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# Modeling the Department of Navy Acquisition Workforce With System Dynamics

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## Abstract

Acquiring effective and efficient materiel solutions that support naval missions is critical to meeting Department of the Navy (DoN) objectives. Maintaining the readiness of the current Navy to fight and win, accelerating the delivery of warfighting capability for the next Navy, and researching and transitioning to new technologies for the Navy after next all require that the DoN maintain a healthy acquisition workforce that is large enough and qualified to be smart buyers over 30+ year time horizons. The naval acquisition workforce faces losses of experience and capacity as the current workforce ages and retires, as knowledge half-life diminishes the relevance of current skills and experience, and as a tightening labor market draws government employees to the private sector. Leaders throughout the DoN are challenged to identify and implement actionable levers to sustain required workforce capability and capacity. This study developed a realistic simulation model of a portion of the naval acquisition workforce and demonstrated its potential use in workforce planning and management.

## Introduction

### *Challenges Facing the Department of the Navy Acquisition Workforce*

The Department of the Navy (DoN) acquisition enterprise exists to put capability in the hands of warfighters so that when necessary they can fight and win. The DoN acquisition workforce manages the planning, design, procurement, manufacturing and construction, testing, and deployment of materiel solutions and services to fulfill the Navy’s mission and support operations. Doing so requires thousands of contracts, millions of contract actions, and billions of dollars each year. The DoN acquisition workforce must be effective and have adequate capacity to fulfill the demand for naval acquisition work.

The DoN faces several challenges in providing an adequate acquisition workforce. First, the demands placed on the acquisition workforce are changing. The naval fleet is growing toward a target of more than 300 ships. Materiel solutions are becoming increasingly complex as threats and technologies evolve. Pacing the threats requires that the acquisition workforce have deeper, more varied knowledge and skills than were required in the past.

In addition to these demand-side challenges, the DoN faces challenges in maintaining the capability and capacity of its acquisition workforce. The current acquisition workforce is relatively old. Therefore the workforce is currently losing, and will soon lose more, experience and capacity as members retire or seek employment elsewhere. Maintaining capability and capacity will require the DoN to recruit and train new acquisition personnel.

The acquisition workforce (AWF) obligates over $300 billion annually to acquire goods and services. The GAO has reported on the need for ensuring that the AWF is adequately sized, trained, and equipped to meet the needs of the DoD. To help address some of the challenges, Congress created the Defense Acquisition Workforce Development Fund (DAWDF). The fund has been applied to a variety of uses, including increasing the size of the workforce. The Better Buying Power (BBP) initiatives (DoD, 2010–2016) also addressed acquisition workforce needs, including improvements in recruiting and hiring, training and development, and retention and recognition. These efforts have generally increased the certification rates of the acquisition workforce (see Figure 1). However, a further challenge in maintaining an adequate AWF is the uncertainty around which of these potential levers addressed by DAWDF or BBP will have the greatest positive impact on AWF performance. Also of concern are temporal lag factors between interventions and effects, and the near certainty of unintended consequences for any AWF change initiative.

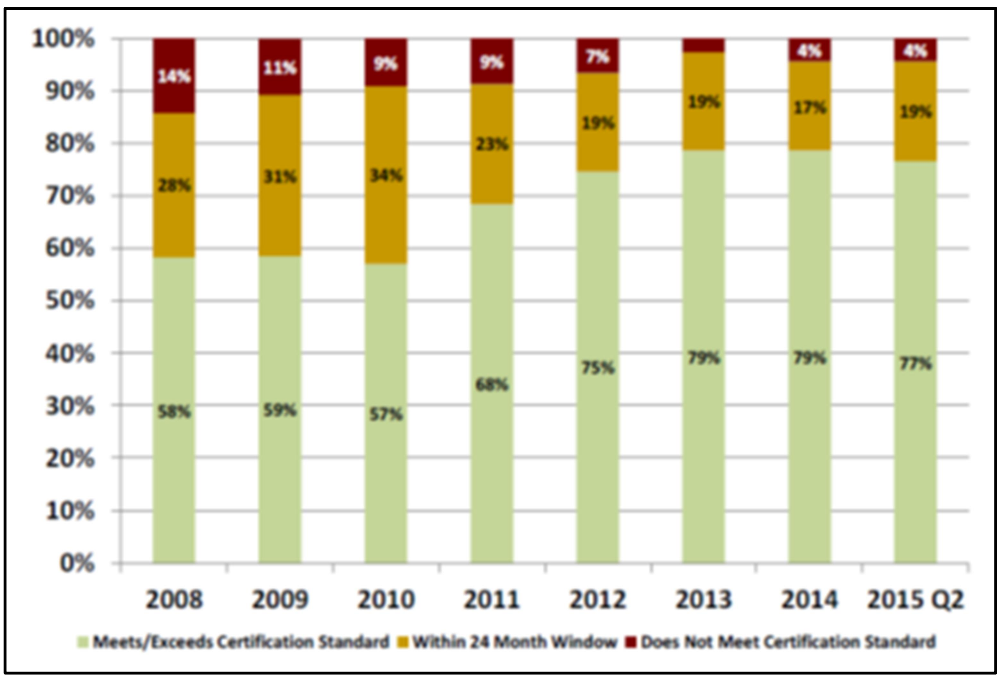



**Figure 1. Acquisition Workforce Meeting Certification Standards (2008–2015Q2)**
(DoD, 2015, Figure 4-1)

The critical role of the temporal dimension is the most important feature shared by the acquisition workforce challenges described previously. Insights and solutions require an understanding of both short-term and long-term impacts of system designs and policies. Given the complexity of the system and the difficulty of conducting experiments in the actual system, realistic models for DoN AWF design and policy development would be useful.

### *Background and Problem Description*

At a macro level, warfighting system demand signals articulated in U.S. National Strategy documents, such as the DoN 30-year shipbuilding plan, generate a certain amount of acquisition work that must be accomplished to get capability into the hands of warfighters. The DoN has allocated various domains of acquisition work among several acquisition system commands (SYSCOMs). Each SYSCOM uses a tailored approach to translate warfighting system demand signals in their domain into a sequenced volume of work to be accomplished. Each SYSCOM's tailored approach estimates how many people (with appropriate knowledge and experience levels) are needed to perform that volume of work. Work accomplished by the DoN AWF enables industry partners in the value stream to construct and deliver warfighting systems. Delivering acquisition, modernization, and maintenance of warfighting capability to warfighters is the aim of the civilian-military-industrial enterprise. The outcome is readiness to fight and win. Changes in national strategy over time have caused cyclical shrinkage and swelling among the ranks of the AWF.

The DoN acquisition workforce system includes many diverse parts, processes, and stakeholders that interact over time in a wide variety of ways. Attempts to improve individual parts of the system (e.g., training, assignment rotation) or aspects of the system (e.g., economics, experience levels) cannot be completely successful if enacted separately. Addressing DoN AWF challenges requires a systems perspective and systems level solutions. The tools and methods that facilitate that perspective and those solutions must be able to integrate the numerous and diverse aspects of the workforce (e.g., specialization, training, experience, assignment rotation and advancement, location) and measures of workforce performance (e.g., capabilities and capacities).

Understanding the interactions among workforce components is critical to developing improved policies. Developing that understanding is not intuitive or obvious, largely because the workforce and its performance are dynamic: they evolve in response to system structure, current conditions, and current and future policies. Those interactions create causal feedback loops, unintended side effects, delays, and resistance to otherwise well-designed policies. Improving acquisition workforce understanding and developing effective and efficient policies requires tools and methods that can capture the systemic, dynamic feedback in the system; can reflect current and future policies; and can reflect their impacts on workforce performance.

## Research Methodology

The research developed a dynamic simulation model that can be used to illustrate DoN acquisition workforce challenges, explain the structural causes of those challenges, and communicate the nature and degree of those challenges to policy-makers. The ultimate goal is a set of tools that can be used by policy-makers to better understand DoN acquisition workforce challenges and design effective and efficient policies.

This initial model demonstrates the potential of a dynamic simulation model to help improve policy-makers' and the workforce's understanding of the system and the impacts of potential policy changes. The model could thereby play a central role in educating and communicating with policy-makers about challenges and possible solutions. To investigate the potential of the model to facilitate meeting these goals, the research addressed the following question: "How can a dynamic simulation model be used to investigate, explain, and communicate DoN acquisition workforce challenges and potential solutions?"

The research applied the system dynamics modeling methodology. The system dynamics methodology combines a broad perspective of systems with a control theory approach to improve the design and management of complex human systems. System dynamics combines servo-mechanism thinking with computer simulation to allow the analysis of systems in ways that are not possible with human reasoning alone. It is one of several established and successful approaches to systems analysis and design (Flood & Jackson, 1991; Jackson, 2003; Lane & Jackson, 1995). Forrester (1961) developed the methodology's philosophy, and Sterman (2000) specified the modeling process with examples and described numerous applications. When applied to engineered systems such as the defense acquisition workforce, system dynamics focuses on how performance evolves in response to interactions within the causal structure of the system (e.g., retirement rates, development of knowledge and experience), development and management policies (e.g., training developed in specialty areas), and conditions (e.g., capacity levels, budget constraints). System dynamics is appropriate for modeling the acquisition workforce because of its ability to explicitly model the diverse set of critical features, characteristics, and relationships that drive behavior and performance.

System dynamics has been applied to military systems, including planning and strategy (Bakken & Vamraak, 2003; Duczynski, 2000; McLucas, Lyell, & Rose, 2006; Melhuish, Pioch, & Seidel, 2009), workforce management (Bell & Liphard, 1978), technology (Bakken, 2004), command and control (Bakken & Gilljam, 2003; Bakken, Gilljam, & Haerem, 2004), operations (Bakken, Ruud, & Johannessen, 2004; Coyle & Gardiner, 1991), logistics (Watts & Wolstenholme, 1990), acquisition (Bartolomei, 2001; Ford & Dillard, 2008, 2009a, 2009b; Homer & Somers, 1988), and large system programs (Homer & Somers, 1988; Lyneis, Cooper, & Els, 2001). Coyle (1996) also provided a survey of applications of system dynamics to military issues.

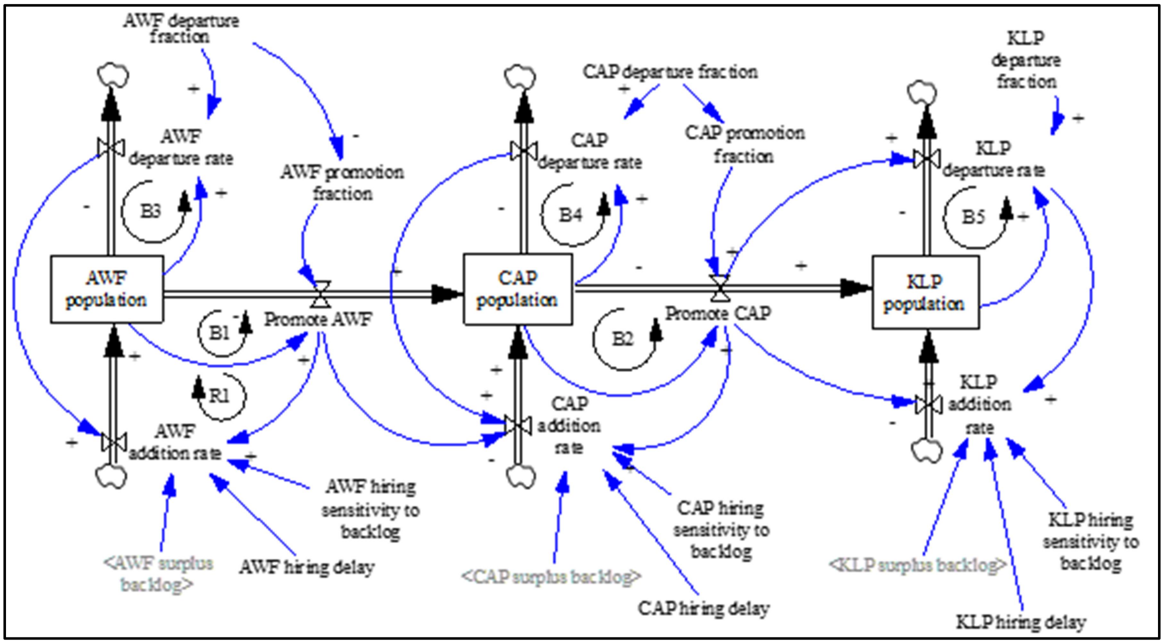
The nature and extent of the acquisition workforce challenges faced by the DoN were identified and described to develop a specific focus for the research. The key variables that best describe the important concepts to be considered in the research were identified. The problem description was used to identify the data required for model development. Available literature was used to build a basic understanding of the core components and processes within the DoN acquisition workforce. Discussions with the DoN Director of Acquisition Career Management (DACM) personnel were used to collect additional information for model development. The problem description was also used to develop a conceptual model of the DoN acquisition workforce using established system dynamics model structures. The conceptual model was formalized into a computer simulation model that uses difference equations to describe the components and relationships in the system. The model structure and policies were fully specified and documented. Estimated parameter values were used to calibrate the formal model. The model was tested to improve the model structure and to develop confidence in the model's ability to reflect DoN acquisition workforce issues. Standard structural and behavior tests for system dynamics models (Sterman, 2000) were used. Structural tests included testing the model's structural similarity to the DoN workforce system and unit consistency tests. Behavior tests included extreme conditions testing and similarity of simulation results to the reference modes. The tested model was used to illustrate DoN acquisition workforce challenges and the impacts of a variety of policies.

## Model Structure

The model described herein represents the DoN acquisition workforce system for a single career field. Primary data for the model were developed at a meeting with the DoN director of Acquisition Career Management (DACM) on May 23, 2017. The model is based on the parallel accumulations and flows of three critical parts of the acquisition workforce system: (1) people, (2) knowledge and experience, and (3) work. The model is purposefully simpler than the actual system to facilitate describing and understanding the workforce-related drivers of acquisition performance. For instance, the model depicts only the government acquisition workforce and does not include the government research and development or readiness and sustainment workforces, nor does it include industry contractors.

### *The Acquisition Workforce*

At any point in time, each person in the system is assumed to be a member of one of three populations, each hereafter referred to as a category: the acquisition workforce (AWF), the Critical Acquisition Positions workforce (CAP), or the Key Leadership Positions workforce (KLP). Each of these populations is modeled as a stock (boxes in Figure 2). A category's population size, combined with its productivity, is taken as a surrogate for the resources applied to perform work. After an average period of time as a member of the AWF, a portion of those persons are promoted to CAP (arrow from AWF to CAP and loop B1). Similarly, a portion of the CAP population is promoted to KLP after a characteristic time as a CAP (arrow from CAP to KLP and loop B2). This creates an aging chain of people moving through the system over time. Each stock is also drained by departures from the SYSCOM/career field (arrows above boxes and loops B3, B4, and B5) and increased by "additions" (hiring and transfer of persons into that category, arrows below boxes). Departures are modeled as a fraction of the population per month. In steady state, AWF additions are assumed to include the replacement of AWF promotions (loop R1); additions to each population equal the net effect of promotions and departures; and KLP departures are assumed to include promotions from CAP.




**Legend of Feedback Loops** [1]

B1 & B2 – Promotion controls the workforce population

B3, B4, & B5 – Departures control the workforce population

R1 – AWF promotions increases AWF hiring which increases AWF population and promotions

**Figure 2. System Structure Diagram of People in the Acquisition Workforce System Dynamics Model**

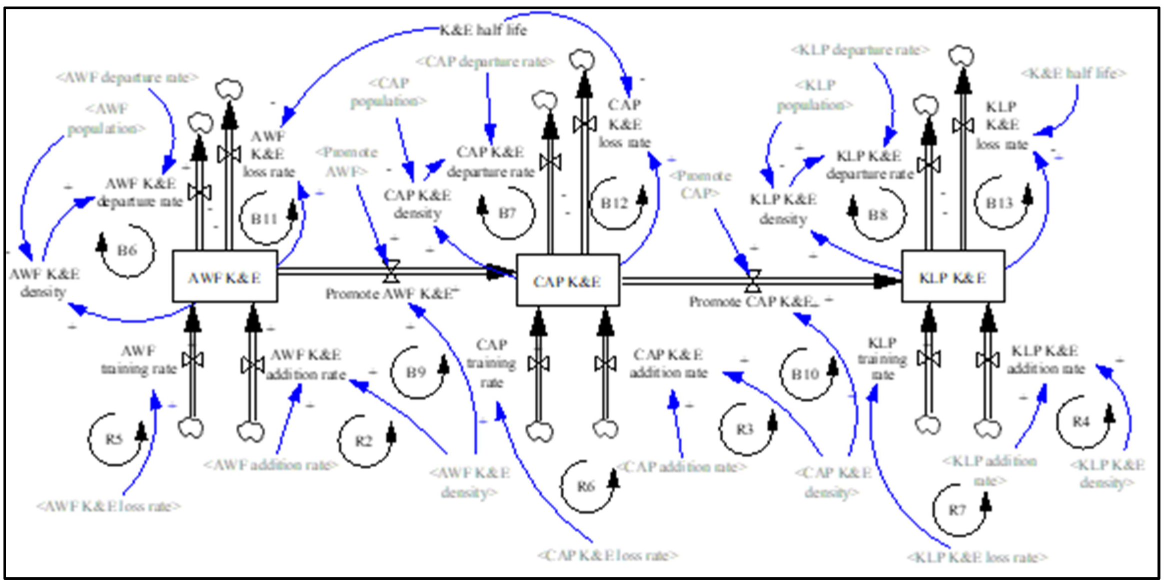
A simple workforce management policy is modeled. The workforce managers are assumed to respond to surplus backlog over a target amount of backlog by adding people to the workforce. People are added through hiring or transfers into each of the three workforce categories (AWF, CAP, KLP) through the “addition rate” inflow to each workforce stock. The size of the addition rate at any point in time is based on three factors: (1) the size of the surplus backlog over the target backlog, (2) the sensitivity of the workforce manager to surplus backlog, and (3) the hiring/transfer delay between the increase in the backlog surplus and when the new staff become productive.

Some levers for improving DoN acquisition system performance increase the numbers of people in some or all of the three categories. For example, retention efforts that are focused on the KLP population reduce the departure rate from the stock of KLP persons (but not the AWF or CAP stocks). People can be added through increased hiring and transfers from outside the SYSCOM or career field. Other levers, such as the average time spent in a category (and thereby the promotion rates), limits on the sizes of category populations, and hiring policies (e.g., hiring for attrition) also impact the inflows to and outflows from the three population stocks.

[1] Feedback loops that are required purely to start the model in steady state conditions are not fully described here for brevity but are included in the formal model.

### *Knowledge and Experience (K&E)*

The accumulations and flows of the total knowledge and experience of each category of persons are modeled in an aging chain (see Figure 3) that mimics the structure of the aging chain of the groups of people described previously. A category's K&E reflects its capability to perform work. Knowledge and experience is measured in generic "K&E units," which include educational degrees, person-years of experience, training, certifications achieved, impacts of mentoring and other on-the-job training, and so forth. For each of the three categories, the average K&E of a person in the category (i.e., the K&E density) is estimated as the stock of K&E divided by the number of persons in that category (loops B6, B7, and B8). When the average density of K&E increases, more K&E is lost through promotions from the category the person is promoted from (loops B9 and B10) and gained by the category that the person is promoted to. Similarly, K&E is lost through departures (loops B11, B12, and B13) and gained through hiring and transfers (loops R2, R3, and R4) based on the K&E density and those flows of persons. K&E is also lost from each stock due to people forgetting and knowledge and experience becoming obsolete (right outflows above stocks in Figure 3 and loops B11, B12, and B13), based on the half-life of the knowledge and experience in that SYSCOM and career field.




**Legend of Feedback Loops**

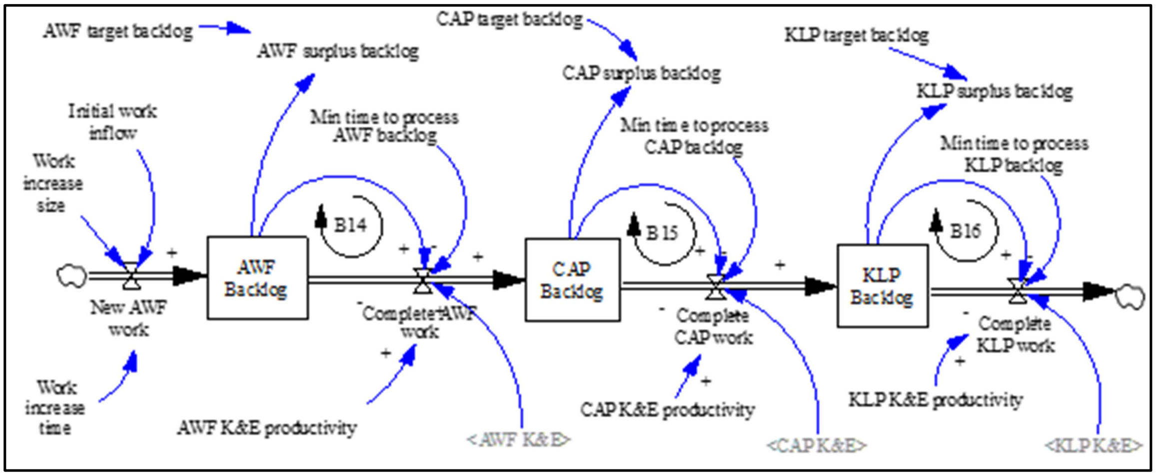
B6, B7, & B8 – If the amount of K&E and therefore the K&E density increases, more K&E is lost when people depart, thereby limiting the amount of K&E
B9 & B10 – If the amount of K&E and therefore the K&E density increases, more K&E is lost when people are promoted, thereby limiting the amount of K&E
B11, B12, & B13 – If the amount of K&E increases, more K&E is lost (e.g., through obsolescence), thereby limiting the amount of K&E
R2, R3, & R4 – If the amount of K&E and thereby the K&E density increases, the amount of K&E added when people join the population also increases. This increases the amount of K&E.
R5, R6, & R7 – K&E losses are replaced by training, which increases the "churn" of K&E

**Figure 3. System Structure Diagram of Knowledge and Experience in the Acquisition Workforce System Dynamics Model**

To describe steady state conditions, the model assumes that K&E losses are replaced by the addition of equal amounts of K&E through training (loops R5, R6, and R7), where “training” is taken as a shorthand label for any development activities that increase capability or capacity to perform the work required, such as education, structured training, on-the-job training, job experience, mentoring, and so forth. Numerous levers can influence the quantity, quality, availability, and impacts of education, experience, and training opportunities, and thereby the K&E inflows and outflows to the three K&E stocks.

***Work***

Each category of persons performs work that decreases their backlog of work to be completed (i.e., the category’s backlog plus work in progress, referred to hereafter as their backlog). Work is measured in small fungible information packets (info packet). An info packet may be taken as a standard work package unit that represents typical acquisition work products such as design documents, contract actions, engineering changes orders, test plans, and so forth. The three backlogs are modeled as stocks with the completion of work moving that work out of the category’s backlog and into the backlog of its downstream category (see Figure 4). This creates the third parallel aging chain of the model. The completion rates increase with the amount of K&E in the category and the average productivity of the category. These flows are also limited by the size of the backlogs to model the constraint that work cannot be completed if the backlog is empty (loops B14, B15, and B16). New work is assumed to enter the most upstream backlog (AWF Backlog) based on the acquisition demand signal. When modeling steady state conditions, the amount of new work added to the AWF backlog is equal to the completion of AWF work. This simplified model assumes that all AWF work must be reviewed and approved or processed sequentially by CAPs and then KLPs, which is not necessarily true in the real system. Further, in reality both CAPs and KLPs may have New Work inflows that do not originate with New AWF work. Also, the model ignores quality of work, error rates, and rework.




**Legend of Feedback Loops**

B14, B15, & B16 – More backlog increases completion, controlling backlogs (prevents negative backlogs)

**Figure 4. System Structure Diagram of Work in the Acquisition Workforce System Dynamics Model**[2]

A simple depiction of management monitoring the workforce for decision-making is modeled. It is assumed that the workforce manager monitors the current backlog (AWF, CAP, and KLP) and compares the current backlog to a target backlog size to estimate the surplus backlogs. In general, larger surplus backlogs indicate worse performance.

Increasing the productivity of applying the K&E in each category can improve DoN acquisition system performance. For example, changes in working conditions (e.g., telecommuting) and schedules (e.g., flexible work schedules) can increase productivity. Performance-based incentives can also increase productivity. Note that increasing productivity does not increase the quantity of K&E (modeled in the K&E sector), but how effectively the K&E is applied.

### *Performance Measures and Model Calibration*

Thirteen traditional measures of aging chain performance are included in the model: three category sizes and the total workforce size, three category work backlogs and the total backlog of work, average time that work stays in the three backlogs and in the whole system, and annual workforce cost.

The model was initially calibrated to steady state conditions to facilitate distinguishing between model adjustment from initial conditions to steady state and model responses to exogenous inputs. Calibrated conditions were estimated by the modelers based upon a generic but realistic single career field in a single SYSCOM.

[2] Feedback loops that are required purely to start the model in steady state conditions are not fully described here for brevity but are included in the formal model.

## Illustration of Model Use

For a demonstration of typical behavior and an illustration of model use, the inflow of work to the AWF backlog was assumed to increase by 25% at month 40 and remain at the higher level. As shown in Figure 5, the AWF initially increases. This is because the current AWF workforce cannot complete more work. However, the increased backlog sends a signal that additional resources are required to the AWF workforce manager in the form of the AWF backlog surplus.

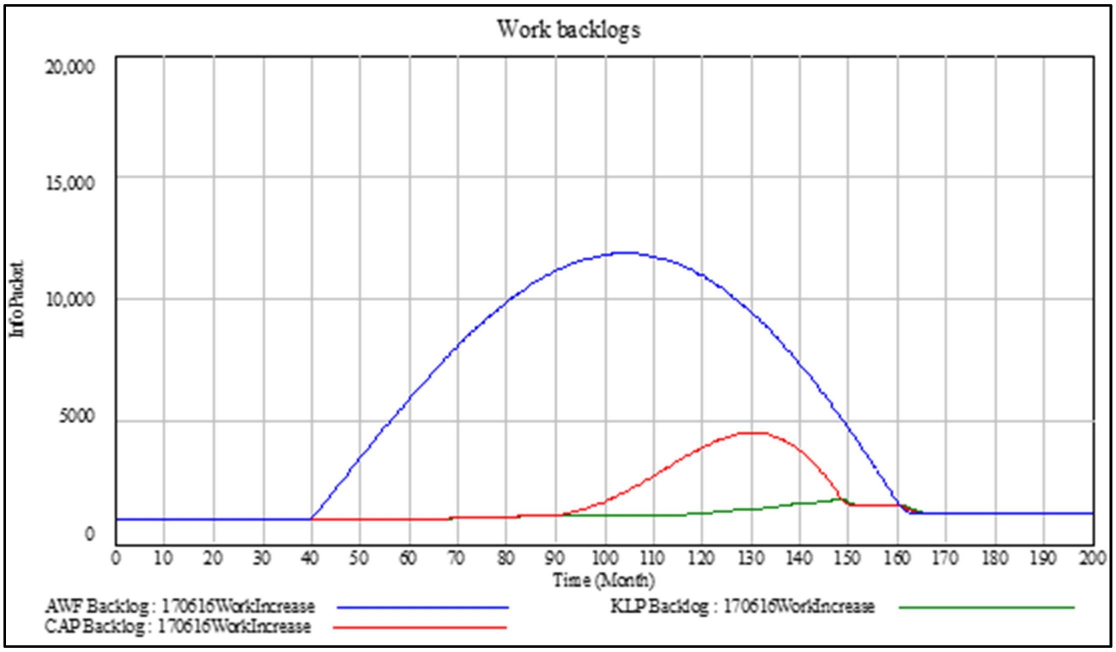



**Figure 5. Changes in Work Backlogs Due to an Increase in Workflow**

After the AWF hiring/transfer delay (assumed to be six months), the number of people in the AWF workforce increases (see Figure 6, months 0–170).

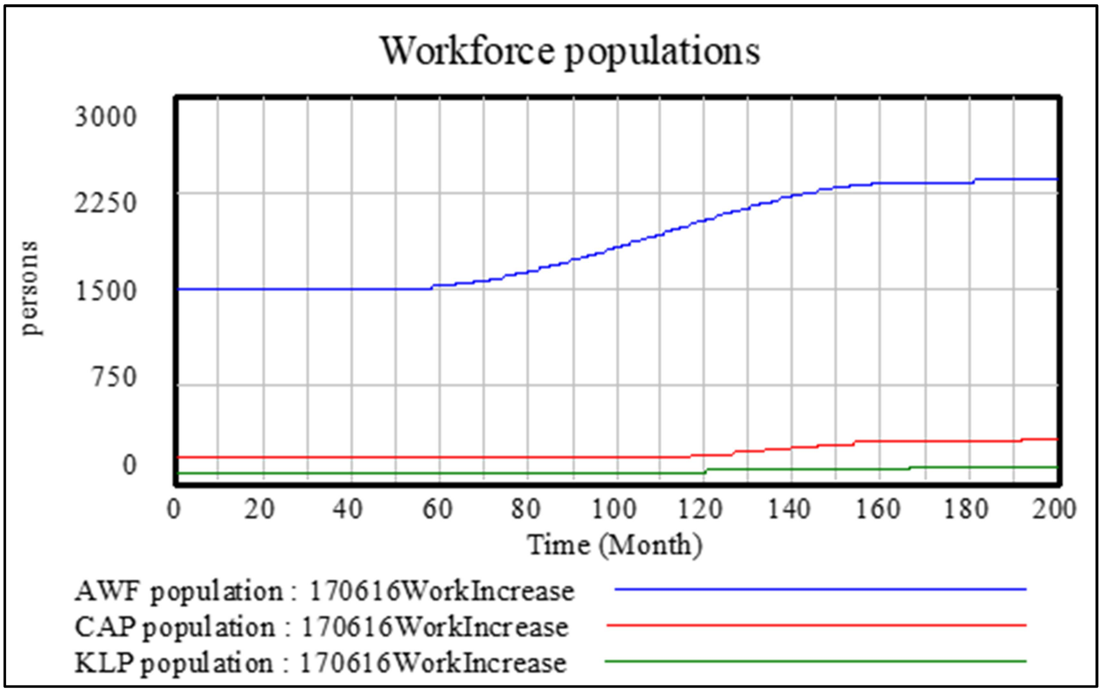



**Figure 6. Changes in Workforce Sizes Due to an Increase in Workflow**

The increase in the AWF population increases the knowledge and experience available to apply to the AWF backlog (see Figure 7, months 60–170). This increased capacity reduces the rate of rise in the AWF backlog (see Figure 5, months 75–105) and then starts to decrease that backlog (see Figure 5, months 105–165). The resulting decrease in the backlog surplus decreases the AWF hiring/transfer rate until a new steady state AWF workforce is achieved (see Figure 6, months 170+), which stabilizes the knowledge and experience in the AWF workforce (see Figure 7, months 170+).

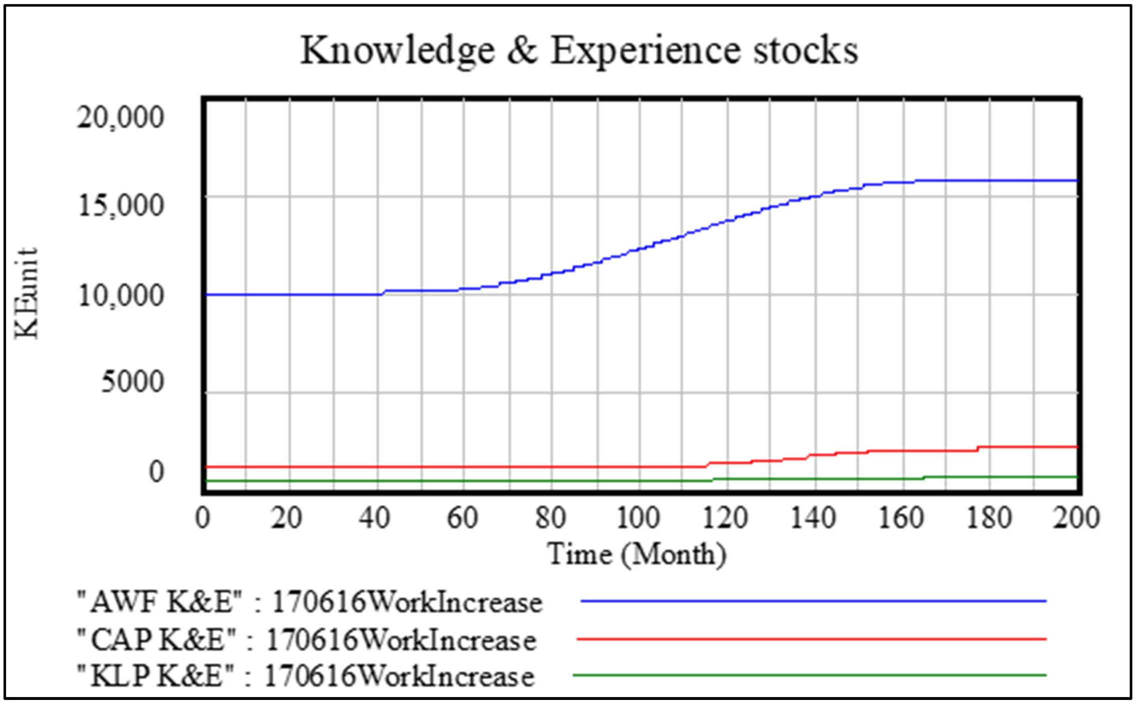



**Figure 7. Changes in Knowledge and Experience Due to an Increase in Workflow**

The increase in the workflow propagates through the AWF workforce, knowledge and experience, and backlogs into the CAP and KLP workforces, knowledge and experience, and backlogs. In turn, each of those two downstream workforces experience an increase in backlog (see Figure 5, months 90–145) and surplus backlog as their current workforce is unable to increase their completion rates. After the CAP and KLP hiring/transfer delays (assumed to be nine and 12 months, respectively) their workforces increase (see Figure 6, months 115–195), which increases their knowledge and experience (see Figure 7, months 115–195) and eventually their production rates, which reduces their backlogs (see Figure 5, months 130–165) to near their target levels.

The model also simulates system performance measures such as changes in the total workforce size (see Figure 8, grey line), average time required for a piece of work to be processed (see Figure 9), and monthly workforce costs (see Figure 10).

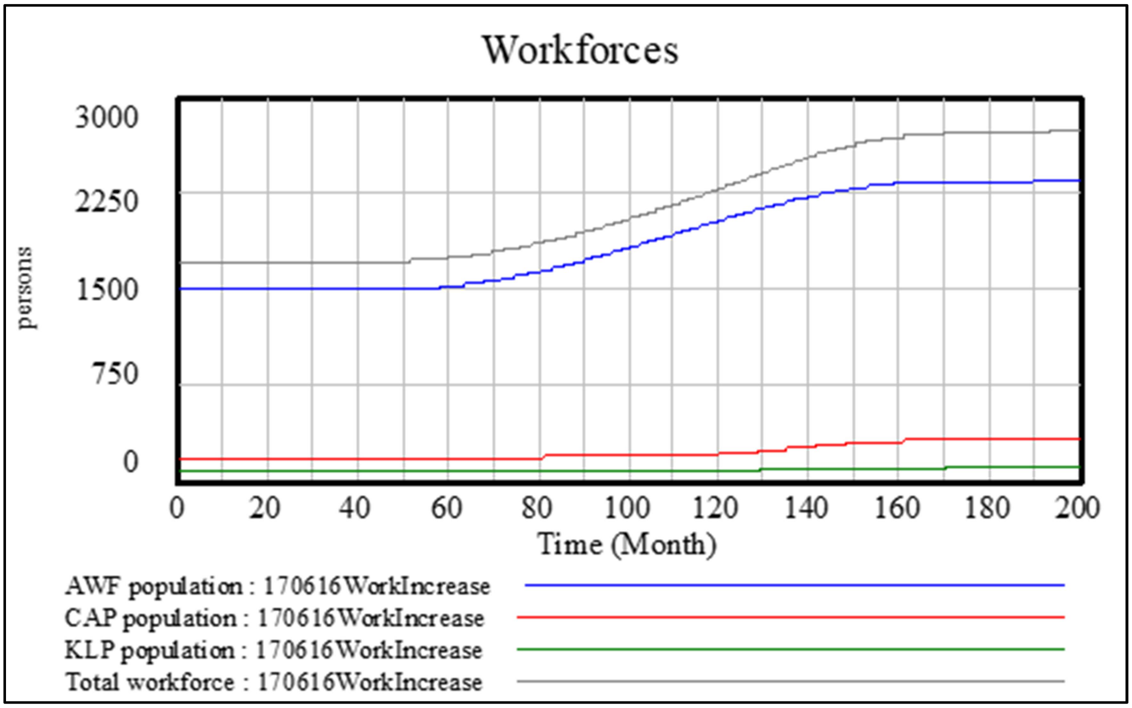



**Figure 8. Changes in Workforce Sizes Due to an Increase in Workflow**

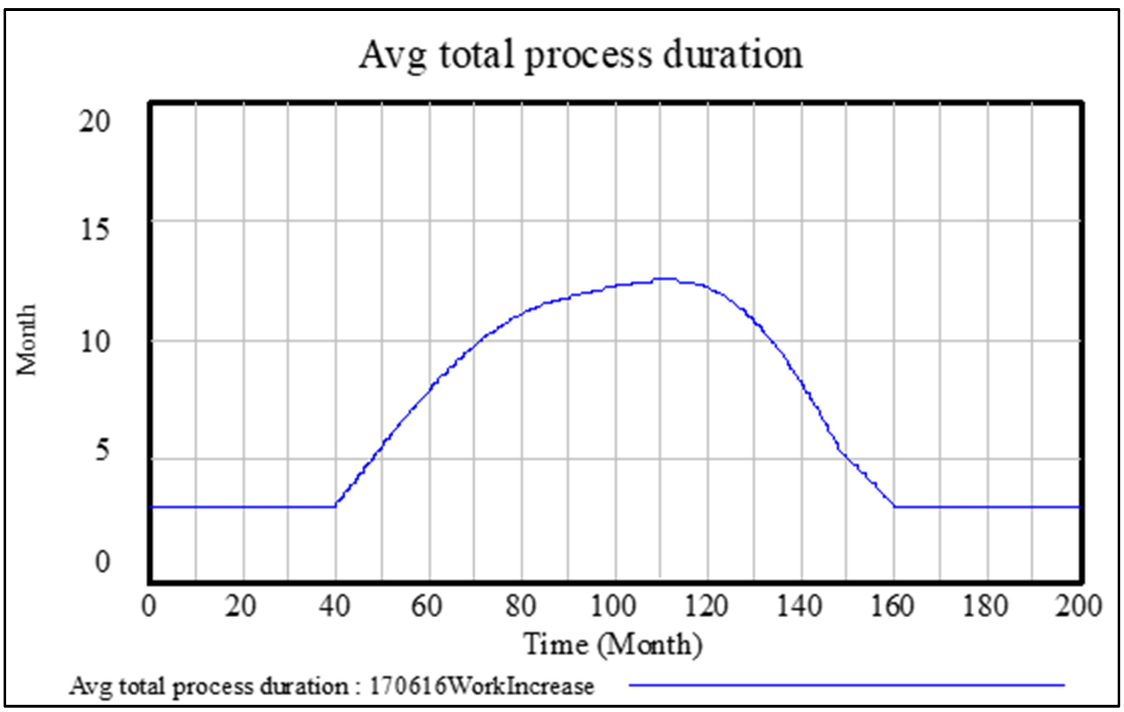



**Figure 9. Changes in Average Time Required for a Piece of Work to Be Processed Due to an Increase in Workflow**

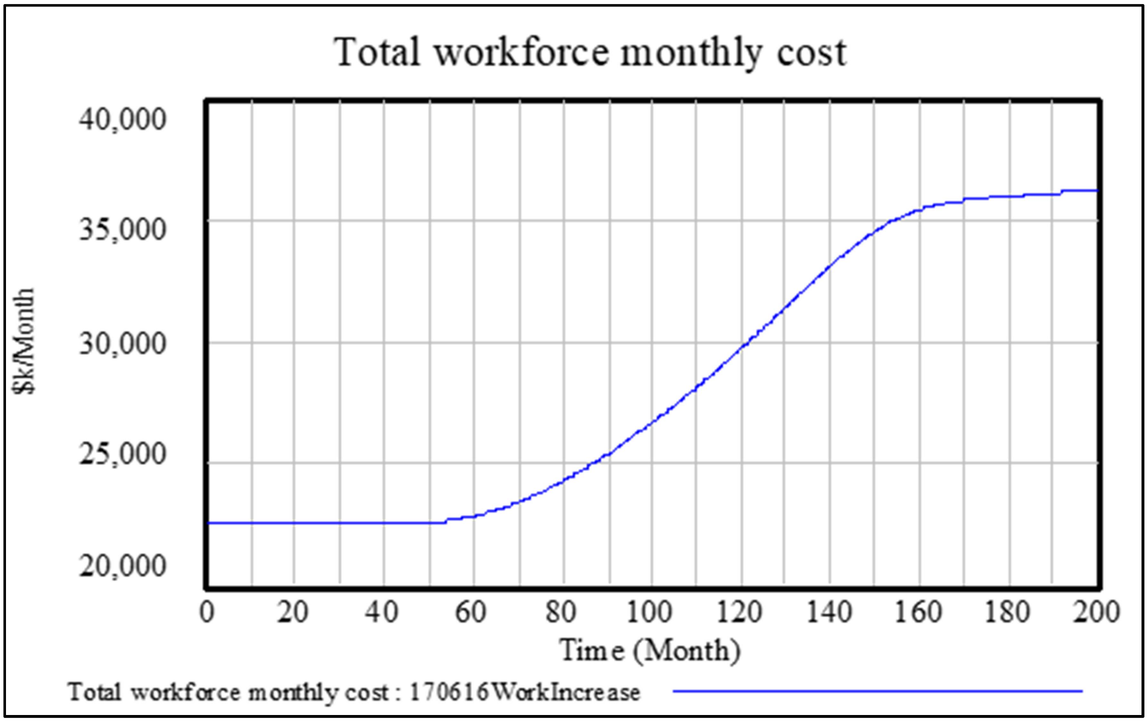



**Figure 10. Changes in Monthly Workforce Cost Due to an Increase in Workflow**

## Planned Model Development

The progression of system descriptors from input (policies, etc.) to output (performance measures) is perceived as progressing through four types of model parameters:

Levers → Mediating Factors → Acquisition Processes → Performance Measures

Example levers, mediating factors, acquisition processes, and performance measures that may be useful in the model include the following:

**Levers**

- Acquisition Category I (ACAT I) versus ACAT II reporting requirements
- Rotation & job swapping
- Defense Acquisition Workforce Improvement Act (DAWIA) certification requirements
- Advanced degrees
- Leadership Development Programs (LDPs)
- Mentoring
- Hiring and retention bonuses
- University of North Carolina (UNC) and University of Virginia (UVA) Darden
- Recruiting strategies
- Various training opportunities

**Mediating Factors**

- Departure fractions and departure rates / Fraction (AWF, CAP, KLP)
- Average time in category/promotion fraction (AWF, CAP, KLP)
- Training and education of the workforce (AWF, CAP, KLP)
- Productivity of applying knowledge and experience (AWF, CAP, KLP)
- Half-life of knowledge and experience
- Hire rates (AWF, CAP, KLP)
- Transfer rates (AWF, CAP, KLP)

**Acquisition Processes**

- Completion rates (AWF, CAP, KLP)

**Performance Measures**

- Dashboard metrics
- Work backlog (AWF, CAP, KLP)
- Total work backlog
- Workforce size (AWP, CAP, KLP)
- Total workforce size
- Workforce cost per month (AWF, CAP, KLP)
- Total workforce cost per month
- Cumulative workforce cost
- Average process duration (time work stays in backlog + work in progress) (AWF, CAP, KLP)
- Average total process duration (time work stays in backlog + work in progress)

Future work can add data on the practices and potential DACM actions within one or more specific categories (i.e., career field in a SYSCOM). This can be used to further develop the model to reflect active and future changes in the workforce system. Data from the categories can be used to calibrate and validate the model. Simulations using the validated model can then be used to analyze current and potential future actions to improve the acquisition workforce. The results can be the basis for recommendations to the DoN DACM.

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