.08 | 2.91 | .49 |
| Female | 2.95 | .27 | 535.45 | 68.99 | 672.73 | 50.44 | 2.87 | .54 |
| ANOVA Results | F(1,161) = 1.40 | | F(1,161) = 0.47 | | F(1,161) = 2.27 | | F(1,157) = .125 | |
| Race | | | | | | | | |
| White | 3.04 | .30 | 527.20 | 77.33 | 690.70 | 54.84 | 2.91 | .51 |
| Black | 2.80 | .28 | 513.75 | 64.13 | 652.50 | 50.64 | 2.76 | .36 |
| Other | 2.99 | .22 | 506.67 | 80.15 | 696.67 | 63.15 | 2.93 | .40 |
| ANOVA Results | F(2,160) = 2.37 | | F(2,160) = 0.48 | | F(2,160) = 1.93 | | F(2,156) = 0.38 | |
| Rank | | | | | | | | |
| O-1 | 3.21 | .24 | 467.89 | 77.72 | 696.32 | 57.27 | 3.05 | .39 |
| O-2 | 3.05 | .29 | 526.34 | 76.09 | 681.41 | 58.24 | 2.96 | .51 |
| O-3 | 2.94 | .30 | 535.80 | 71.01 | 696.38 | 52.69 | 2.81 | .50 |
| O-4 | 2.95 | .43 | 587.50 | 62.38 | 672.50 | 42.72 | 2.94 | .71 |
| ANOVA Results | F(3,159) = 4.59* | | F(3,159) = 5.23* | | F(3,159) = 1.07 | | F(3,155) = 1.74 | |
| Undergraduate Institution | | | | | | | | |
| USAFA/USNA | 3.06 | .30 | 489.55 | 75.51 | 672.05 | 49.44 | 2.84 | .38 |
| Other Institutions | 2.93 | .28 | 538.15 | 73.25 | 695.63 | 56.58 | 2.93 | .38 |
| ANOVA Results | F(1,162) = 6.34* | | F(1,161) = 13.91* | | F(1,161) = 5.96* | | F(1,157) = 1.16 | |

Note. N varies according to missing data and group size. * $p < .05$

*Hierarchical Multivariable Regression Results*

While descriptive statistics, alone, provide some insight into the predictive validity of the AFIT GEEM admission requirements, hierarchical multivariable regression analysis allows for further exploration of the relationships between admission requirements and measures of graduate school success, while controlling for potentially influential demographic variables – i.e., age, gender and TDELTA. Table 4.2 presents the standardized β coefficients for each of the five regression models under each dependent variable – GGPA, coursework GGPA, thesis grade, and FYGGPA. For all four dependent variables, the control variables – age, gender, and TDELTA – were not significant ($p > .05$) predictors of the respective measures of graduate school success when entered into a model by themselves.

For the GGPA model, TDELTA ($\beta = 0.38$, $p < .05$) and UGPA ($\beta = 0.29$, $p < .05$) were both significant only when UGPA was entered into the model beyond the control variables. Entering UGPA into the model significantly explained more variance in GGPA ($\Delta R^2 = .07$, $p < .05$), producing an $R^2 = .10$. When both GRE (verbal) ($\beta = 0.19$, $p < .05$) and GRE (quantitative) ($\beta = 0.08$, $p < .05$) were entered beyond the controls, only GRE (verbal) was significant. Entering both GRE scores beyond the control variables significantly explained more variance in GGPA ($\Delta R^2 = .05$, $p < .05$), producing an $R^2 = .08$. Only TDELTA ($\beta = 0.32$, $p < .05$) and UMGPA ($\beta = 0.35$, $p < .05$) were significant when all the independent and control variables were entered into the GGPA model. Entering all control and independent variables into the model significantly explained more variance in GGPA ($\Delta R^2 = .11$, $p < .05$), producing an $R^2 = .15$.

For the coursework GGPA model, only UGPA was significant ($\beta$ = .21, $p < .05$) in the model that consisted of controls and only UGPA. Adding UGPA to the model significantly explained more variance in coursework GGPA ($\Delta R^2$ = .03, $p < .05$), producing an $R^2$ = .10. Adding both the GRE (verbal) and GRE (quantitative) significantly explained more variance in coursework GGPA ($\Delta R^2$ = .08, $p < .05$), producing an $R^2$ = .14. However, only GRE (quantitative) ($\beta$ = .17, $p < .05$) was significant beyond the control variables. UMGPA was not significant ($\beta$ = .02, $p > .05$) when entered by itself beyond the control variables. When all control and predictor variables were entered into the model, none of the predictors were significant. However, adding all of the predictors to the model did significantly explain more variance in coursework GGPA ($\Delta R^2$ = .10, $p < .05$), producing an $R^2$ = .17.

For the thesis grade model, no admission requirements were significant when added individually beyond the control variables. For these models where admission requirements were entered individually beyond the control variables, none of the $\Delta R^2$ values were significant ($p < .05$). When all of the control and independent variables were entered into the model, only UMGPA was significant ($\beta$ = 0.24, $p < .05$). However, this result was not accompanied by a significant increase in explained variance in thesis grade ($\Delta R^2$ = .03, $p < .05$).

The FYGGPA model showed similar results to the GGPA model. The controls were not significant predictors of FYGGPA by themselves. However, when UGPA was added to the model, both UGPA ($\beta$ = 0.29, $p < .05$) and TDELTA ($\beta$ = 0.40, $p < .05$) were significant. Entering UGPA to the model significantly explained an additional seven percent of variance in FYGGPA beyond the control variables ($\Delta R^2$ = .07, $p < .05$), producing an $R^2 = .13$. When both GRE (verbal) ($\beta = 0.18$, $p < .05$) and GRE (quantitative) ($\beta = 0.14$, $p < .05$) were entered beyond the controls, only GRE (verbal) was significant. Entering both GRE scores into the model significantly explained an additional seven percent of the variance in FYGGPA beyond the control variables ($\Delta R^2 = .07$, $p < .05$), producing an $R^2 = .13$. Only TDELTA ($\beta = 0.23$) and UMGPA ($\beta = 0.05$) were significant ($p < .05$) when all the control and independent variables were entered into the model. Entering all the control and independent variables into the model significantly explained an additional twelve percent of the variance in FYGGPA beyond the model with only control variables ($\Delta R^2 = .12$, $p < .05$), producing an $R^2 = .19$.

Table 4.4

Standardized Beta Coefficients and Regression Goodness of Fit Statistics for AFIT GEEM Admission Requirements

| | Dependent Variables | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GGPA | | | | | Thesis Grade | | | | | Coursework GGPA | | | | | FYGGPA | | | | |
| | Standardized β Coefficients | | | | | Standardized β Coefficients | | | | | Standardized β Coefficients | | | | | Standardized β Coefficients | | | | |
| | 1[a] | 2[b] | 3[c] | 4[d] | 5[e] | 1[a] | 2[b] | 3[c] | 4[d] | 5[e] | 1[a] | 2[b] | 3[c] | 4[d] | 5[e] | 1[a] | 2[b] | 3[c] | 4[d] | 5[e] |
| Controls | | | | | | | | | | | | | | | | | | | | |
| Age | -.01 | -.16 | -.05 | –.02 | –.14 | -.09 | –.16 | -.12 | -.08 | -.16 | .17 | .06 | .14 | .16 | .10 | .05 | -.10 | .02 | .03 | –.07 |
| Gender[f] | –.04 | –.07 | -.04 | –.04 | –.06 | –.04 | –.05 | –.03 | –.04 | –.05 | -.01 | –.03 | –.02 | –.01 | –.04 | –.08 | –.11 | –.09 | –.08 | –.11 |
| Time between Undergraduate & Graduate Education | .19 | .38* | .17 | .20 | .32* | .05 | .14 | .05 | .03 | .13 | .10 | .23 | .07 | .11 | .14 | .20 | .40* | .18 | .23 | .32* |
| Selection Criteria | | | | | | | | | | | | | | | | | | | | |
| UGPA | | .29* | | | –.18 | | .13 | | | -.15 | | .21* | | | .21 | | .29* | | | -.15 |
| GRE (V) | | | .19* | | .15 | | | .06 | | .03 | | | .18 | | .15 | | | .18* | | .15 |
| GRE (Q) | | | .08 | | .04 | | | –.05 | | -.06 | | | .17* | | .16 | | | .14 | | .10 |
| UGPA (Math) | | | | .027 | .35* | | | | –.04 | .24* | | | | .02 | -.14 | | | | .05 | .32* |
| $R^2$ | .03 | .10 | .08 | .04 | .15 | .01 | .03 | .01 | .01 | .04 | .06 | .10 | .14 | .06 | .17 | .06 | .13 | .13 | .07 | .19 |
| $\Delta R^{2(g)}$ | - | .07* | .05* | .01 | .11* | - | .02 | 0 | 0 | .03 | - | .04* | .08* | .00 | .11* | - | .07* | .07* | .01 | .12* |

Notes. N ranges from 145 to 174. * $p < .05$

a. The regression model included only control variables.
b. The regression model included control variables and the UGPA.
c. The regression model included the control variables and the GRE (verbal) and GRE (quantitative) scores.
d. The regression model included the control variables and the UMGPA.
e. The regression model included the control variables and the UGPA, GRE (verbal), GRE (quantitative), and the UMGPA.
f. Gender was binarily coded: 1= Male, 0 = Female.
g. $\Delta R^2$ represents the change in $R^2$ from the $R^2$ of the model that contains only the control variables.

*Bivariate and Regression Analysis with GRE (Analytical) Scores*

Data was collected on the AFIT GEEM student's GRE (analytical) score (N = 163). The mean score of the GRE (analytical) component was M = 637.25 (SD = 74.86). The AFIT GEEM program does not require a minimum GRE (analytical) score. A ninety-five percent confidence interval about the mean GRE (analytical) score ranges from 513.73 to 760.77. Table 4.1 presents the bivariate correlations between variables in this study. Of the three measures of graduate school success, the GRE (analytical) section significantly correlated with both FYGGPA ($r = .17$, $p < .05$) and coursework GGPA ($r = .20$, $p < .05$). Table 4.3 presents the standardized β coefficients for each of three regression models – controls alone, controls with GRE (analytical), and controls with all predictor variables, including GRE (analytical) for each of four dependent variables.

When regressed against FYGGPA, the GRE (analytical) score was significant as the only predictor entered beyond the control variables ($\beta = 0.17$, $p < .05$). Adding only the GRE (analytical) score beyond the controls significantly explained more variance in FYGGPA ($\Delta R^2 = .03$, $p < .05$). When regressed against coursework GGPA, the GRE (analytical) score was significant as the only predictor beyond the control variables ($\beta = 0.22$, $p < .05$). Adding only the GRE (analytical) score beyond the controls significantly explained more variance in coursework GGPA ($\Delta R^2 = .05$, $p < .05$). The GRE (analytical) score was not significant as the only predictor beyond the controls in either the GGPA or thesis grade models.

When GRE (analytical) was entered into the FYGGPA regression model along with the controls and all other independent variables, only UGPA was significant ($\beta$ =

0.32, $p < .05$). When all the control and independent variables were entered into the FYGGPA model, more variance in FYGGPA was significantly explained ($\Delta R^2 = .13$, $p < .05$). UGPA was the only significant predictor when all control and independent variables were entered into the GGPA ($\beta = .35$, $p < .05$) and the thesis grade ($\beta = .24$, $p < .05$). The GGPA model that included all the control and independent variables significantly explained more variance in GGPA ($\Delta R^2 = .11$, $p < .05$). The thesis grade model that included all the control and independent variables did not significantly explain more variance in thesis grade ($\Delta R^2 = .03$, $p > .05$). When all the control and independent variables were entered into the coursework GGPA model, more variance in coursework GGPA was significantly explained ($\Delta R^2 = .11$, $p < .05$), although no single predictor was significant.

Table 4.5

Standardized Beta Coefficients and Regression Goodness of Fit Statistics for AFIT GEEM Admission Requirements and GRE (Analytical) Scores

| | GGPA Standardized β Coefficients | | | Thesis Grade Standardized β Coefficients | | | Coursework GGPA Standardized β Coefficients | | | FYGGPA Standardized β Coefficients | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1[a] | 2[b] | 3[c] | 1[a] | 2[b] | 3[c] | 1[a] | 2[b] | 3[c] | 1[a] | 2[b] | 3[c] |
| Controls | | | | | | | | | | | | |
| Age | -.01 | .01 | -.14 | -.09 | -.10 | -.18 | .17 | .21 | .12 | .05 | .08 | -.06 |
| Gender[d] | -.04 | -.03 | -.06 | -.04 | -.05 | -.06 | -.01 | .01 | -.03 | -.08 | -.06 | -.11 |
| Time between Undergraduate & Graduate Education | .19 | .17 | .32 | .05 | .05 | .14 | .10 | .07 | .13 | .20 | .18 | .31* |
| Selection Criteria | | | | | | | | | | | | |
| UGPA | | | .35* | | | .24* | | | .20 | | | .32* |
| GRE (V) | | | .15 | | | .52 | | | .13 | | | .14 |
| GRE (Q) | | | .04 | | | -.04 | | | .13 | | | .10 |
| GRE (A) | | .12 | .01 | | -.04 | -.07 | | .22* | .08 | | .17* | .03 |
| UGPA (Math) | | | -.18 | | | -.15 | | | -.14 | | | .03 |
| $R^2$ | .04 | .05 | .15 | .01 | .01 | .04 | .06 | .11 | .17 | .06 | .09 | .19 |
| $\Delta R^{2(e)}$ | - | .01 | .11* | - | .00 | .03 | - | .05* | .11* | - | .03* | .13* |

Notes. N ranges from 145 to 174. * $p < .05$
a. The regression model included only the control variables.
b. The regression model included the control variables and the GRE (analytical).
c. The regression model included the control variables, the UGPA, the GRE (verbal), GRE (quantitative), GRE (analytical), and the UMGPA.
d. Gender was binarily coded: 1 = Male, 0 = Female.
e. The $\Delta R^2$ represents the change in $R^2$ from the $R^2$ of the regression model with only the control variables.

## Discussion

### *General Conclusion*

This study examined the predictive validity of the AFIT GEEM admission requirements – UGPA, GRE (verbal), GRE (quantitative), and UMGPA – against four measures of graduate school success – GGPA, thesis grade, coursework GGPA, and FYGGPA – for the population of 173 students from the classes of 1995 through 2002.

Descriptive statistics of the admission requirements and the measures of graduate performance revealed that students were admitted from a broad range of undergraduate scores, both above and below the stated minimum admission standards, but on the graduate performance grade scale, which extended from 3.00 to 4.00, student performance huddled within a remarkably tight range. For example, the lower end of the ninety-five percent confidence intervals about the mean UGPA ($\underline{M}$ = 3.02, $\underline{SD}$ = .30) and the mean UMGPA ($\underline{M}$ = 2.91, $\underline{SD}$ = .50) extended from 2.53 and 2.09, respectively. Lower-end confidence intervals about the mean GRE (verbal) score ($\underline{M}$ = 525.03,$\underline{SD}$ = 76.75) and the mean GRE (quantitative) score ($\underline{M}$ = 689.26, $\underline{SD}$ = 55.60) extended from 389.39 and 597.52, respectively. Yet, the confidence interval about the mean GGPA ($\underline{M}$ = 3.69, $\underline{SD}$ = .16) was distinctively tighter than those about the means of the admission requirements, ranging from 3.43 to 3.95. The FYGGPA and coursework GGPA also saw a clustering of student performance in a tight range in the upper-half of the graduate performance measurement scale. A slightly larger confidence interval extended beyond the mean thesis grade ($\underline{M}$ = 3.72, $\underline{SD}$ = .31), ranging from 3.21 to 4.00. The interval was wider than those around the other three measures of performance only because thesis grades were awarded at distinct levels on the scale of assignable grades.

One-way ANOVA of the admission requirements and measures of graduate performance revealed statistically significant differences in only a few of the mean values according to gender, race, rank, and undergraduate institution (coded as a '1' if the student attended a US Service Academy, '0' if otherwise). For example, one-way ANOVA did not highlight any statistically significant differences in the means of any of the four admission requirements or any of the four measures of graduate school success according to race and gender. This result is quite possibly the product of the small number of women (N = 23) and minorities (N = 19) in the population used in this study. The population was predominantly white and male and there were, arguably, proportionately not enough women and minorities to highlight the differences in admission requirements or performance means significantly. This hypothesis is supported by the results of the one-way analyses for rank and undergraduate institution, where students at different ranks existed in more proportional numbers throughout the population. When analyzed by military rank, significant differences in the means of UGPA, GRE (verbal), GGPA, coursework GGPA, and FYGGPA appeared. Statistically significant differences also appeared for UGPA, GRE (verbal), GRE (quantitative), GGPA, and FYGGPA according to whether or not the student attended a US Service Academy (coded as a '1').

Bivariate correlation analysis revealed weak to moderate statistically significant relationships between the admission requirements and the measures of graduate school success. In general, the UGPA, GRE (verbal), and GRE (quantitative) score correlated significantly with the GGPA, coursework GGPA, and FYGGPA. Although not strong, there was some weak-to-moderate relationship between the admission requirements and the graduate grade-based measures of performance. UMGPA, however, demonstrated no significant correlations with any of the measures of graduate school performance. If the purpose of the AFIT GEEM admission process is to identify those students with the greatest potential to perform, as defined graduate grades and the thesis grade, then the UMGPA is a useless predictor. It significantly explains no variance in the dependent measures of graduate school performance and should not be used as a discriminator among applicants. The thesis grade did not correlate significantly with any of the AFIT GEEM admission requirements. The admission requirements have no predictive validity against the thesis grade and, therefore, cannot differentiate between applicant levels of graduate performance potential.

Hierarchical regression analysis revealed that the admission requirements are more often significant predictors of graduate school success when entered into a regression model by themselves. When entered into a regression model together, there is an increase in the variance explained – most likely due to an increase in the number of variables in the model – but few, if any, of the predictors are significant. For example, when UGPA was entered by itself, it was a significant predictor for GGPA ($\beta = .29$, $p < .05$), coursework GGPA ($\beta = .21$, $p < .05$), and FYGGPA ($\beta = .29$, $p < .05$). Significant coefficients for UGPA were also found for GGPA ($\beta = .35$, $p < .05$), thesis grade ($\beta = .24$, $p < .05$), and FYGGPA ($\beta = .32$, $p < .05$) when all controls and independent variables, including GRE (analytical) were entered into the regression model. Significant coefficients were derived for GRE (verbal), entered by itself beyond the control variables, for GGPA ($\beta = .19$, $p < .05$) and FYGGPA ($\beta = .18$, $p < .05$). A significant coefficient for GRE (quantitative), entered by itself beyond the control variables, was derived only against coursework GGPA ($\beta = .17$, $p < .05$). Significant coefficients for UMGPA were only derived in combination with all controls and other independent variables against coursework GGPA ($\beta = .17$, $p < .05$). The coefficients for GRE (analytical), entered by itself beyond the control variables, were only significant for coursework GGPA ($\beta = .22$, $p < .05$) and FYGGPA ($\beta = .17$, $p < .05$). TDELTA was the only control variable that had significant Beta coefficients: with UGPA against GGPA ($\beta = .38$, $p < .05$) and FYGGPA ($\beta = .40$, $p < .05$) and in combination with all other independent variables for GGPA ($\beta = .32$, $p < .05$), FYGGPA without GRE (analytical) ($\beta = .32$, $p < .05$), and FYGGPA with GRE (analytical) ($\beta = .31$, $p < .05$).

The descriptive, ANOVA, correlation, and regression results of this study support the conclusion that the AFIT GEEM admission requirements are not the only influences on the student's performance in graduate school. There must be some other influences that cause the clustering of student graduate performance despite broad ranging undergraduate backgrounds. One-way ANOVA shows that military rank and undergraduate institution may have some influence on performance, for the means of graduate performance variables significantly differed by these classifications. Although the ANOVA did not show any significant differences in means according to race and gender, these findings are suspect considering the small representation of these groups in the population. So, while the one-way analysis on race and gender did not directly provide support for the conclusion that there are other influences on graduate school performance, it did not directly work against the conclusion either. Weak-to-moderate correlations between admission requirements and measures of graduate school success further support the conclusion that there are other influences on graduate school performance than the stated admission requirements.

Currently, UGPA, GRE (verbal), GRE (quantitative), and UMGPA are, officially, the only influences on the student's admission to the AFIT GEEM program. The AFIT GEEM program does not officially consider gender, race, rank, or undergraduate institution in admitting students. The results of this study do not imply that the AFIT GEEM admission process is necessarily a bad process. These results merely suggest that the current AFIT GEEM admission is simply not the best process and that the process may be improved by looking at other influences on graduate school performance.

*Assumptions*

The major conclusion of this study – that there are other influences on graduate performance – relies upon two assumptions: first, generalizations could be made from the population used; and second, the measures of graduate school success used in this study were appropriate to the goals of the AFIT GEEM program.

*Population*. Before performing any statistical analysis, it was thought that the tremendous homogeneity found in the population would produce higher predictive validity coefficients than those published in most other studies. It was thought that racial homogeneity (most of the population was White) would serve to minimize concerns over racial bias in the UGPA and GRE General Test scores. Gender homogeneity (most of the population was male) would serve to minimize concerns over gender bias in the UGPA or GRE General Test scores. Considering that the majority of students in the population were US military officers with engineering undergraduate degrees and that a good number of the students (47 of the 173 students) came from the same undergraduate institution – the US Air Force Academy, it was thought that this study would succeed in minimizing the "noisy data problems" caused by differing backgrounds and academic experience (Schneider and Briel, 1990).

However, the results of this study did not produce the expected predictive validity coefficients. Bivariate correlations of the admission requirements against FYGGPA were slightly lower than those published in the ETS's 2000-2001 Guide to the Use of Scores for engineering graduate students. Homogeneity of the population cannot be blamed, specifically, for this study's slightly weaker relationships. The ETS qualifies its results with a warning that "available samples of minority students…have been very small" (ETS Guide to the Use of Scores, 2000-2001: p. #9). Rather, homogeneity can, more appropriately, be suspected for contributing to the weak predictive relationships, in general. For example, while most of the population was White, not all of the population was White. While most of the population was male, not all of the population was male. If racial and gender bias existed in UGPA and GRE measures recorded in this study, it is possible that those biases were not adequately accounted for in the correlation and regression coefficients. When the overwhelming majority of the population bears a specific characteristic – i.e., eighty-seven percent of the population was male -- the contribution of the minority characteristics are minimized in correlation and regression analyses. If the contributions of these students are minimized, then this study cannot completely investigate the predictive validity of the AFIT GEEM admission requirements.

If homogeneity of the population does, in fact, reduce the predictive validity of the coefficients, then questions about the generalizability of this study's results are appropriately raised. Originally, this study was designed to focus, specifically, on validating the AFIT GEEM admission criteria. Generalizability beyond the context of the GEEM program was not a primary concern at the outset. However, in hindsight, the results of this study may be of interest to other eighty-one graduate engineering management programs published in the 2001 Peterson's Guide to Graduate Education in Engineering and the Applied Sciences. The AFIT GEEM program admission requirements and process are not terribly different from the majority of these programs. Other validity studies on graduate engineering management admission requirements may benefit from the realization that the UMGPA does not correlate with any of the four measures of graduate school success. They may benefit from the realization that the thesis grade does not satisfy the normality and constant error variance assumptions of the General Linear Model (GLM) and that none of the admission requirements significantly correlated with the thesis grade. Most importantly, other studies may benefit from the realization that although AFIT admits students both well below and above its minimum admission requirements, the mean AFIT GEEM GGPA is $M = 3.69$ ($SD = .16$) with a ninety-five percent confidence interval about that mean ranging from 3.43 to 3.95. Other programs may find that their admission requirements perform in a manner similar to those of the AFIT GEEM program and can enhance their own admissions processes by identifying the other influences on graduate performance.

*Measures of Graduate School Success.* Before examining the validity of admission requirements or positing any other influences on graduate performance, however, the conceptualization of graduate school success must developed. The measures of graduate school success must be in-line with the goals of the respective graduate program. The AFIT GEEM program focuses on coursework and research, accomplished through the thesis study. As seen in this study, however, the thesis grade was statistically not a good measure of graduate performance. The thesis grade does not satisfy two of the major assumptions of the General Linear Model and, thereby, prevents the use of regression analysis.

However, there were not too many alternative definitions for graduate school success in the AFIT GEEM program. For the classes of 1995 through 2002, 99.4% of students graduated within eighteen month and completed a thesis study. There has been no consistent capstone course in the AFIT GEEM program over the study period. Graduate grade-based measures of success were the only viable alternatives for the AFIT GEEM program. Dependent measures like the FYGGPA and coursework GGPA captured student performance in the graduate classroom but neglected the research aspect of the AFIT experience. Perhaps the best measure, from a definitional standpoint, was the GGPA, which captured the six quarters of coursework grades and the thesis grade. Despite the GGPA being the optimal conceptualization – strictly in the sense that in captured both the coursework and research aspects of the AFIT GEEM program's focus – the admission requirements still did not demonstrate tremendous predictive validity of this measure.

On that point, this study recommends one of two courses of action: either keep the GGPA as the measure of success and search for other influential admissions data; or find a different measure of graduate school success for which the current admission requirements demonstrate a higher predictive validity.

# Appendix A

| Number and Types of Degrees Earned by AFIT GEEM Students from 1995-2002 | |
|---|---|
| **Degree** | **Count** |
| AeroEng | 1 |
| Arch Eng | 1 |
| BAE, Arch Engr | 1 |
| BS Architecture | 1 |
| BS ENG SCI | 1 |
| BS Physics | 1 |
| BS, Aero Engr | 1 |
| BS, Architecture | 2 |
| BS, Biology | 2 |
| BS, CE | 79 |
| BS, CE (ENV) | 8 |
| BS, CE (HCON) | 1 |
| BS, Chemistry | 1 |
| BS, Chem Engr | 1 |
| BS, EE | 24 |
| BS, EE (BEE) | 4 |
| BS, ENG | 1 |
| BS, Economics | 1 |
| BS, Engr Mech | 1 |
| BS, Env Eng | 3 |
| BS, Env Sci | 1 |
| BS, Geo/Math | 1 |
| BS, Geology | 1 |
| BS, Industrial Engineering | 6 |
| BS, Intl Affairs | 1 |
| BS, Mech Eng | 27 |
| BS, Oceanography | 1 |
| BS, OE | 1 |
| **Total** | **174** |

*One student obtained two BS degrees: a BS, EE from SUNY Binghamton and a BS, Biology from USAFA.

Appendix B

| Number of Students in AFIT GEEM (1995-2002) for Varied Undergraduate Institutions | | | |
|---|---|---|---|
| Undegraduate Institution | Count | Undergraduate Institution | Count |
| Arizona SU | 2 | | |
| Auburn | 2 | Stevens Institute | 1 |
| BYU | 2 | Syracuse U | 2 |
| Carnegie Mellon | 2 | Texas A&M | 5 |
| Citadel | 1 | Texas Tech | 1 |
| Clarkson U | 3 | Tufts | 1 |
| Clemson | 3 | U Akron | 1 |
| Fl Intl U | 1 | U Alabama | 1 |
| Florida SU | 1 | U Arizona | 1 |
| Geneva College | 1 | U Cinncinnati | 2 |
| Georgia Tech | 4 | U Florida | 2 |
| Humbolt State | 1 | U Illinois | 3 |
| Illinois IT | 1 | U Kentucky | 2 |
| Illinois SU | 1 | U Louisville | 2 |
| LSU | 2 | U Maine | 1 |
| Lehigh | 2 | U Minnesota | 2 |
| Loyola Marymont | 1 | U Missouri | 1 |
| MIT | 1 | U Missouri - Columbia | 1 |
| Michigan SU | 1 | U Missouri - Rolla | 3 |
| Milwaukee Sc Eng | 1 | U New Hampshire | 3 |
| Montana SU | 3 | U Oklahoma | 1 |
| NC A&T | 1 | U Portland | 2 |
| NC State | 1 | U Santa Clara | 2 |
| New Mexico SU | 1 | U So Florida | 1 |
| Notre Dame | 1 | U Tennessee | 2 |
| OK Christian U | 2 | U Texas | 1 |
| Ohio SU | 4 | U Toledo | 1 |
| Ohio U | 1 | U Washington | 2 |
| Oklahoma SU | 1 | USAFA | 47 |
| Oregon SU | 3 | USC | 1 |
| Penn State | 5 | USNA | 2 |
| Purdue | 1 | UVA | 1 |
| RPI | 3 | VMI | 3 |
| Rose-Hulman | 2 | Vanderbilt | 1 |
| SUNY Binghamton | 1 | W. New Eng. College | 2 |
| So Dakota School of Mines | 1 | Washington SU | 1 |
| So Illinois U | 1 | Worcester PI | 1 |
| South Dakota SU | 2 | Total | 173 |

Appendix C.1

10 October 2001

MEMORANDUM FOR AFIT/RRD

FROM: AFIT/ENV

SUBJECT: Request for Access to Educational Records for Research

1. In partial fulfillment of the AFIT graduation requirements, I have proposed to conduct a thesis study, focused on examining the validity of graduate level admissions criteria as predictors of academic success for students in the Engineering and Environmental Management program. The proposed study relies upon information about current students and graduates found in education records and the personnel data system (PDS). This letter documents a formal request before AFIT/RRD for access to educational records and the PDS in pursuit of the proposed study.
2. Based on 34 CFR § 99.31 (a)(1) of the Family Educational Rights and Privacy Act of 1974 (FERPA) regulation, disclosure of educational records is allowed, within an agency, when the agency has determined the requestor has a "legitimate educational interest." I submit to you that the proposed study meets such a standard for it seeks to advance the Institute's ability, in the context of the contemporary applicant pool, to select those candidates most likely to thrive in the AFIT academic environment. The publication of several preceding, similarly focused, theses efforts testifies to continual need for reexamination of such a study with the progressive changes in the Air Force's demographic. In light of programmatic changes and several subsequent years of continuity, I maintain that the time has come to, again, reexamine the admissions criteria for graduate students in the Engineering and Environmental Management program. Additional guidance on this issue can be found in the 1998 "Guidelines for Postsecondary Institutions for Implementation of the Family Educational Rights and Privacy Act of 1974 as Amended," published by the American Association of Collegiate Registrars and Admissions Officers. The example provided on page 72 justifies granting a similar request.
3. Any and all information obtained as part of the proposed study will remain confidential among Major Mark Ward, Dr. Charles Bleckmann, Major Daniel Holt, and myself. No information about any individual will be disclosed to anyone beyond those persons previously named. Results of this research will be presented only in aggregate form. Names of the data subjects will appear nowhere in the study or any associated reports.
4. The proposed study considers all students enrolled in AFIT's Graduate Engineering and Environmental Management program from 1993 through 2001 to be viable data subjects. The proposed predictors of academic success mirror the AFIT admission requirements: Undergraduate Grade Point Average (UGPA) and Graduate Review Examination (GRE) and/or Graduate Management Admission Test (GMAT) scores. The proposed measure of academic success relies upon Cumulative and Quarterly AFIT GPA and AFIT thesis grade, as documented in educational records. To the best of my knowledge, the data hereby requested is sufficient to execute the proposed study. However, should different data be required, I will submit an second request to AFIT/RRD at that time.

5. Please direct all questions to either me or Major Daniel Holt. I can be reached at (937)431 8565 or charles.zitzmann@afit.edu. Major Holt can be reached at X 2998 or daniel.holt@afit.edu.

CHARLES C. ZITZMAN, LT, USAF
Graduate Student
AFIT/ENV

DANIEL T. HOLT, MAJ, USAF
Instructor
AFIT/ENV

File 10 DTH

# Registrar's Office
# Air Force Institute of Technology

Admissions and Registrar Directorate, Wright-Patterson Air Force Base, Ohio 45433-7102

**Memorandum for Record** **15 Oct 2001**

Access to Student Records

1. Purpose of the research: Determine the predictive validity of the Engineering & Environmental Management's selection criteria. That is, do the selection criteria predict graduate school success.

2. Data needed (e.g., GPA, GMAT, GRE): Undergraduate GPA, Undergraduate math GPA, GRE scores, AFIT GPA, AFIT Thesis grade

3. The group to which the needed data is limited (e.g., specific program, GPA < 3.0, etc): Students enrolled and graduated from the GEE program since 1993.

15 Oct 2001

Signature (I agree to protect the confidentiality of the data gathered) (date)
CHARLES C. ZITZMANN, 1st Lt, USAF

15 Oct 2001

Instructor/Advisor's signature (I approve the project described above~~/attached~~) (date)
DANIEL T. HOLT, Major, USAF

RANDELL BAKER
**Associate Registrar**
**Air Force Institute of Technology**

Appendix D.1

Figure 1

Frequency Histogram of GGPA

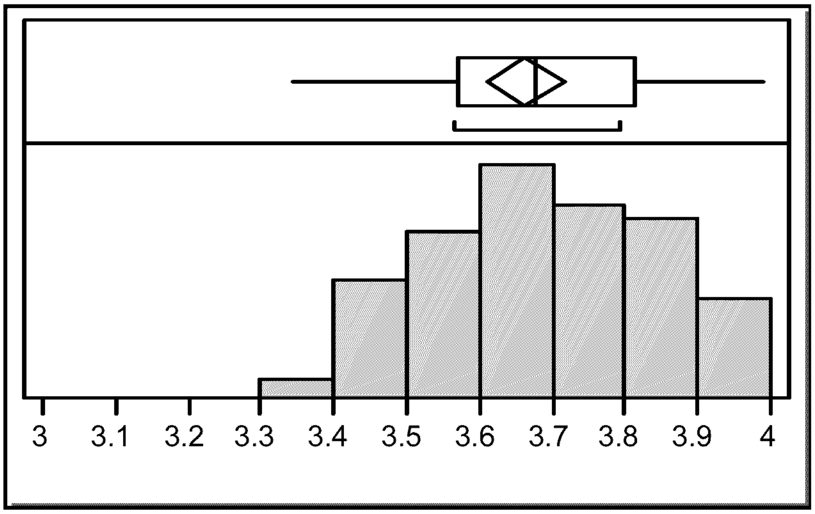
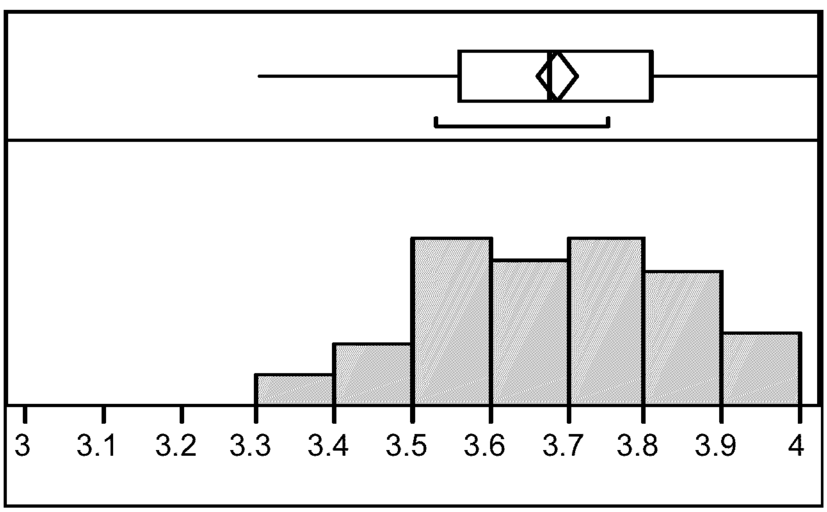



Figure 2

Frequency Histogram of Coursework GGPA



Appendix D.2

Figure 3

Frequency Histogram of Thesis Grade

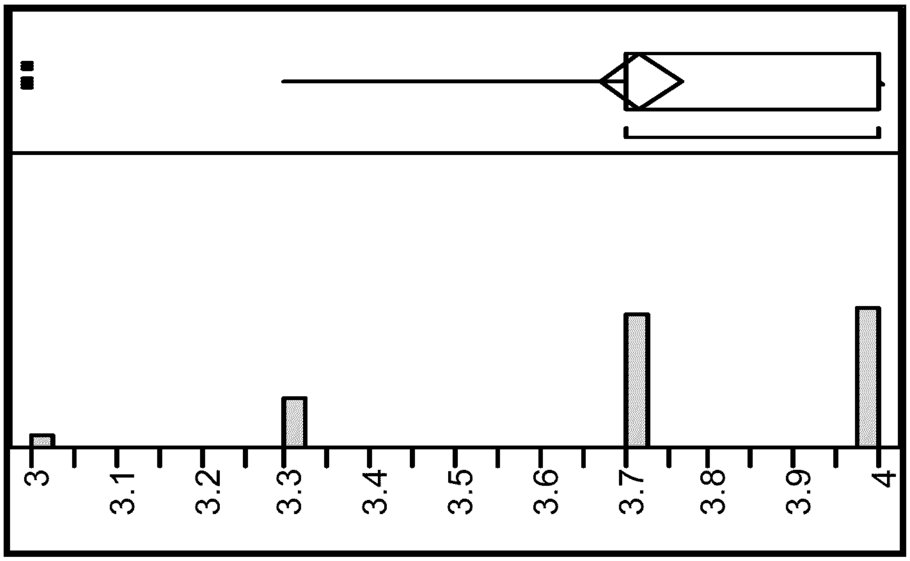
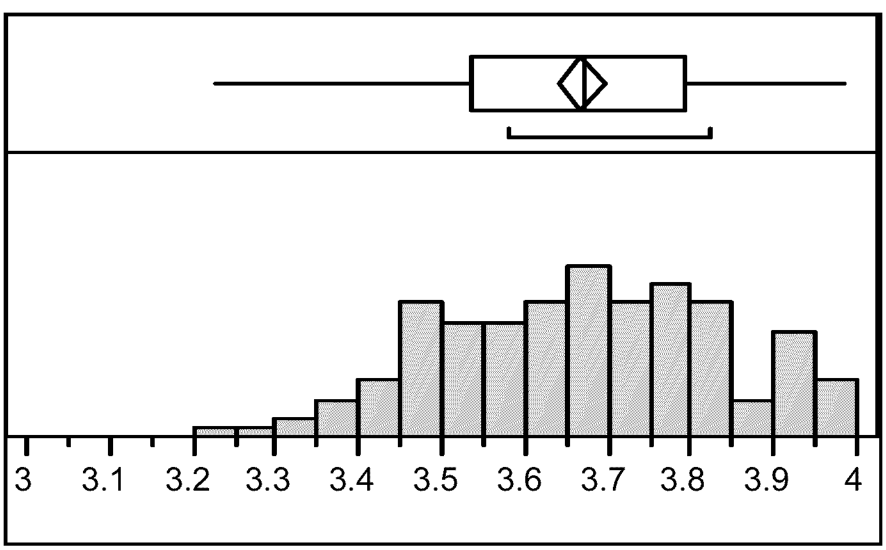



Figure 4

Frequency Histogram of FYGGPA



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## Vita

First Lieutenant Charles C. Zitzmann graduated from Chaminade High School in Mineola, Long Island, New York. He entered undergraduate studies at the United States Air Force Academy, where he graduated with a Bachelor of Science degree in Legal Studies in May 1998.

His first assignment was at Wright-Patterson AFB as a cost analyst in the Reconnaissance System Program Office, Global Hawk Unmanned Aerial Vehicle Program in August 1998. In August 2000, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the Air Force Cost Analysis Agency in Crystal City, Virginia.

## REPORT DOCUMENTATION PAGE

*Form Approved OMB No. 074-0188*



| 1. REPORT DATE (*DD-MM-YYYY*) | 2. REPORT TYPE | 3. DATES COVERED (*From – To*) |
|---|---|---|
| 26-03-2002 | **Master's Thesis** | Aug 2001 – Mar 2002 |

**4. TITLE AND SUBTITLE**

THE PREDICTIVE VALIDITY OF THE AFIT GRADUATE ENGINEERING AND ENVIRONMENTAL (GEEM) ADMISSION REQUIREMENTS.

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**

Zitzmann, Charles, C., First Lieutenant, USAF

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)**

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**8. PERFORMING ORGANIZATION REPORT NUMBER**

AFIT/GAQ/ENV/02M-16

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

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**10. SPONSOR/MONITOR'S ACRONYM(S)**

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

Recognizing that a "strong commitment to advanced technical and management education" (Van Scotter, 1993, p. 1) serves to maintain the capability and strength of the United States Air Force (USAF), the Air Force Institute of Technology (AFIT) Graduate School of Engineering and Management (GSEM) offers a full-time, eighteen-month, Graduate Engineering and Environmental Management (GEEM) program to military officers and Department of Defense (DoD) civilian employees. The AFIT uses the applicant's undergraduate grade-point average (UGPA), Graduate Record Examination (GRE) General Test verbal and quantitative scores, and undergraduate mathematics course grade-point average (UMGPA) to select applicants for admission.

This study analyzed how well these selection devices predicted success in the GEEM program for students admitted to the classes of 1995 through 2002. Controlling for age, gender, and the time (in years) between undergraduate and graduate education (TDELTA), the UGPA, GRE (verbal) score, GRE (quantitative) score, and UMGPA were sequentially entered into a hierarchical, multivariable, linear regression model. Using this technique, three separate regression model were built, one for each operationalization of graduate school performance: cumulative graduate grade-point average (GGPA), AFIT thesis grade, and first-year graduate grade-point average (FYGGPA).

Every independent variable, either alone or in combination with other predictor variables, except for age, gender, and GRE (quantitative), demonstrated statistical significance as a predictor of both FYGGPA and GGPA. Only UMGPA, combined with all other predictor variables, significantly predicted thesis grade.

**15. SUBJECT TERMS**

GRE, Graduate Education, Grade-Point Average, Admission Requirements, Graduate School Success, Academic Performance

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
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| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | Mark A. Ward, Maj, USAF (ENV) |
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