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Women in Science, Technology, Engineering, and Mathematics in the United States Air Force Research Laboratory: Factors Associated with Attrition and Promotion

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Air Force Research Laboratory

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14. ABSTRACT

For United States (U.S.) government civilian employees in Science, Technology, Engineering, and Mathematics (STEM) fields across the Air Force Research Laboratory (AFRL), this effort investigated various differences between men and women including promotion and attrition. Data obtained from a personnel database in January 2020 revealed 3,103 personnel in the AFRL STEM workforce covering equivalent civil service grade levels GS-07 through GS-15, which consisted of 545 (17.56%) women and 2,558 (82.44%) men. Women and men differed with regard to grade level (Z=-7.4663, p<0.0001), base salary (t(3,101)=8.4183, p<0.0001), education (for doctoral degrees p=0.0013, OR=1.5493, 95% CI (1.1853, 2.0250)), age (t(3,101)=5.8568, p<0.0001), time in AFRL (t(852.7149)=5.5374, p<0.0001), veteran status (p<0.0001, OR=1.8433, 95% CI (1.4842, 2.2892)), and minority status (p<0.0001, OR=1.8218, 95% CI (1.4483, 2.2916)). The relationship between gender and grade level, after controlling for education, age, and veteran status, showed that men were 21.0% more likely to be of a higher grade level (p<0.0001, OR=1.2102, 95% CI (1.1013, 1.3298)). Utilizing additional data from 2010-2018, the average annual attrition, or the reduction in staff due to all causes, was 6.6%; attrition was higher for women every year except 2013 (i.e., federal sequestration). For a subset of personnel who started in AFRL between 2011 and 2018, women were 57.1% more likely to leave the organization compared to men (p=0.0002, Odds Ratio=1.5713, 95% CI (1.2359, 1.9976)). Understanding these discrepancies is critical to the success of AFRL in meeting national security priorities.

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1.0 ABSTRACT

For United States (U.S.) government civilian employees in Science, Technology, Engineering, and Mathematics (STEM) fields across the Air Force Research Laboratory (AFRL), this effort investigated various differences between men and women including promotion and attrition. Data obtained from a personnel database in January 2020 revealed 3,103 personnel in the AFRL STEM workforce covering equivalent civil service grade levels General Schedule (GS)-07 through GS-15, which consisted of 545 (17.56 percent (%)) women and 2,558 (82.44%) men. Women and men differed with regard to grade level (Z=-7.4663, p<0.0001), base salary (t(3,101)=8.4183, p<0.0001), education (for doctoral degrees p=0.0013, odds ratio (OR)=1.5493, 95% confidence interval (CI) (1.1853, 2.0250)), age (t(3,101)=5.8568, p<0.0001), time in AFRL (t(852.7149)=5.5374, p<0.0001), veteran status (p<0.0001, OR=1.8433, 95% CI (1.4842, 2.2892)), and minority status (p<0.0001, OR=1.8218, 95% CI (1.4483, 2.2916)). The relationship between gender and grade level, after controlling for education, age, and veteran status, showed that men were 21.0% more likely to be of a higher grade level (p<0.0001, OR=1.2102, 95% CI (1.1013, 1.3298)). Utilizing additional data from 2010-2018, the average annual attrition, or the reduction in staff due to all causes, was 6.6%; attrition was higher for women every year except 2013 (i.e., federal sequestration). For a subset of personnel who started in AFRL between 2011 and 2018, women were 57.1% more likely to leave the organization compared to men (p=0.0002, OR=1.5713, 95% CI (1.2359, 1.9976)). Understanding these discrepancies is critical to the success of AFRL in meeting national security priorities.

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2.0 INTRODUCTION

In an era of globalized technology, competitive markets, and trends toward knowledge-based economies, the most successful organizations must constantly innovate at the leading-edge. Such an innovative organization depends on access to the latest technological advancements as well as the right mix of human resources [1]. People with science, engineering, and research skills are a necessary part of this mix. However, organizations must think holistically, beyond the sum of individuals' education and experience, and consider what combination of personnel and skillsets most effectively innovates *as a whole*. From an organizational leadership standpoint, the question is, "What balance of personnel investments will reap the greatest returns?" This enduring question has often been centered on diversity and is most frequently investigated with qualitative (versus quantitative) studies [2].

Quantifying a return on investment in human resources is challenging due in part to: (1) indirect relationship with organizational outcomes; (2) lack of data. Research on this topic has thus skewed towards qualitative analyses. However, two recent studies employed quantitative statistical methods to analyze the relationship between diversity and organizational outcomes for a combination of over one thousand companies in fifteen countries [2,3]. The McKinsey study established a statistically significant positive correlation between gender diversity at the highest levels of an organization and the likelihood of two financial performance indicators being above industry median: profitability (21% likelihood above industry median, $N=991$, $p<0.05$) and long-term value creation (27% likelihood above industry median,($N=991$, $p<0.05$) [2]. The Boston Consulting Group study identified a statistically significant ($N = 171$, $p < 0.05$) positive relationship between gender diversity in management positions (at any level) and innovation revenue (revenues from enhanced or entirely new products/services in the most recent three-year

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period) [3]. Notably, a high percentage of female employees has no statistically significant effect on innovation unless women hold more than 20% of management positions (Lorenzo et al, 2017). Although these studies identify a correlation between diversity and organizational outcomes, causation has not yet been proven. Nonetheless, the studies indicate a progressive move towards more rigorous, quantitative, data-driven approaches to understanding the link between an organization's demographics and its effectiveness in a competitive global environment.

The AFRL is the hub of science and technology innovation for the U.S. Air Force (USAF) and U.S. Space Force (USSF). For AFRL, the drive to innovate goes far beyond a business case. The national security of the U.S. depends on AFRL and other Federal research labs to remain steadfast global leaders in technological innovation [4]. Delivering on this promise requires attracting and sustaining the most capable and effective technical workforce [5].

In the context of recent research that links diversity to innovation, and as one part of a self-examination toward this end, the AFRL Commander requested an analysis of the gender diversity of the workforce. This analysis explored two specific areas:

1. Promotion: Do women get promoted in AFRL? Are they in leadership positions? How does AFRL compare to the U.S. STEM workforce? If promotion is a challenge, what are the barriers?
2. Attrition: Do women stay in AFRL? If not, when do they leave? How does AFRL compare to the U.S. STEM workforce? If retention is a challenge, why do women leave?

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AFRL personnel data were statistically analyzed to investigate these questions. This analysis does not investigate the relationship with organizational outcomes, e.g. innovation metrics. Such follow-on investigations would be insightful towards understanding the impact of the results brought to light by this study. Nonetheless, the current results are considered and discussed in the context of relevant published research. Findings and recommendations were presented to the AFRL Executive Leadership.

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3.0 METHODS

Literature Search

Leveraging library staff expertise at the United States Air Force School of Aerospace Medicine (USAFSAM) Franzello Aeromedical Library, the medical library associated with the AFRL, two main areas were explored: 1) Are female STEM employees getting promoted, as compared to their male counterparts? and 2) Are female STEM employees leaving their jobs at a higher rate than their male counterparts? The ProQuest database revealed 17 peer-reviewed articles, PubMed revealed 16 peer-reviewed articles, and library staff recommended 26 additional results. An internet search of the popular published book literature also revealed 14 additional potential sources of information, and discussions with colleagues involved in the effort uncovered 26 additional reports. Redundant sources were eliminated. Sources were reviewed for relevance and scientific merit. Specifically, written material which was opinion-based or anecdotal was culled. Research focused on higher education, and education in general was not investigated in-depth, as that was outside the scope of this effort.

Data Sources

Data were obtained from electronic personnel databases from the AFRL Personnel Directorate. The first dataset was extracted in January 2020, included the following variables for all current AFRL employees: age; veteran status (not a veteran; pre-Vietnam-era veteran; Vietnam-era veteran; post-Vietnam-era veteran; not a Vietnam-era veteran); organizational office code (from which technical directorate was defined); base salary; salary including locality pay; pay plan code (used to identify those in the Scientist & Engineer career fields); occupational series code (used to create career field categories); grade level; gender/minority status (minority female; minority male; white female; white male); Professional Military Education (PME) completion

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dates (from which a completion yes/no variable was created); position title (from which supervisory status was obtained); start date (from which time in AFRL was calculated); and educational degree levels obtained (highest level was retained). These data were used for descriptive statistics and to investigate factors associated with promotion to a higher grade level.

Additional historical data were obtained from a separate personnel database to conduct a longitudinal analysis to investigate attrition. An annual data pull was extracted from the start of each calendar year (i.e., January), covering the years 2010-2019 (inclusive). These data included a subset of the variables listed above, with the same data types: base salary; gender/minority status; position title; pay plan code; occupational series code; and grade level. In addition, duty station location (i.e., U.S. state) was included. Data from January 2019 were utilized to determine if personnel who were in the dataset in January 2018 were still in the dataset, and thus still in AFRL. If they were no longer in the dataset, they were considered to have left AFRL. This logic was repeated for all available years, creating a longitudinal dataset that included data from 2010 to 2018. Data from 2019 were not included as they were not available for the entire year (however, they were used to determine which personnel were still in AFRL at the end of 2018). Because the data were from a different personnel database than the one previously listed, January 2020 data were not included in the attrition analysis.

Descriptive Statistics

First, this effort investigated differences between men and women with regard to descriptive statistics. Depending on the variable type, the following statistical tests were utilized: for ordinal data, a Cochran-Armitage test for trend; for categorical data, a Pearson chi-square statistic; for

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continuous data, a *t*-test (type dependent upon if variances were equal or unequal); and for comparing medians, a Wilcoxon rank-sum test. These tests were also utilized to investigate differences between those who left AFRL and those who stayed (i.e., attrition).

Promotion

The intent of this analysis was to investigate the relationship between grade level (ordinal with four levels) and gender (binary, extracted from gender/minority status), controlling for education (categorical with three levels: PhD, MS, and BS or below) and experience, including military experience (in the form of veteran status (collapsed to binary, yes or no)). Years of experience were not available, but age (continuous) was utilized as a surrogate. Given that the outcome was ordinal, ordinal logistic regression modeling was conducted.

Time in AFRL (continuous) was highly associated with age so was not considered in the model. Base salary (continuous) and supervisor status (binary, yes or no) were both independently, directly connected with the outcome variable, grade level, so were not considered in the model either. Because salary including locality pay differs based on geographic area, this variable was not analyzed. In addition, career field and technical directorate were not considered for the model due to multiple levels. A subset analysis of PME and supervisory status was included in the descriptive portion of the results, but not included in the regression analysis because these variables do not apply to the majority of personnel.

Thus, the final additional variable for consideration in the model was minority status (extracted from the gender/minority status variable; binary, white or minority). Since this research question

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was outside the scope of this study, it was analyzed separately as it was of interest to the AFRL community. The regression was repeated with gender replaced by minority status. One final model was conducted using an interaction variable combining gender and minority status.

Attrition

The planned approach for this analysis was to conduct a time-to-event analysis with censoring to examine attrition, while accounting for years of service in AFRL. Unfortunately, this dataset did not contain years of AFRL service, age, veteran status, or education. Instead, descriptive statistics were investigated utilizing attrition (binary: left versus stayed) as the comparison variable.

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4.0 RESULTS

Descriptive Statistics

In January 2020, there were 7,008 government personnel in AFRL. There were 1,259 (17.97%) military personnel (383 (5.47%) enlisted and 876 (12.50%) officers) and 5,749 (82.03%) civilians. Of the civilians, 33 (0.57%) were members of the Senior Executive Service (SES) or equivalent grade level (ST, SL), and three (9.09%) of those were women.

Of the 5,749 civilians, 3,110 (54.10%) were in Lab Demo pay plan, indicating they were in the Science and Engineering (S&E) workforce. The Lab Demo (DR) pay plan includes grade levels DR-01 (equivalent to civil service grades GS-07 through GS-11), DR-02 (GS-12 and GS-13), DR-03 (GS-14), DR-04 (GS-15), and DR-05. The DR-05 grade level is unique to Department of Defense (DoD) science and technology laboratories that is a higher grade level than DR-04 but lower than SES. It should be noted that the DR-05 grade level is tied to specific positons within the organization, not the person filling those positions (thus, if they vacate the position, they no longer hold the DR-05 rank). In AFRL, there were 7 DR-05s, all of whom were men. Although basic descriptive statistics were available for the highest AFRL ranks (DR-05, SES, ST, and SL), numbers were limited. As such, the remainder of this paper will focus on the S&E employees in the DR pay plan in grades DR-01 through DR-04 (N=3,103).

Table 1 shows descriptive statistics of AFRL S&E employees, of which there were 545 (17.56%) women and 2,558 (82.44%) men. Among the highest grade level, DR-04, there were 70 women (out of 696 DR-04s), making up 10.06% of the workforce. Looking across all grade levels, a Cochran-Armitage test for trend (Z=-7.4663, p<0.0001) indicated a statistically significant

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difference between men and women, meaning that the probability of being a woman decreased as grade level increased.

Table 1. Descriptive statistics of the Air Force Research Laboratory Science and Engineering workforce

	Females	N=545	**Males**	N=2,558	**All**	N=3,103	
Grade Level	**N**	**%**	**N**	**%**	**N**	**%**	***p*-values**
DR-01	48	8.81%	97	3.79%	145	4.67%	
DR-02	234	42.94%	888	34.71%	1,122	36.16%	
DR-03	193	35.41%	947	37.02%	1,140	36.74%	
DR-04	70	12.84%	626	24.47%	696	22.43%	$p<0.0001^{\dagger}$
Supervisor	**N**	**%**	**N**	**%**	**N**	**%**	
Yes	59	10.83%	233	9.11%	292	9.41%	
No	486	89.17%	2,325	90.89%	2,811	90.59%	$p=0.2126^{\ddagger}$
Base Salary ($)	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	
DR-01	64,517	6,442	65,548	6,169	65,207	6,257	$p=0.3521^{*}$
DR-02	87,983	8,297	89,530	8,334	89,207	8,346	$p=0.0116^{*}$
DR-03	111,631	7,972	113,117	7,615	112,865	7,694	$p=0.0144^{*}$
DR-04	134,147	6,071	134,807	5,583	134,741	5,633	$p=0.3526^{*}$
Overall	100,220	20,769	108,433	20,661	106,991	20,912	$p<0.0001^{*}$
Education	**N**	**%**	**N**	**%**	**N**	**%**	
BS	112	20.55%	453	17.71%	565	18.21%	
MS (ref=BS)	276	50.64%	1,137	44.45%	1,413	45.54%	$p=0.8833^{\ddagger}$
PhD (ref=BS)	154	28.26%	965	37.72%	1,119	36.06%	$p=0.0013^{\ddagger}$
Associates/None	3	0.55%	3	0.12%	6	0.19%	
Age (years)	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	
DR-01	31.33	10.25	27.84	4.56	28.99	7.13	$p=0.0284^{*}$
DR-02	39.63	10.01	39.42	9.60	39.47	9.68	$p=0.7687^{*}$
DR-03	48.77	9.02	50.55	9.79	50.25	9.68	$p=0.0198^{*}$
DR-04	54.01	8.22	56.29	6.87	56.06	7.04	$p=0.0280^{*}$
	43.98	11.51	47.23	11.80	46.66	11.82	$p<0.0001^{*}$
Time in AFRL (years)	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	
DR-01	1.93	2.51	1.63	1.70	1.73	2.00	$p=0.4641^{*}$
DR-02	7.76	7.18	7.94	7.51	7.90	7.44	$p=0.7326^{*}$
DR-03	14.25	9.44	16.42	10.87	16.05	10.67	$p=0.0044^{*}$
DR-04	23.18	10.93	21.75	10.62	21.89	10.65	$p=0.2861^{*}$
	11.53	10.17	14.22	11.24	13.74	11.11	$p<0.0001^{*}$
Veteran	**N**	**%**	**N**	**%**	**N**	**%**	
Yes	123	22.57%	894	34.95%	1,017	32.77%	
No	422	77.43%	1,664	65.05%	2,086	67.23%	$p<0.0001^{\ddagger}$
Minority	**N**	**%**	**N**	**%**	**N**	**%**	

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Yes	124	22.75%	356	13.92%	480	15.47%	
No	421	77.25%	2,202	86.08%	2,623	84.53%	$p<0.0001^{\ddagger}$

†Cochran-Armitage test for trend, ‡Pearson chi-square statistic, *t-test

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Currently, PME (specifically Air War College (AWC) or equivalent) is highly recommended for promotion from grade level DR-03 to DR-04. In this dataset, 30.00% of DR-04 women (21 of 70) had completed AWC compared with 27.64% (173 of 626) of DR-04 men (data not shown). This difference was not statistically significant (p=0.6757, OR=0.8911, 95% CI (0.5191 1.5297)).

Among all grade levels (DR-01 through DR-04), 9.41% of personnel were in supervisory positions. A higher proportion of women were classified as supervisors (10.83% versus 9.11% of men), but this difference was not statistically significant (p=0.2126 OR=0.8255, 95% CI (0.6104, 1.1164)). No data were available on leadership positions not considered supervisory, nor were data available on leadership training program completion (other than AWC). Average base salaries (not including federal locality pay, which is based on duty location) for women was statistically lower overall (t(3,101)=8.4183, p<0.0001) and although lower at every grade level, only statistically significantly lower for grade levels DR-02 and DR-03 (DR-01 t(143)=0.9336, p=0.3521; DR-02 t(1,120)=2.5288, p=0.0116; DR-03 t(1,138)=2.4514, p=0.0144; DR-04 t(694)=0.9301, p=0.3526).

Over 80% of employees held a graduate degree as their highest level of education. A higher proportion of women held masters degrees (50.64% versus 44.45% for men) and a higher proportion of men held doctorates (37.73% versus 28.26% for women). Using bachelor's degrees as the reference group, the difference between women and men holding master's degrees was not statistically significant (p=0.8833, OR=1.0185, 95% CI (0.7971, 1.3014)). However, the

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difference in doctoral degrees was statistically significantly different between men and women (p=0.0013, OR=1.5493, 95% CI (1.1853, 2.0250)), indicating that men were 54.93% more likely to have a doctorate (again, using bachelor's degrees as the reference group). Among those with doctorates, the difference in base salary between men and women was statistically significant (t(1,119)=-4.05, p<0.0001, data not shown).

On average, compared to men, women were younger overall and in the higher grade levels of DR-03 and DR-04, but female DR-01s were older. The difference in age was statistically significantly different overall and at all grade levels except DR-02. (Overall t(3,101)=5.8568, p<0.0001; DR-01 t(56.3884)=-2.2491, p=0.0284; DR-02 t(1,120)=-0.2942, p=0.7687; DR-03 t(1,138)=2.3336, p=0.0198; DR-04 t(80.1435)=2.2375, p=0.0280.) AFRL employees ranged in age from 21 to 85 years and the median age was 46 (data not shown).

The average years of employment in AFRL was over 13 years, with women having fewer years of service on average (11.53 years versus 14.22 for men); this difference was statistically significant (t(852.7149)=5.5374, p<0.0001). Differences by grade level were only statistically significant at the DR-03 level. (DR-01 t(68.9951)=-0.7362, p=0.4641; DR-02 t(1,119)=0.3418, p=0.7326; DR-03 t(306.47)=2.8723, p=0.0044; DR-04 t(694)=-1.0676, p=0.2861.) The range of years of service across AFRL was less than a year to over 54 years, and the median time was nearly 11 years (data not shown).

Veterans represented 32.77% of the S&E workforce; men were 84.3% more likely to be a veteran (p<0.0001, OR=1.8433, 95% CI (1.4842, 2.2892)). Minorities represented 15.47% of

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the S&E workforce and the difference between men and women was statistically significant (p<0.0001, OR=1.8218, 95% CI (1.4483, 2.2916), meaning men were 82.2% more likely to be white, compared to women).

Looking at U.S. Office of Personnel Management categories [6], 68.97% of AFRL S&E employees were assigned to the Engineering & Architecture occupational group, and proportionally more men than women were assigned to this group (72.48% of men versus 52.48% of women). See Table 2. A higher proportion of women were in the Mathematical Sciences group (18.35% of women versus 10.32% of men). Considering all technical directorates in AFRL [7], women made up the highest proportion of the workforce in the 711th Human Performance Wing at 32.49% (115 out of 354 personnel). Systems Technology had the lowest proportion at 6.59% (11 out of 167), and Aerospace Systems with the second lowest proportion at 10.66% (58 out of 544).

Table 2. Proportion of Air Force Research Laboratory Science and Engineering personnel by career field category and technical directorate

	Females	N=545	**Males**	N=2,558	**All**	N=3,103
Career Field	**N**	**%**	**N**	**%**	**N**	**%**
Engineering & Architecture	286	52.48%	1,854	72.48%	2,140	68.97%
Physical Sciences	63	11.56%	324	12.67%	387	12.47%
Mathematical Sciences	100	18.35%	264	10.32%	364	11.73%
Natural Resources Management & Biological Sciences	37	6.79%	44	1.72%	81	2.61%
Social Science, Psychology, & Welfare	29	5.32%	51	1.99%	80	2.58%
Medical, Hospital, Dental, & Public Health	30	5.50%	21	0.82%	51	1.64%
Technical Directorate	**N**	**%**	**N**	**%**	**N**	**%**
Aerospace Systems	58	10.64%	486	19.01%	544	17.54%
Sensors	51	9.36%	382	14.95%	433	13.96%
Information	70	12.84%	314	12.28%	384	12.38%
711th Human Performance Wing	115	21.10%	239	9.35%	354	11.42%
Materials & Manufacturing	64	11.74%	258	10.09%	322	10.38%
Munitions	37	6.79%	208	8.14%	245	7.90%
Space Vehicles	42	7.71%	175	6.85%	217	7.00%

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Directed Energy	35	6.42%	169	6.61%	204	6.58%
Systems Technology	11	2.02%	156	6.10%	167	5.39%
AFRL Headquarters	42	7.71%	113	4.42%	155	5.00%
AF Office of Scientific Research	15	2.75%	41	1.60%	56	1.81%
AF Strategic Development Planning & Experimentation	5	0.92%	15	0.59%	20	0.64%

Promotion

To investigate the relationship between gender and grade level, an ordinal regression analysis was conducted and the crude model showed that men were 37.2% more likely to be a higher grade level than women (p<0.0001, OR=1.3719, 95% CI (1.2585, 1.4959). Although statistically significant, the lack-of-fit test's p-value was also significant (X^2(2)=7.1603, p=0.0279), indicating there was evidence to conclude there is a lack of fit in the model. After adding age (which was used as a surrogate measure for years of experience), education, and military experience (veteran status yes versus no) to the model, the fit of the model greatly improved (X^2(8,638)=5,312.27, p=1.000). The relationship between gender and grade level, after controlling for education, age, and veteran status showed that men were 21.0% more likely to be of a higher grade level (p<0.0001, OR=1.2102, 95% CI (1.1013, 1.3298)). Not only was this result statistically significant, the narrow CI indicates precision around the estimate. Table 3 shows the details of the regression model. As shown, all variables were associated with grade level and these effects were statistically significant.

Table 3. Ordinal regression model with outcome rank (ordinal) and independent variable gender

	Parameter Estimate	**Standard Error**	**Chi-Square**	**Odds Ratio**	**Lower CI**	**Upper CI**	***p*-value**
Intercept [4]	-8.3837	0.2444	1,176.50	-	-	-	<0.0001
Intercept [3]	-5.8785	0.2162	739.34	-	-	-	<0.0001
Intercept [2]	-1.9528	0.1972	98.10	-	-	-	<0.0001
Gender [Male vs. Female]	0.1908	0.0481	15.73	1.2102	1.1013	1.3298	<0.0001
Education [PhD vs. BS or below]	0.7636	0.0555	186.97	2.1460	1.9235	2.3942	<0.0001
Education [MS vs. BS or below]	0.3887	0.0513	57.32	1.4751	1.3339	1.6313	<0.0001

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Age [High to Low]	0.1310	0.0044	887.56	1.1400	1.1302	1.1500	<0.0001
Veteran [Yes vs. No]	0.1753	0.0455	14.87	1.1916	1.0889	1.3040	0.0001

Although outside the scope of this study, one additional variable for consideration in the regression model was minority status, as it was of interest to the AFRL community. This variable (binary, white or minority) was extracted from the gender/minority status variable and was analyzed separately. The regression was repeated with gender replaced by minority status. Results were similar for minorities as they were for women (OR= 1.2847, 95% Confidence Interval (CI) (1.1640, 1.4190)), controlling for the same factors (education, age, and veteran status). Thus, whites were 28.5% more likely to be a higher rank compared to minorities, after controlling for education, age, and veteran status. One final model was conducted using an interaction variable combining gender and minority status, which was found to be non-significant statistically, indicating there was not a combined effect of these two variables (after controlling for the other variables in the model).

Attrition

To investigate attrition, longitudinal data from the nine-year period spanning January 2010 to January 2019 were obtained; data were in the form of annual snapshots of the workforce. A total of 4,718 DR-01 through DR-04 employees were cumulatively employed in AFRL during this time, 1,709 (36.1%) of whom left the organization and did not return during the period. The rate of attrition per year was as follows: for 2010, 5.2% (144/2,775); 2011, 6.5% (186/2,856); 2012, 10.0% (288/2,872); 2013, 5.7% (158/2,778); 2014, 6.3% (171/2,728); 2015, 5.8% (160/2,778); 2016, 5.6% (164/2,907); 2017, 6.0% (179/2,991); and in 2018, 8.6% (260/3,013). The average attrition over the last nine years was 6.6%, with the years 2012 and 2018 being outliers (i.e., more than one standard deviation above the mean). Attrition was higher for women every year

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except 2013. See Figure 1. From 2010 to 2018, the average rate of attrition for women was 8.3% per year compared to 6.3% for men. This analysis included those who left AFRL for any reason, including retirement.

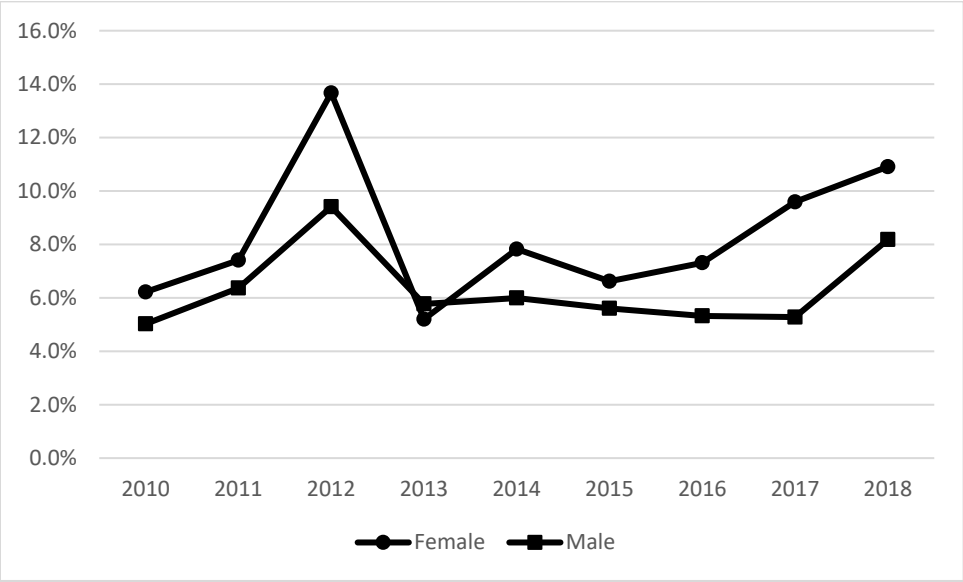

Figure 1. Rates of attrition, calendar years 2010-2018

Statistics in Table 1 showed a difference between genders with regard to grade level. Utilizing the longitudinal data, an analysis was conducted to determine if the starting grade level for personnel was different between men and women. Analysis was restricted to 2011-2018 as those in the dataset in 2010 may have started in AFRL prior to 2010. Thus, results presented here reflect hiring practices in recent years. Results were as follows (subset n=1,943, data not shown): 25.22% (n=113) of women started at the DR-01 grade level compared with 18.73% (n=280) of men; for DR-02, 54.91% (n=246) of women versus 57.12% (n=854) of men; for DR-03, 15.18% (n=68) of women versus 19.00% (n=284) of men; and for DR-04, 4.69% (n=21) of women versus 5.15% (n=77) of men. These differences were statistically significant, indicating

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that women were more likely to start their AFRL career at a lower grade level (Cochran-Armitage Z=-2.7425, p=0.0061). Similarly, starting base salary was statistically significantly lower for women (mean of $79,662 versus $83,622 for men; $t(1,941)=3.9030$, $p<0.0001$).

Table 4 shows descriptive statistics of the longitudinal data, restricting the data to 2011-2018 as above. Of the 1,943 personnel in this data subset, 448, or 23.06%, were women. The number of personnel in each grade level was as follows: DR-01 n=169, DR-02 n=1,071, DR-03 n= 528, and DR-04 n=175. Of the DR-01s, 59 (34.91%) were women, of the DR-02s, 253 (23.62%), of the DR-03s, 108 (20.45%), and of the DR-04s, 28 (16.00%) were women (data not shown).

Also within the 2011-2018 data subset, 22.39% (n=435) of all personnel left the organization. Of those who departed, 29.66% were women (n=129); of those who stayed (n=1,508), 21.15% (n=319) were women. Looking at the data another way, 28.79% of women left compared to 20.47% of men (129 out of all 448 women versus 306 out of all 1,495 men). This difference was statistically significant and indicated that women were 57.1% more likely to leave compared to men (p=0.0002, OR=1.5713, 95% CI (1.2359, 1.9976)). See Table 4.

Overall, those who left AFRL, regardless of gender, the mean time until departure was 2.16 years. Those who left were more likely to be of a lower grade level, which was statistically significantly different compared to those who stayed (Cochran-Armitage Z=-4.3894, $p<0.0001$). Similarly, base salary was lower for those who left (mean of $86,400) versus those who stayed ($93,680; $t(618.7515)=6.4382$, $p<0.0001$).

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Attrition was not associated with minority status (p=0.5228, OR=1.115, 95% CI(0.7982, 1.5579)). There is no apparent difference in attrition with regard to career field. Attrition appeared higher at duty stations other than Ohio, with the exception of Florida. Considering only those who started in 2011 or later, annual attrition rates for AFRL sites in Ohio and Florida were 19.72% (213 out of 1,080) and 20.11% (35 out of 174), respectively, whereas the rates for all other sites were over 25% (sample numbers shown in Table 4, row percentages not shown).

Table 4. Descriptive statistics of longitudinal data, 2011-2018

	Left	N=435	**Stayed**	N=1,508	**All**	N=1,943	
Gender	**N**	**%**	**N**	**%**	**N**	**%**	***p*-values**
Female	129	29.66	319	21.15	448	23.06	
Male	306	70.34	1,189	78.85	1,495	76.94	p=0.0002‡
Rank (at departure)	**N**	**%**	**N**	**%**	**N**	**%**	
DR-01	67	15.40	102	6.76	169	8.70	
DR-02	242	55.63	829	54.97	1071	55.12	
DR-03	88	20.23	440	29.18	528	27.17	
DR-04	38	8.74	137	9.08	175	9.01	p<0.0001†
Base Salary ($, at departure)	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	
	86,400	21,520	93,680	17,962	92,050	19,054	p<0.0001*
Time in AFRL between 2011 and 2018 (years)	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	
	2.16	1.90	3.37	2.55	3.10	2.47	p<0.0001*
Minority	**N**	**%**	**N**	**%**	**N**	**%**	
Yes	49	11.26	187	12.40	236	12.15	
No	386	88.74	1,321	87.60	1,707	87.85	p=0.5228‡
Career Field	**N**	**%**	**N**	**%**	**N**	**%**	
Engineering & Architecture	280	64.37	982	65.12	1,262	64.95	
Mathematical Sciences	54	12.41	204	13.53	258	13.28	
Physical Sciences	56	12.87	193	12.80	249	12.82	
Natural Resources Management & Biological Sciences	18	4.14	41	2.72	59	3.04	
Social Science, Psychology, & Welfare	12	2.76	46	3.05	58	2.99	
Medical, Hospital, Dental, & Public Health	15	3.45	42	2.79	57	2.93	
Duty Station	**N**	**%**	**N**	**%**	**N**	**%**	
Ohio	213	48.97	867	57.49	1,080	55.58	
New Mexico	78	17.93	224	14.85	302	15.54	

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New York	56	12.87	158	10.48	214	11.01	
Florida	35	8.05	139	9.22	174	8.96	
Virginia	13	2.99	28	1.86	41	2.11	
Other	40	9.20	92	6.10	132	6.79	

‡Pearson chi-square statistic, †Cochran-Armitage test for trend, *t-test, **Wilcoxon rank-sum test

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5.0 DISCUSSION

The National Science Board reports that in 2017 49.4% of S&E bachelor's degrees awarded in the U.S. were awarded to women, and that 45.2% of S&E doctoral degrees were awarded to women [8]. Additionally, women made up 39.8% of the U.S. workforce with highest degree in S&E while representing only 29% of those workers in S&E occupations [11]. These data suggest that women are obtaining higher education in science and engineering fields but are not working in S&E jobs. In AFRL, only 17.5% of the workforce are women.

In January 2020, the AFRL workforce was 54.10% S&Es – 17.56% women and 82.44% men. At another federal laboratory, Los Alamos National Laboratory (LANL), 28.82% of the technical workforce were women (unpublished data from 2019). AFRL's proportion of women was lower than LANL and overall U.S. data. However, hiring data suggests improvement in recent years, since those who joined AFRL between 2011 and 2018 were 23.06% female. Over that same time period, women were 29.66% of those who departed AFRL and 21.15% of those who stayed. Thus, despite the encouraging data on recent hires, the balance is skewed towards a higher percentage of women departing AFRL than are being hired or are staying. Efforts should be made to understand and address factors contributing to this disparity.

The majority (68.97%) of AFRL S&E employees were assigned to Engineering & Architecture occupational group (72.48% of men, 52.48% of women). In the U.S. in 2017, approximately 28% (1,927,000 of 6,769,000) of employed S&Es were Engineers or Architects (33% of men, 17% of women). Overall, the female share in S&E occupations in the U.S. was approximately: 58.7% psychology and social sciences; 47.9% life sciences; 29.2% physical sciences; 26.9% computer and mathematical sciences; and 17.0% engineering and architecture; as well as 57.9%

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S&E-related occupations, primarily those that are health-related [9,10]. Comparing to AFRL data (calculated from Table 2), women represent: 36.3% of the Social Science, Psychology, & Welfare career field; 45.7% of the Natural Resources Management & Biological Sciences field (which is largely comprised of biological scientists); 16.3% of the Physical Sciences field; 27.5% of the Mathematical Sciences field (includes Computer Sciences); 13.4% of the Engineering and Architecture field (largely engineers); and 58.8% of the S&E-related fields (Medical, Hospital, Dental, & Public Health). Digging further into the Engineering and Architecture field, the largest category in AFRL, the following subspecialties were identified: Electronics Engineer (32.52% of the Engineering and Architecture category), General Engineer (22.62%), Aerospace Engineer (17.29%), Materials Engineer (9.86%), Mechanical Engineer (8.04%), Computer Engineer (5.84%), other engineer (3.74%), and 0.09% Architecture. Comparing to the Science and Engineering Labor Force data published in 2019 [1], women in AFRL made up slightly smaller proportions of many of the individual specific engineering subspecialties: Electronics Engineers, 9.48% in AFRL versus 10.7% nationally; Aerospace Engineers, 10.27% in AFRL versus 12.5% nationally; Materials Engineers, 16.59% in AFRL versus 16.1% nationally; Mechanical Engineers, 6.98% in AFRL versus 8.6% nationally; and Computer Engineers, 9.60% in AFRL versus 7.1% nationally. While this is a crude comparison, it suggests AFRL is behind in every main occupational category except two: S&E-related health fields; and computer and mathematical sciences by a very thin margin. A more rigorous comparison could be conducted, which would include further analysis of specific career fields and degree levels represented in these statistics.

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Among the highest S&E grade levels in AFRL (utilizing the January 2020 data), 0% of DR-05s were female and 10.06% DR-04s were female. The probability of being a female statistically significantly decreased as grade level increased, although a higher proportion of women were supervisors (10.83% versus 9.11%), which was not statistically significant. Average base salaries were statistically significantly lower for women overall (across pay grades) and for women in mid-level grades (DR-02 and DR-03). The analysis also revealed that female DR-01s were older than their male counterparts. A statistically significantly higher proportion of men held doctoral degrees versus women (37.73% versus 28.26%). Men were 54.93% more likely to have a doctorate. In the U.S., 45.2% of S&E doctoral degrees were awarded to women in 2017 [8]. Future work may explore base salary, age, and other relevant variables in relation to degree level and the number of years at a specific rank.

Although minority status was not extensively explored in this analysis, similar questions about racial and ethnic diversity are the obvious follow-on to this work. In AFRL, 15.47% of the S&E workforce were minorities (22.75% of women and 13.92% of men); men were 82.2% more likely to be white compared to women (which was statistically significant). In 2017, U.S. underrepresented (non-Asian) minorities (28.1% of population ages 21+) were in 17.0% of all occupations (bachelors or higher), and 13.3% of all S&E occupations [10]. All (including Asian) minorities (35.9% of population ages 21+) were in 28.6% of all occupations (bachelors or higher) and 35.0% of all S&E occupations [9]. In 2017, underrepresented (non-Asian) minorities' (and all minorities) percent share in S&E occupations was approximately: 22% non-Asian (30.2% all minorities) psychology and social sciences; 9% (32.0%) life sciences; 11% (27.6%) physical sciences; 13% (39.5%) computer sciences and mathematics; and 12% (30.8%)

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engineering[10]. Overall, without further analysis or testing for statistical significance, AFRL compares unfavorably to the U.S. demographics for all minorities (15.47% minority S&Es versus 35.0%). Increased fidelity on race/ethnicity (beyond a binary minority yes/no) is necessary to better understand AFRL demographics. In general, personnel are required to be a U.S. citizen to be hired as a government civilian; future work should investigate if this is a factor in the lack of racial/ethnic diversity in AFRL. It is also recommended that future work investigate the statistically significant disparity in the proportion of female versus male minorities at AFRL.

Promotion

The Federal Government offers a unique scenario to investigate promotion, due to its specific rank structure. In AFRL, male S&Es were 21.0% more likely to be of higher grade level than female S&Es (which was statistically significant with a narrow CI), after controlling for age, education, and veteran status. Education, age, and veteran status were all positively and statistically significantly associated with grade level as well.

Although analysis on promotion to the highest levels of AFRL leadership was infeasible, some observations were made based on the available data on factors related to promotion. We do know that PME (specifically AWC or equivalent) is highly recommended for promotion from grade level DR-03 to DR-04. In this dataset, there was not a statistically significant difference between DR-04 women and men having completed AWC (30.00% of women (21 of 70) compared with 27.64% (173 of 626) of men). Among all grade levels included in this study, 9.41% of personnel were in supervisory positions. A non-statistically significant higher

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proportion of women were classified as supervisors (10.83% versus 9.11% for men). No data were available on leadership positions not considered supervisory, nor were data available on leadership training program completion (other than AWC). Due to incomplete data regarding leadership training and leadership experience, the relationship of these factors to promotion and gender cannot currently be analyzed. Personnel data collection should be expanded to include these factors so that analysis can be performed to better understand promotion in this context.

In addition to sparse data, the literature on STEM-specific senior positions (in or outside the government) was limited. A few articles were found, however. Women in SES positions in the federal workforce has been increasing in recent years and the number of women in c-level suites is growing[12,13]. Still, a lower proportion of women (40%) versus men (56%) aspire to have senior leadership positions, and a higher proportion of women (32%) versus men (21%) say they don't want the pressure of being in a senior leadership position[14]. However, equal proportions of women and men (42%) don't want to be senior leaders due to family commitments [14]. Given the paucity of information about gender diversity in top positions, more research should be done in this area, particularly since it was shown that it is directly correlated to organizational outcomes [2].

Attrition

For 2010-2018, the rate of attrition for women in AFRL was 8.3% compared to 6.3% for men. For a subset of data representing those who started in AFRL between 2011 and 2018, women were statistically significantly more likely to start their AFRL career at a lower grade level and lower base salary. Women were statistically significantly 57.1% more likely to leave compared

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to men. This is consistent with Frehill, *et al* [15], who reported that female engineers leave the profession at a higher rate than male engineers (23% versus 11%). Not only were women more likely to depart AFRL than men, women were also leaving at a higher rate (29.7%) than women were staying (21.2%) or being hired (23.1%). If this disparity persists over time, the population of women in AFRL is on a long-term declining trend. This data should continue to be tracked and efforts should be made to understand and address the root causes.

Overall, for those who left AFRL, regardless of gender, the mean time until departure was 2.16 years, which is consistent with the literature [16]. Those who left were statistically significantly more likely to be a lower grade level and have a lower base salary. Glass [16] also reported that women were more likely to leave STEM jobs (compared to other professional jobs), especially early in their career. Attrition in AFRL was not associated with minority status or career field. Unfortunately the dataset did not allow for statistical models to control for age, education level, or salary but those variables should be looked at in future studies.

Why Women Leave

This effort did not investigate why personnel left AFRL. However, there is a fair amount of literature on why women leave STEM jobs. Women left STEM because of the desire to balance career demands with family commitments, including balancing with their spouse's career [17,18]. This is particularly challenging for women because women are more likely to be part of a dual career couple, meaning both partners are working professionals [19]. Women left engineering due to a variety of factors: workplace culture, climate, and conditions; too much travel; lack of advancement and low salary; their boss specifically; and to spend time with family [17,20,21]. Isolation, lack of networks, and underrepresentation in leadership were additional

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reasons why women left S&E jobs [17,18,19,21,22]. Finally, Diekman, *et al* [23] found that women were more likely to be focused on communal goals, and found that incongruent with STEM jobs, which is one reason they left.

Future work is recommended to investigate why female S&Es leave AFRL. Specifically, based on the findings of a literature review and best practices study, AFRL should implement (or update) methods of collecting data on why employees stay and why they depart. Another thing to consider is how the Diekman finding regarding communal goals could be relevant in the context of civil service in AFRL [23]. The communal goal aspect of public service may be a factor to tap into in order to increase retention in AFRL and other civil service careers.

Next Steps

AFRL executive leadership is utilizing these data to inform ongoing efforts such as a revision of a workforce strategy and supervisory training curriculum development. The literature suggests that expansion of flexible work policies, which benefit both working women and men, are effective strategies to promote employee retention in STEM jobs [20,22,24,25]. Not surprisingly, men also desire flexible policies to balance work and family commitments [24,26]. Prior to the COVID-19 pandemic, AFRL was introducing new policies to allow for increased telework and flexible work schedules for all employees. The pandemic accelerated the adoption of these polices and AFRL expects them to continue to be utilized post-pandemic. However, since the pandemic forced accelerated adoption of these policies, their effectiveness should continue to be assessed and optimized over time.

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Another potential area for change is in the processes for hiring supervisors, as it has been shown that employees in technical jobs leave managers, not companies [22]. The right ingredients for effective management and leadership, even in technical and engineering fields, are people skills, managerial skills, and relational skills, not technical skills [22,27]. Thus, an individual's high technical performance does not correlate with high managerial performance. This must be taken into consideration as AFRL and other technical organizations assess and look to improve practices for hiring and training the most capable and effective supervisors.

Finally, the role of sponsorship is well documented in the literature as a potential solution to some of these challenges, including advancement of underrepresented groups [24,28,29]. AFRL has been focused on a culture of mentorship, which is one important part of employee development. However, AFRL should consider promoting a culture of sponsorship, which involves an active and concerted effort towards advancement of specific employees. A culture of sponsorship focused on underrepresented employees may be useful towards improving diversity in leadership positions and higher ranks in AFRL.

Although the quantitative analysis presented herein has not been correlated with causes or organizational outcomes for AFRL, the relevant literature does provide context and high-potential solutions to identical issues faced across national and global science, engineering, and technology organizations. Given the documented link between diversity and organizational outcomes, it is incumbent upon AFRL and other technical organizations to consider the presented challenges as imperative to success of the organization [2,3]. It behooves these organizations to continue to track and analyze diversity data, especially as it relates to

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organizational performance such as innovation metrics. In many cases it will be required to expand the demographic information that is collected, as well as develop and establish relevant organizational performance metrics. For DoD laboratories specifically, they are the hub of innovation for the warfighter. The national security of our country depends on AFRL and other DoD labs addressing these challenges to remain consistent global leaders with a competitive edge [4].

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SYMBOLS, ABBREVIATIONS AND ACRONYMS

%	percent
AFRL	Air Force Research Laboratory
AWC	Air War College
CI	confidence interval
DoD	Department of Defense
DR	
GS	General Schedule
LANL	Los Alamos National Laboratory
OR	odds ratio
PME	Professional Military Education
S&E	Science and Engineering
STEM	Science, Technology, Engineering, and Mathematics
U.S.	United States
USAF	U.S. Air Force
USSF	U.S. Space Force

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