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# **Retention Analysis Modeling for the Acquisition Workforce**

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### Abstract

We analyze the long-run career trajectory of a subset of the civilian AWF to find that 1) the AWF does well in retaining diversity, 2) one of the strongest predictors of career longevity is prior military service, and 3) workers with more education have longer careers. AWF leadership should invest in the workforce by encouraging/subsidizing education and actively recruiting and hiring from active duty to seamlessly transition them into the civilian workforce. However, as the AWF remains predominantly white due to racial imbalance at the point of hiring, the leadership should focus on attracting diverse workforce at the junior level. We then create a proof-of-concept dynamic retention model that is able to 1) simulate the long-run stay-or-leave decision of a representative worker and aggregate the individual up to the entire workforce, 2) introduce compensation changes to simulate the response of the workforce, and 3) preview the ability of the model to forecast and actively shape the AWF through dynamic simulations.

### Introduction

As the defense acquisition system continues its rapid transformation, it is more vital than ever to have a talented, experienced, and well-qualified civilian workforce with a deep enough bench to have the capability and flexibility to support the ever-changing needs and increasing demands of the modern warfighters. As part of this broad effort, the Department of Navy (DoN) Acquisition Workforce (AWF) FY 19–24 Strategic Plan has clarified the need to continually reshape the workforce by developing metrics to track the overall "health" of the AWF and predict how different policy choices in talent management can affect its effectiveness. To increase these capabilities, the report recommends modernizing analytical tools, leveraging data, and building workforce forecasting tools.

The Section 809 Panel has proposed changes to the Department of Defense's (DoD) career management framework to continue to improve and develop the workforce. In addition, the DoD AWF Strategic Plan—FY 2016–FY 2021 has previously highlighted efforts undertaken since 2010 to strategically restore and reshape the AWF after a period of roughly 20 years of continuous shrinkage.



Figure 1, borrowed from the DoD Strategic Plan, shows that a severe reduction in the AWF resulted in a "hollowing out" of the workforce, especially in the mid-career segment. The long-run prospects of neglecting the shape of the workforce as it stood in Fiscal Year (FY) 2008 was dire. Beyond the simple lack of manpower due to the culling of the workforce, the distribution of the remaining workforce was problematic. As the workforce aged, the "bathtub" depression would simply travel forward on the horizontal axis, leading to potentially serious shortfall in experienced professionals after one to two decades. The objectives as stated in the Strategic Plan were to increase the overall size of the force as well as to reshape it "by deliberate and targeted growth of specific career fields" (DoD, 2015). Concurrently, the DoD made substantive efforts to improve the quality of the civilian acquisition employees. Figure 1 also shows that the leadership had strived to "fill in" the hollowed-out portion of the workforce by concerted hiring, such that by FY 2015, the overall size of the workforce had increased and the relative depth of the bathtub had become much shallower. While the overall trends in reshaping the AWF have been admirable, it is difficult to argue that shrinking the workforce in such a way as to create the bathtub in the first place was optimal.

In addition, it is unclear whether the workforce has been "re-grown" in an efficient and effective manner. While it is impossible to definitively critique the new shape of the AWF based on Figure 1 alone, the workforce now seems very "top-heavy," with senior employees more numerous than mid- and early-career professionals combined. In most organizations, the preferred distribution of employees by experience-level is more bottom-heavy, with many more junior and mid-level employees and fewer senior-level managers. The imbalance in workforce composition may lead to wasteful use of effort, with senior-level employees engaged in work that does not make optimal use of their abilities or experience.

As these senior professionals reach retirement age in the next five years, we may again see a sharp (natural and unavoidable) shrinkage of the workforce. Along with the loss in numbers, the experience lost may create a vacuum in leadership that is difficult to replace immediately. The leadership may then be forced to "play defense" again, shoring up the workforce by hiring in greater numbers. To prevent such crises in the future, hiring of employees in re-growing the workforce should not be done indiscriminately, but with an eye toward re-building a deep bench of acquisition professionals.



Figure 1. Civilian AWF Retirement Eligibility Distribution. (DoD, 2015)

The DoN and DoD AWF Strategic Plans also describe the future goals to sustain the progress made in restoring its workforce, making further changes in the force structure to accommodate the required skillsets, improve employee quality and professionalism, and



recruit and retain a more diverse workforce to maximize effectiveness. These are ambitious goals that are further complicated by the need to attract and retain (and perhaps terminate) employees differentiated along multiple skill and characteristic dimensions. A centralized plan is required to keep track of the myriad of different types of employees and how they may all have different career profiles and objectives.

Many of the goals described in the strategic plans are aspirational in nature without a long-term plan for specifics. How many employees need to be hired at each period? What are the transitional paths toward the final shape of the workforce? What is the final distribution of quality, experience, education, and other socio-demographic characteristics? In addition, the ambitious goals of each sub-branch of the AWF may be more easily achievable with a clearer understanding of the overall long-term plan. Efficiency gains may also be achievable by avoiding duplicates in recruiting and hiring efforts.

To assist the DoN and the DoD in these goals, and directly address the recommendations put forth in the DoN FY 19–24 strategic plan, this project will develop a Dynamic Retention Model (DRM) specifically designed from the ground up for the acquisition workforce. A simpler version of the model being proposed has been used by the DoD to assess the potential impact of various talent management policy changes. The DRM and its extensions have been the workhorse of personnel analysis in the military for the past 30 years, yielding valuable insights into the labor market decisions of officers and enlisted personnel.

Our DRM uses a powerful mathematical/econometric technique called dynamic programming. It takes a complex, multi-period problem (such as the lifetime labor market decisions of an acquisition field employee) and breaks it down into simpler, one-period sub-problems in a recursive manner. Solving a single-period problem "nests" the future decisions that the employee will make, allowing the estimation and prediction of complex behavior in a surprisingly manageable framework. The set-up of the model allows researchers, once estimation of the model is complete with data, to simulate how various modifications in policy, such as changes in salaries, retirement, and bonuses, would have affected the labor market decisions of the workforce. In doing so, the model can help the leadership in achieving the desired workforce size and structure, as described by the two strategic plans.

To understand the relevant features of the workforce, in this report, we conduct the following analysis:

- 1. We do a deep dive into a sub-group of the AWF. We construct a panel (longitudinal) dataset that tracks employees from the start of their careers to, in many cases, the end. We examine how demographic characteristics such as gender and race affect the length of their career. We zero in on education as a particularly important characteristic to examine. We find that employees with different amounts of education have sharply different career experiences. Higher levels of education are associated with longer careers. Surprisingly, we also find that employees who attain an additional degree while working stay substantially longer at their jobs compared to employees who started with the higher credentials. This has strong implications for how the leadership should recruit and invest in its workforce over the long run. We conduct both graphical trend analysis and survival regression analysis using a Cox proportional-hazard model.
- 2. We create a proof-of-concept model that provides an intuitive way to examine and experiment with the long-term labor market behavior of the employees. An individual employee's career decisions (whether to stay in or separate) at



Acquisition Research Program: Creating Synergy for Informed Change every point in time in their career is modeled using insights from dynamic programming. Once we create a model that allows for a logical and timeconsistent decision-making behavior by one employee, we aggregate up to the entire workforce. Then, once we can examine the behavior of an entire workforce, we simulate changes in monetary factors that can affect an individual's career decisions and follow how the sum of these individual decisions leads to large changes in the shape of the AWF. Thus, we successfully demonstrate the utility of the proof-of-concept model.

The next section introduces the data. We then describe the data using simple summary statistics and graphical long-run trend analysis. Our primary empirical model is presented and analyzed in the next section. After the empirical section is concluded, we switch gears to describe dynamic programming in more detail. We then run a proof-ofconcept model to show off some of the capabilities of the model.

#### Data

We received a data extract (covering September 1987 through December 2018) from Defense Manpower Data Center (DMDC) of the 1,000-byte Appropriated Funds Civilian Personnel Master File. Our current analytical sample does not constitute the whole of the AWF. We were restricted to analyzing civilian employees in the Contracting, Industrial Property Management, or Purchasing fields (Occupation Codes 1102, 1103, and 1105) across the entire DoD.<sup>1</sup> That is, we also include employees who entered from, or left to work in other DoD departments, even outside of the AWF as a whole, if they were ever in Contracting, Industrial Property Management, or Purchasing. Restricting analysis to employees who begin and finish their careers in Contracting significantly cuts down on the sample. We only keep employees born after January 1, 1950, and before December 31, 1980. Many employees born before 1950 would have retired by 1990, and their labor market experience (primarily concentrated in the 1970s to 1980s) would be less relevant for forecasting career pathways. Employees born after 1980 would be at the very early stages of their careers and would not provide much information on long-term career trajectories.

Even after restricting the sample, we have more than two million observations, as the data tracks employees monthly. More than 13,000 DoD employees are tracked throughout their careers in this current sample. Table 1 presents some summary statistics for our sample.

<sup>&</sup>lt;sup>1</sup> We have the capacity to restrict the analysis to Navy AWF employees. For the analysis in this report, all DoD employees are used.



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Variables		Mean (Std. Dev) [Min/Max]		
Female		0.632		
White		0.776		
African-Americ	an	0.222		
Hispanic		0.045		
Asian		0.081		
Native America	an / Native Alaskan	0.011		
Has Identified	Disability	0.202		
Prior Military S	ervice	0.619		
Has Bachelor's	s Degree	0.547		
Has Post-grad	uate Degree	0.332		
Gained Additio	onal Education in AWF	0.441		
Career Length	in AWF (in months)	143.6 (103.8) [1 / 309]		
Age at Entry		33.0 (8.2) [15 / 65]		
Age at Exit		48.2 (10.55) [20 / 68]		
Position Type:	Professional	0.657		
(Ever Held)	Technical	0.245		
	Blue-Collar	0.018		
	White-Collar	0.297		
Ever Ranked Not Fully Satisfactory		0.575		
Highest Salary		95,143.67 (30,410.74) [27,397 / 189,600]		
Observations		13,590		

# Table 1.Summary Statistics for the DoD Acquisition Workforce.(DMDC, 2019)

The workforce is majority white and female. The majority of the workforce is highly educated with more than half of the sample having a college degree or above, at some point in their careers. Interestingly, 44% of the sample acquire additional education during their careers. While the bulk of these are employees who enter with a bachelor's degree obtaining a post-graduate degree, a small number of employees who start with a high school degree successfully finish college while in the AWF.

On average, employees start their career at 33, which means that the first time we observe them in the data set is usually not their first job. In fact, more than 60% of the workforce has had prior military experience. Most employees stably match within the DoD for a long period of time. Average tenure is around 12 years, which is close to double the average tenure in private sector occupations. For the purposes of this analysis, inter-departmental transfers *within* the DoD are not treated as separation. Therefore, at least from the summary statistics, the AWF does not seem to have major issues holding on to employees.

Most of the employees we examine in this year's technical report hold professional or technical positions. This is reflected in their education level, as described above, as well as the level of the maximum salary, at almost \$100,000, they attain in their career. That said, a deeper dive into performance ratings of these employee show that more than half the workforce has received a performance rating below fully satisfactory at some point in their DoD careers. A deeper dive to examine possible predictors of poor performance may be valuable.



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### **Descriptives and Trend Analysis**

Examining the fraction of employees who leave the workforce by months of employment shows some surprising trends. Figure 2 shows the differences in attrition rates by gender. The lines on the graph should be interpreted in the following manner: among newly hired Acquisition employees, 100% are still with the job after "zero" months. After about 100 months (approximately eight to nine years), about 70% of the original employees remain. By about 300 months (approximately 25 years of service), roughly one-quarter of the employees are left. An additional feature worth noticing is that there are not substantive differences in attrition rates across gender. In fact, women on average tend to have slightly longer careers, especially beyond 200 months. This trend is in stark contrast to what we observe among naval officers. Figure 3, from "Retention Analysis Model (RAM) for Navy Manpower and Personnel Analysis," (Arkes et al., 2019), shows very early and widening gaps in career longevity across gender. By 55 quarters (i.e., around 165 months) of active service from the date of commissioning, approximately half of the male officers are still in the Navy, while more than 70% of female officers have left. At similar career points in the civilian AWF, male and female attrition rates both hover around 60%.



### Figure 2. Career Trajectory of Employees by Gender

The simple gender trends observed in the civilian AWF present an interesting contrast with the most recent data from the Current Population Survey (CPS). In general, while average job tenure in the private sector among men has fallen from 8.3 years to 7.4 years in the span of 30 years (1983 to 2012), women's average job tenure has risen from 5.8 years to 6.9 years. While job tenure is observed to be on a path to convergence across gender, it should still be noted that average career length for men is still longer. Our sample shows a more extreme shift, with women on average having longer careers compared to men.





Figure 3. . Quarterly Retention Rates Among Naval Officers Commissioned in FY1999, by Gender.

(Arkes et al., 2019)

The patterns observed in the CPS sample can be attributed to ongoing changes in the labor market that allow women to more easily avoid long spells of employment disruptions due to childbirth along with better and earlier options for childcare. Viewed from this perspective, a stable job in the DoD AWF with generous benefits may then be particularly attractive for females who desire to have long careers.



# Figure 4. Career Trajectory of Employees by Minority Status

Figure 4 shows differences in career lengths by ethnicity. African-American and Hispanic employees are combined into the "minority" category, and White and Asian employees are combined into the "white" category. Similar to observed trends across gender, no large differences are observed across race. Minority employees attrite slightly faster during mid-career (between seven and 15 years) and slightly slower near the end of their careers. We were also unable to find substantive differences in attrition across citizenship status or duty station. Unfortunately, we do not have access to marital status or number/age of dependents for the civilian data.





Figure 5. Career Trajectory of Employees by Education Level

While a diversified workforce is important in its own right, we are also interested in the effectiveness and productivity of the workforce. To that end, we examine the impact of education level on career longevity in Figure 5. We take the employee's highest degree obtained (whether education was obtained prior to entry or acquired during their career). Encouragingly, there is a strong positive correlation between education level and longevity. While those with a high school degree or less attrite such that less than half the of the original cohort remains after 15 or so years, the most qualified employees, identified as those with post-undergraduate degrees, are retained at more than 50% well beyond 20 years. Attrition rate does increase rapidly beyond 20 years for these employees, as these employees are reaching retirement age more quickly than employees without graduate degrees, due to entering the workforce at least two to three years later. It is possible that employees with lower levels of education leave the AWF to return to school, so we should not automatically assume that lower productivity employees are leaving the workforce en masse. We do emphasize that while the attrition rate for the average employee looks encouraging, there are several important caveats that warrant the reader's attention.

First, the graphs of the attrition rates do not imply anything about the overall composition of the workforce. From the summary statistics, we saw that white and female employees comprise the vast majority of the AWF. We see that women have lower attrition rates compared to men, especially late in their careers. As for race, even though attrition may look largely the same, if whites comprise the majority of the initial cohort, the aggregate gap will not close. Table 2 shows this in detail. If the leadership wishes to close the racial gap, it will have to change the demographic distribution drastically at recruitment, or by retaining higher percentages of minority employees during their careers. Once estimation and simulations are completed, the demographic implication of changes to hiring and promotion policies can be fully examined in our dynamic programming model.

Second, while the trends are informative, they do not reveal compositional differences within categories. For example, even though females comprise roughly 63% of the employees at entry, narrowing the labor pool to those holding a post-undergraduate degree shrinks this number to 54%. Similarly, white composition increases in 77.8% to 79.8% when we restrict the sample to only those who hold post-undergraduate degrees. This implies that the "lower rungs" of the career ladder tend to be more heavily female and minority, compared to the rest of the workforce.



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	Percent female	Percent white
At entry	0.632	0.778
At 1 year	0.632	0.779
At 10 years	0.681	0.801
At 20 years	0.739	0.785

Table 2.	Compositional Change of A	WF Cohort Through Time
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Third, trend analysis cannot reveal why behavioral differences across groups may or may not arise. To a certain extent, extrapolation of intent from the data becomes unavoidable. However, we must be cautious in interpretation of such data, as policy based on speculation may lead us astray. Figure 6 demonstrates this. Because we found education level to be a strong differentiator in career longevity, we examined employees who attained additional education during their careers, compared to those who chose not to acquire additional human capital. The results are quite striking. Employees who attained an additional degree have much longer careers. This result is somewhat puzzling, as one would assume that additional education would make the employee more valuable in the private sector. That these ambitious employees tend to stay much longer in the AWF could be an encouraging sign. However, we must be cautious about drawing too many conclusions from these trends. Figure 7 charts the career of those who hold postundergraduate degrees. We split this sample into those who entered the workforce with the degree initially and those who acquired the degree during their career. Although both groups have the same terminal degree, those who acquire the degree mid-career have much longer careers in the AWF.



Figure 6. Career Trajectory of Employees by Those Who Do/Do Not Obtain Additional Education





# Figure 7. Career Trajectory of Employees Who Obtain Master's Degrees at Different Points in Career

One possible interpretation of this figure is that those who attain the postundergraduate degree are employees who are most enthusiastic about their government careers, and the degree is a signal to the leadership that indicates the willingness of these employees to improve at their craft. In contrast, those who entered the field with a graduate degree may have had the technical skills required for the job, but not the drive, leading them to exit prematurely. If this is the correct description of the workforce, leadership should discourage hiring of those with master's degrees and above, concentrate on those with bachelor degrees, and actively promote going to graduate school to advance careers in the AWF.

However, another interpretation is that there is a quality difference in the graduate degree obtained by those mid-career compared to those who already had the degree at entry. The civilian employees who stayed are not choosing to do so, but are not highly sought after by private industry. Indeed, even if there is no gap in "quality," if the field of study that these mid-career students choose to pursue is tightly and narrowly connected to their tasks in their current position, this may not boost their desirability to the private sector, even with the advanced degree.

To examine this issue further, Figure 8 graphs the career trajectory of three separate sub-samples: those who enter with a bachelor's degree and never pursue an additional degree, those who enter with a bachelor's degree and go on to obtain a post-undergraduate degree, and those who enter with a post-undergraduate degree.





### Figure 8. Career Trajectory of Employees Who Enter the AWF with a Bachelor's, Master's, or Obtain a Master's Degree Mid-Career

The relative proximity of the lines for those who enter/exit with only a bachelor's degree or master's degree, compared to those who make additional investments in education, lends support to the assertion that the human capital investments civilian employees make are directly related to a desire for a longer career in the DoD.

# **Regression Analysis**

The AWF sample is analyzed using duration (survival) analysis. Survival analysis has been widely used across many fields, including biostatistics, operations research, demography, and actuarial studies, as well as economics and other social sciences. For analytical tractability, we assume that the observed career trajectories of the employees are of single-spell durations obtained by flow sampling. That is, we assume that once a employee chooses to leave the workforce, they do not return. The principal variable of interest is the "survival time" of a subject. In this case, survival time equates to the career length of the employee.

Specifically, we estimate a Cox proportional hazards model. While the rigorous econometric justifications are outside the scope of this report, there are a few compelling reasons to use this estimator.<sup>2</sup> Other "fully parametric" duration models are simpler to estimate, but can produce inconsistent (read: incorrect) parameter estimates if any part of the model is mis-specified. Although the literature has introduced a myriad of ways to choose flexible parametric models that are robust to mis-specification, an alternative method is to use a semiparametric estimator that requires less rigorous distributional assumptions.

We estimate four different models, and present the coefficient estimates as well as the hazard ratios in Table 3. In general, a positive parameter estimate (and a hazard ratio greater than 1) indicates that the probability of transitioning to a different state (that is, going from working to leaving the workforce) increases. On the other hand, a negative parameter estimate (and a hazard ratio less than 1) means that the probability of leaving the workforce,

<sup>&</sup>lt;sup>2</sup> Interested readers are directed to Lancaster (1990).



ACQUISITION RESEARCH PROGRAM: CREATING SYNERGY FOR INFORMED CHANGE conditional on surviving to this period, declines, compared to the base case. Note that the hazard ratio must be greater than zero.

To interpret, the parameter estimate on a female in Model 1 is -0.1866, and the hazard ratio is exp(-0.1866) = 0.8298. The negative number (and the hazard ratio less than 1) indicates that women, compared to men with identical attributes, are less likely to change status (leave), given that they survived to that period. As a concrete example, say that the probability that a male employee who just completed 10 years of employment at the AWF has a 5% chance of quitting within one month. Then, an otherwise identical female employee has about a 4.15% chance of quitting in the same period.

Model 1 contains the fewest number of independent variables. All variables in Model 1 are exogenous. That is, these variables are unquestionably predetermined prior to entry into the workforce, and thus, the regression estimates can reasonably assumed to be causal. We see that race has no effect on the career longevity of employees one way or another. Female and disability status yield moderately longer acquisition careers, but the variable that has the greatest effect on longevity is whether the employee has prior military experience. In fact, the hazard ratio for prior military background. Employees who are sliding over from the military are almost guaranteed to have a long career in the acquisition field.

Looking forward a little bit, these results are robust across all four model specifications. Specifically, for the prior military experience variable, we may speculate that large impact on career length may be due to specific human capital match across the two jobs. It is most likely that these employees had complementary experience in the military and moved over to the civilian side to continue similar work. There may be little disruption in the types of day-to-day tasks performed, and most of the professional networks formed during the military career may be directly taken advantage of in the job. Given these circumstances, an employee with military experience would find the job less taxing compared to a civilian colleague who lacks similar experience, and it stands to reason that their performance would also stand out, leading perhaps, to faster promotions and more desirable assignments.

One other plausible explanation could be that the employee with prior military experience is over-specialized to the extent that the AWF (or comparable positions in the DoD) is the only place where they can receive compensation commensurate with their experience. In either case, it stands to reason that if the leadership hopes to maintain and increase the job tenure of the average employee, they should focus recruiting among soldiers and officers who are billeted to positions that deal with acquisition issues.

Model 2 adds education level to the analysis. In this case, we used the highest education level that the employee has attained, according to the administrative data. We should caution here that use of these specific variables "breaks" the exogeneity claim made in Model 1. That is, we can no longer state with certainty that having a bachelor's degree or post-undergraduate degree results in a longer career for an employee. The reason for this is that, as we saw in the summary statistics, a significant number of employees acquire an additional degree mid-way through their career. Since this choice is made after the employee has decided to join the AWF, and more importantly, since advancing one's education makes a real difference in the employee's productivity and thus their value to the organization, education level is no longer "outside the model." Of course, we could have chosen to include education level at the point of entry into the workforce. However, given that more than 40% of the workforce attains additional education while working in the AWF, it also seems somewhat disingenuous to discount this decision-making process. In fact, this



is one of the important reasons to model the career of these employees using a dynamic programming framework. A more complex model than the proof-of-concept model we present later in this report can introduce additional decision-making capabilities of the employee merely beyond stay-or-leave the workforce. A third option of stay-and-acquire-education can be added. For this particular regression, we should interpret these parameter estimates more as correlative relationships. Employees who have advanced degrees are more likely to stay with the workforce for a longer period.

	Mode	el 1	Model 2		Model 3		Model 4	
	Coef.	Hazard	Coef.	Hazard	Coef.	Hazard	Coef.	Hazard
Female	-0.1866*	0.8298	-0.2292*	0.7952	-0.1619*	0.8505	-0.1126*	0.8935
	(0.0252)	(0.000)	(0.0259)	(0.000)	(0.0262)	(0.000)	(0.0261)	(0.000)
African-Am.	-0.0214	0.9789	-0.0250	0.9753	0.0008	1.0008	0.0573	1.0590
	(0.0291)	(0.463)	(0.0292)	(0.391)	(0.0292)	(0.978)	(0.0293)	(0.051)
Hispanic	-0.0492	0.9520	-0.0625	0.9394	-0.0247	0.9756	0.0352	1.0358
	(0.05461)	(0.368)	(0.0546)	(0.252)	(0.0547)	(0.652)	(0.0548)	(0.520)
Native Am.	-0.0414	0.9594	-0.0501	0.9511	0.0306	1.0311	-0.0090	0.9910
	(0.1178)	(0.725)	(0.1178)	(0.671)	(0.1179)	(0.795)	(0.1178)	(0.939)
Disability	-0.1331*	0.8754	-0.1312*	0.8771	-0.1154*	0.8910	-0.0723§	0.9303
	(0.0327)	(0.000)	(0.0327)	(0.000)	(0.0327)	(0.000)	(0.0328)	(0.028)
Prior Military	-3.0036*	0.0496	-2.9681*	0.0508	-2.9652*	0.0516	-3.0574*	0.0470
	(0.0358)	(0.000)	(0.0361)	(0.000)	(0.0364)	(0.000)	(0.0384)	(0.000)
BA degree	-	-	-0.1069*	0.8986	-0.0050	0.9950	0.0319	1.0324
			(0.0242)	(0.000)	(0.0275)	(0.841)	(0.0267)	(0.231)
Post-BA	-	-	-0.1598*	0.8523	-0.0051	0.9949	-0.0626 <sup>§</sup>	0.9393
			(0.0282)	(0.000)	(0.0297)	(0.863)	(0.0314)	(0.046)
Add'n Degree	-	-	-	-	-0.4513*	0.6368	-0.3025*	0.7389
					(0.0272)	(0.000)	(0.0274)	(0.000)
Professional	-	-	-	-	-	-	-1.2607*	0.2835
							(0.0295)	(0.000)
Technical	-	-	-	-	-	-	-1.0919*	0.3356
							(0.0359)	(0.000)
Deficient Rank	-	-	-	-	-	-	-1.2102*	0.2981
							(0.0328)	(0.000)
Observations	1,951,	719	1,951	,719	1,951	,719	1,951	,719
-In L	63,297	.701	58,79	5.086	58,65	2.802	57,393	3.441

#### Table 3. Cox Proportional Hazard Model Parameter and Hazard Ratio Estimates

Note: §, \* denote statistical significance at the 5% and 1% levels. For coefficient estimates, standard errors are in parentheses. For Hazard ratios, P-values are in parentheses.

Model 3 takes the analysis from Model 2 one step further, by adding an indicator variable for employees who attained additional education while in the workforce. When this variable is included, we see immediately that the parameter estimates for college and postgraduate degrees become much smaller in magnitude and statistically insignificant. Instead, the variable on additional education is large (in absolute magnitude) and statistically significant, indicating that employees who attain an additional degree are strongly associated with a longer career. On the one hand, this is very encouraging. Additional education adds to human capital, which increases a given employee's productivity. That these employees, after acquiring more education, are shown to stay longer in the workforce may imply that the AWF is an attractive place to work, and highly skilled employees do not wish to leave. On the other hand, the magnitude and clarity of the association (by the small standard error), should lead us to treat these results with some degree of caution. The



analysis of employees' choice in staying in the DoD may be overly optimistic for several reasons:

1. Employees who most desire staying with the AWF may be the ones earning the additional degree.

If the additional degree is purely a signal from the employees to the leadership of their desire to stay in the workforce, then the parameter estimates may only be reflective of the self-selection of these employees into getting additional education to show that they are valuable to the leadership. This additional investment may not lead to an increase in productivity.

2. Additional education may be a requirement for advancement.

The positive correlation between career longevity and acquisition of an additional degree may reflect a formal or informal professional requirement. As an example, if an employee without a college degree is precluded from advancing beyond a certain grade, he or she may be induced to obtain a degree. There are many examples in the private sector as well as the military where advanced degrees are either an explicit or an implicit prerequisite for promotion. For example, teachers who aspire to become a principal must obtain an EdD degree. Starting with those in the Year Group 2015, the Navy will require its officers to have a master's degree before taking major command (at the O-6 level) (Burke, 2018). Outside of whether the additional degree adds productivity, there will be a functional positive relationship between career length and acquiring a degree.

As a simple illustrative example, assume that every employee enters the workforce with 16 years of education. After working 10 years in the AWF, they are promotable to a position that requires a master's degree (two years of additional education). Then, if we looked at a cross-tabulation of average years of education and career length, at the promotion point, we may observe something akin to the following:

Table 4.	Example of Positive Functional Relationship Between Education and
	Career Length

	Before Promotion Point	After Promotion Point
Average Years of Education	15	16
Average Years in AWF	5	15

The relationship between education and career length now has a positive slope ((16-15)/(15-5) = +1/10), unrelated to whether education actually adds any productivity, purely based on the fact that it is an administrative requirement.

3. Employees may be adding human capital that is specific to the AWF.

Even if employees self-select into acquiring an additional degree to send a signal to management, the education itself may lead to a positive impact on employee productivity without leading to an increased exit for these newly productive employees if the additional degree adds specific human capital. Specific human capital refers to education that adds to the productivity of tasks that are directly related to the civilian acquisition workforce and it only.

This is in contrast to general human capital, which would be education or training that is valuable to other firms in the private sector or in government. As an example, learning to use a computer software that is custom-designed for acquisition work may make the employee more productive in their daily tasks within the current organization, but it is questionable whether this skill would transfer in a substantive fashion in a work environment where this software is not used. On the other hand, if an employee is trained in using



Microsoft Excel (or other software suites that are used across fields and firms), this training should provide value to any firm that hires this employee.

While the employee becomes more productive, this productivity maximized in jobs within the AWF. Therefore, the value of these employees increases substantively for their increased capabilities in the acquisition field, but the private sector would not find these employees much more desirable than prior to obtaining the additional degree. In these circumstances, economic theory predicts that a) employees themselves would not be interested in obtaining this degree without financial and professional incentives provided by the leadership, and b) employees should not expect to receive extraordinary compensation (commensurate with their new productivity) after attaining the degree. We plan to follow up on this analysis in subsequent years' reports.

We should note that these three potential reasons listed above are not necessarily negative factors for the AWF. As a signal or administrative requirement, the degree lets leadership know which employees are committed to a long career in the field. This can provide clarity on which employees to invest in for the long term. In addition, if indeed the additional education mostly adds specific human capital, the leadership should promote additional education mid-career and provide incentives to induce employees to take up training.

4. The additional degree does not add valuable general human capital.

While it is possible that the focus of the additional degree is in increasing specific human capital, it is somewhat difficult to envision a degree that does not add at least some amount of general human capital. Yet, the strong positive impact of additional education on career longevity points to the possibility that the quality of education pursued by these employees does not yield enough of a value to work outside the acquisition field to garner strong, competing interest from the private sector. If the degree does not add any useful human capital, the cost, in terms of direct tuition as well as the time and effort spent, is a waste.

We should note that this interpretation may co-exist with the signaling explanation. The point is not that signaling is not useful, but that if this additional education does not actually add productivity, this ends up being a very heavy price to pay just to let the senior leadership know that the employee is interested in a long-term employment relationship.

Ultimately, the summary statistics and long-run trend analysis lead us in tailoring our models in the following ways:

- 1. A simple static model will not be rich enough to capture the salient features of an employee in the AWF. While the decision to stay or leave the workforce is interesting and important, a primary differentiator across employees seems to be how they attain human capital. Since almost half of the sample acquire additional education mid-career, it is important for us to model this as well.
- 2. Demographic differences may not play as large a role in retention decisions compared to Navy officers. In prior research with Navy officer data, we had been struck by the stark differences in observed attrition dates across gender. We also found some differences across ethnicities. In contrast to the fundamental gender and racial imbalance in the Navy officers corps, we were surprised to find no such differences in the acquisition workforce. This is encouraging for the leadership in that the workforce, after intake of these employees, do not suffer from systematic over-attrition of any minority group. That said, the AWF is still a very white workforce, and more efforts at the



point of recruitment may be necessary to achieve better demographic representation. For our modeling purposes, these factors imply that we may not need to be overly concerned with modeling gender and race separately throughout career. This should decrease the "state space," making the model more tractable.

3. More empirical exploration between the role of education/degrees and promotions may be necessary. While higher education (especially degree earned mid-career) has a positive effect on career longevity, it is not clear why career length is affected so strongly, when there are good theoretical reasons why the effect should be in the opposite direction.

We next describe how our full dynamic model will be constructed, starting with a nontechnical description. The empirical insights in this section will inform the structure of the full model.

### **Dynamic Programming Model**

In this section, we provide a detailed description of the proof-of-concept DRM that could be used to analyze the AWF. The basic assumption about employees is that they are fully rational agents that, in every moment, make decisions regarding their careers that maximize their lifetime utility (i.e., lifetime "happiness"). This assumption implies that, at the beginning of each period (for instance, a month or a year), the individual selects to stay for another period or leave the workforce after trading off all the benefits and disadvantages involved in the decision, including monetary (e.g., wages and bonuses) and nonmonetary components (e.g., preference for working in the public sector). At this stage of the model development, we will assume that the decision to leave the workforce is irreversible, that is, once an employee chooses to leave, they cannot be rehired later. The initial model is also not considering potential periods when voluntary separation is restricted (e.g., after receiving a bonus with a promise to stay for two years.) These features will be added to the model in the future, increasing its precision to predict retention behavior.

Note that the assumption of the fully rational agent is a very high standard. Employees must, in theory, be able to correctly predict professional outcomes (in and out of the acquisition field) at every point in their career, as well as changes to personal status, and make the optimal decision at every point in time. Considering the fact that we will require the use of a cluster server (the Hamming supercomputer at the Naval Postgraduate School) to solve this model, our model may appear to be unrealistic. However, there are four reasons to choose dynamic programming as the modeling framework.

The first reason is that the fully rational assumption can be supported in a more modest sense when we consider that people do try to think through important choices and gather advice from friends, family, and senior employees, and the DoD itself has outreach programs to try to educate personnel on making smart retirement decisions. Even if a civilian employee making retirement decisions is not a supercomputer, as long they are making rational decisions following best practices and good advice from experts, dynamic programming models are expected to have good predictive powers. The second reason is that dynamic programming models have been shown in the academia to have good performance in actually modeling and predicting dynamic systems in a number of different labor markets, as well as industrial organization problems. The third reason is that with the estimates from the model, we are able to generate powerful simulation exercises to explore a myriad of policy changes. The final reason is that prior models used to generate predictions or recommendations are fundamentally flawed. We discuss shortcomings of these other models later in the report. In this initial proof-of-concept model, the decision-



maker considers the following monetary elements: 1) regular compensation and bonuses and 2) compensation that the individual could obtain in the private sector. We also assume that the nonmonetary components are given by the employee's preference or "taste" for the government (versus working in the private sector.)

The basic model variables are as follows:  $W_t^m$  indicates the regular compensation that the individual can obtain in period t (including bonuses),  $W_t^c$  denotes the compensation that the employee can obtain in the private sector in period t, T represents time horizon of the decision problem (e.g., number of periods until retirement),  ${}^3\beta = \frac{1}{1+r}$  indicates the discount factor, and r is the subjective discount rate of the employee,  $\omega^m$  denotes taste that captures the monetary equivalent of the preference for AWF/military work,  $\omega^c$  denotes taste that captures the monetary equivalent of the preference for the civilian life,  $E_t$ .] is the expectation operator given the information in period t,  $\varepsilon_t^m$  and  $\varepsilon_t^c$  are *iid* random variables. Super-index L represents the choice to leave the AWF voluntarily while super-index S denotes the decision to stay one more period. Then, the decision-maker's maximization problem can be cast as:

$$V_t^L = W_t^c + \omega^c + \beta E_t[V_{t+1}^L] + \varepsilon_t^c = \sum_{\tau=t}^T \beta^{\tau-t} (W_\tau^c + \omega^c) + \varepsilon_t^c$$
(1)

$$V_t^S = W_t^m + \omega^m + \beta E_t[V_{t+1}] + \varepsilon_t^m, \tag{2}$$

$$V_t = Max[V_t^L, V_t^S] \tag{3}$$

where  $V_t^L$  denotes the present value of leaving the acquisition field to enjoy a career in the private sector while  $V_t^S$  indicates the present value of remaining in the AWF one more period. In this context, the employee will choose to remain when the present value of staying,  $V_t^S$ , is larger than the present value of departing,  $V_t^L$ . The individual will face this decision at the beginning of each period until they leave. To start simulating the proof-of-concept model for a representative employee, we initially chose the parameter values showed in Table 5. Table 5 shows that the parameters are constant over time (i.e., during the work life of the employee). We initially assume that military/AWF and private sector compensation ( $W_t^m$  and  $W_t^c$ , respectively) are equal at 1. The time horizon (T) is 30 and implies that the individual works for 30 years. The discount factor ( $\beta$ ) is set at 0.95, which implies a subjective discount rate (r) of around 5.26% per year. The military/AWF and private-sector taste parameters ( $\omega^m$  and  $\omega^c$ , respectively) are equal at the value of 0.1. Finally, the *iid* random shocks ( $\varepsilon_t^m$  and  $\varepsilon_t^c$ ) have zero mean and standard deviations equal to 0.1.

<sup>&</sup>lt;sup>3</sup> In this version of the model, we assume that retirement income is the same in the private and public sector, regardless of the individual decisions. This simplification allows us to disregard income after the time horizon T. This feature will be added in the next year's report.



Parameter	Value		
w. <sup>m</sup>	1	ω	0.1
	-	$\mu_{\varepsilon,m}$	0
W <sub>t</sub>	1	Исс	0
т	30	P-2,2	
6	0.95	$\sigma_{\varepsilon,m}$	0.1
$\omega^m$	0.1	$\sigma_{\varepsilon,c}$	0.1

**Initial Parameter Values** 

Table 5.

This initial parameterization describes a representative employee who could earn roughly the same salary by working for the AWF or the private sector. It also assumes that the individual has similar tastes for both types of jobs. We start simulating the model using these parameter values. While varying those parameter values would naturally change the simulation figures, the main conclusions would remain roughly the same. In fact, we later analyze the effects of changing the parameter capturing military compensation ( $W_t^m$ ) on employee behavior. Specifically, we study the retention impact of a permanent increase in military pay of 2% after 15 YOS and of paying a one-time bonus of 15% at YOS 15.

While our proof-of-concept model simplifies reality considerably, we show in the figures below that it already captures some key features observed in the data. We start by replicating the bathtub problem described by the DoD AWF Strategic Plan—FY2016–FY2021 in Figure 9. It refers to the lack of employees with five to 15 years of experience in the AWF as a consequence of several years of personnel reduction. The vertical axis shows the number of employees, while the horizontal axis depicts the number of years until retirement. We simulate the model with the parameterization outlined in Table 5 and show its prediction about retention behavior for a representative employee in Figure 10. As expected, the figure shows that attrition is high in the initial years and diminishes continuously as time passes.



Figure 9. AWF Bathtub Problem





### Figure 10. AWF Retention Rate

With the predicted behavior of a representative employee over their career, we simulate the model to forecast the evolution of the workforce distribution over time in the context of a "myopic" personnel policy. This policy assumes the AWF hires employees only at the beginning of their careers (i.e., in Year 1) and has no long-run planning of the structure of the force. The result is displayed in Figure 11, which suggests that the bathtub problem would move to the right over time, progressively reducing the number of experienced leaders as time passes. The Strategic Plan clearly describes the bathtub problem around employees with five to 15 years of experience and suggests that, within five years, roughly 50% of the workforce would be retired or eligible for retirement. The leadership has addressed and ameliorated this problem by implementing substantial hiring and retention efforts. While it is easy to conclude that higher salaries will induce employees to stay longer, it is quite a bit more complicated to predict how individuals will react to different types of incentives at dissimilar moments of their career. That is one of the main aspects where the DRM we have developed in the first year can start helping the leadership when analyzing changes in compensation (e.g., raising wages or paying bonuses).

Figure 12 shows the employee retention behavior with a 2% pay increase after 15 years of service. That is, the salary of the individual is  $W_t^m = 1$  in Years 1 through 15 and 1.02 in Year 16 through 30. The model assumes the individual knows at moment 0 they will receive the 2% raise starting in Year 16. Compared to Figure 10, Figure 12 shows that the wage rise induces employees to stay more in early and mid-career years. Another interesting feature of Figure 12 is its similarity with actual career trajectories shown in Figure 2. Both figures suggest that employee attrition is relatively high in the initial career years, diminishing during the mid-career years, and increasing again close to the end of the employee's tenure.



# Figure 11. Evolution of AWF Without Active & Forward-Looking Intervention

Figure 13 shows how the bathtub problem would evolve with a salary rise. The main difference with respect to Figure 11 is increased retention during the early and mid-career years, though the central bathtub problem persists. Figure 14 exhibits the retention behavior of an employee that receives a one-time bonus at Year 15 equivalent to 15% of pay. That is,



the employee earns a wage  $W_t^m = 1$  in all years, except in Year 15, when they earn  $W_t^m = 1.15$ . As before, the model assumes the individual is aware at moment 0 of the bonus. The main difference to Figure 10 is the increased retention in the years right before YOS 15, as well as increased attrition in the years right after the 15-year mark. This particular behavior creates a clear kink at YOS 15, similar to that observed with military members around YOS 20.

The time evolution of the bathtub problem in the context of the 15-year bonus is displayed in Figure 14. The main departure from Figure 11 is higher retention in the initial and mid-career years, but as expected, the undesired bathtub problem remains over time. The previous simulations of the model suggest that it can be used to forecast the evolution of the entire workforce distribution, allowing decision-makers to have a better sense of the long-term trajectory of the workforce.



Figure 12. AWF Retention Rate with 2% Pay Increase



Figure 13. AWF Evolution Without Forward-Looking Intervention with 2% Pay Increase



Figure 14. AWF Retention Rate With 15% Bonus at Year 15



ACQUISITION RESEARCH PROGRAM: CREATING SYNERGY FOR INFORMED CHANGE The DoD has been using the original DRM for more than 30 years to predict the effect of changes in compensation on service-member retention behavior, a period during which the computing power has increased dramatically. These gains in computer capabilities allow us to start introducing into the model relevant demographics of AWF employees. Thinking about extending on this proof-of-concept model, we can use the data set used in this report to estimate the model to allow us to characterize employees by groups of interest. For instance, we may estimate model parameters for employees in the Contracting field (Occupation Code 1102), which will allow the AWF leadership to understand more precisely the attrition behavior of this specific group of employees. The same can be done with other groups of interest, such as employees in the Industrial Property Management and Purchasing fields (Occupation Codes 1103 and 1105, respectively), as well as by gender, race, prior military service, disability, and level of education (or any desired combination of available demographics).

In addition, the model can be extended in different important directions. For instance, we may incorporate the effect of the FERS pension and Thrift Savings Plan (TSP) on retention behavior. We can also extend the model to help leaders make hiring/firing decisions at various points of the employee experience distribution to achieve a target shape of the force in a certain number of years (e.g., inverted-U shape, flat, descending, or virtually any desired shape of employee distribution.) Figures 15, 16, and 17 show some potential desired shapes for the workforce employee distribution. The model will also be able to describe the evolution of AWF over time in special contexts, such as periods of hiring freeze or of restricted layoffs.



Figure 15. Inverted-U Shape AWF Target Distribution



Figure 16. Flat Shape AWF Target Distribution





Figure 17. Descending Shape AWF Target Distribution

# Conclusion

It is difficult to envision the size and shape of an efficient and effective workforce without a quantitative model that will allow decision-makers to see how many and what kind of employees must be recruited, maintained, and let-go each year. The model should inform what the workforce looks like today, what the transition path is, and what it will take to get to the desired goal a set number of years into the future.

The overarching goal of our project is to create a custom dynamic model of the AWF from the ground up that will allow the leadership to manage manpower proactively by expanding the time horizon for which labor demand, supply, and transition will be predictable. While we would not claim that the model will allow the leadership to avoid any and all disturbances or inefficiencies in shaping the workforce, it is our hope that the model will allow a more strategic, long-term planning of talent management as well as quicker and more effective responses to unforeseen political and economic gyrations that affect the AWF's mission and/or resources. In this report, we accomplished two foundational tasks that will support the effort to build, estimate, and simulate using the final model. First, we collected and examined a subset of the workforce data, paying close attention to the career trajectory of these employees. We found that while there is relatively little separation in behavior of these employees across gender or ethnicity, several factors, such as prior military experience and education level have large impacts on career longevity. Identification of factors that affect (and perhaps just as important, those factors that do not affect) career decisions will be central in building and estimating the dynamic programming model.

Our second task was to build a proof-of-concept model to demonstrate some of its capabilities. After describing the model in some detail, we showed that the model is able to create an economic agent (employee) who makes rational, time-consistent decisions about whether to stay in the workforce or leave at each point in time. When we are able to create a useful model of behavior for one agent, it is then possible to create as many thousands of these virtual employees as is necessary to simulate the entire workforce. We then showed that it is possible to forecast what such a workforce would look like as it matured through time. In addition, we demonstrated that the model is capable of simulating changes in monetary compensation policies, such as a 2% annual raise or a one-time 15% bonus at a certain point in the career. When these changes take effect, the employee re-evaluates their decision-making and changes career trajectory logically in response. Once again, if we can correctly model this change for one employee, we can aggregate up to the entire workforce. Thus, we demonstrated the impact on the entire AWF of such a policy change as well.

The salient conclusions from our empirical analysis is that higher education level is positively correlated with career longevity. This is good news, as it seems to indicate that the



AWF has little trouble retaining high-quality employees. In addition, we found that employees who acquired additional education while working are even more likely to stay longer. Subject to some caveats, this implies that one way the leadership can upgrade productivity *and* retain its best people is to encourage and perhaps even subsidize continuing education for the workforce.

Ultimately, it is difficult to plan for the future when we do not understand how decisions made today alter decisions and environments through time. Our research project will ensure that the AWF leadership can approach talent management with better information and more confidence to grow a diverse, agile, highly qualified, and motivated workforce of acquisition professionals.

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