



PROJECT AIR FORCE

Projecting Air Force Rated Officer Inventory Across the Total Force

Total Force Blue Line Model for Rated Officer
Management

Tara L. Terry, Jeremy M. Eckhause, Michael McGee, James H. Bigelow,
Paul Emslie

For more information on this publication, visit www.rand.org/t/RR2796

Library of Congress Cataloging-in-Publication Data is available for this publication.

ISBN: 978-1-9774-0169-4

Published by the RAND Corporation, Santa Monica, Calif.

© Copyright 2019 RAND Corporation

RAND® is a registered trademark.

Limited Print and Electronic Distribution Rights

This document and trademark(s) contained herein are protected by law. This representation of RAND intellectual property is provided for noncommercial use only. Unauthorized posting of this publication online is prohibited. Permission is given to duplicate this document for personal use only, as long as it is unaltered and complete. Permission is required from RAND to reproduce, or reuse in another form, any of its research documents for commercial use. For information on reprint and linking permissions, please visit www.rand.org/pubs/permissions.

The RAND Corporation is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest.

RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

Support RAND

Make a tax-deductible charitable contribution at
www.rand.org/giving/contribute

www.rand.org

Preface

The U.S. Air Force must carefully manage the flow of its rated officers into and out of the force. Traditionally, the Air Force has largely focused personnel management efforts on rated officers in the Regular Air Force, but many of the rated officer career fields in all three components are experiencing shortages in personnel, increases in demand and operational tempo, and a decline in retention. The reduction in the number of aircraft in the Air Force has further exacerbated an already complex personnel management issue, as there are fewer aircraft for training, which, in effect, restricts the number of rated officers the Air Force can train and the amount of experience gained by these officers during their careers.

Thus, the Air Force needs to manage the rated officer force from a total life cycle perspective while accounting for the interactions across the Total Force—Regular Air Force, Guard, and Reserve. However, it has lacked the tools to do that in an integrated and effective manner. Moreover, other factors complicate management of the rated force. These factors include (1) the Total Force manned-aircraft pilot shortage, mostly felt in the fighter pilot career field; (2) increased hiring of military pilots by commercial airlines at rates never seen before, which is likely to continue for the next five to ten years; (3) a shortage of maintenance and career enlisted aviators; and (4) rapidly increasing demand for pilots in the emerging remotely piloted aircraft pilot career field.

This report documents our efforts to develop a long-term career field planning model, the Total Force Blue Line model, which can be used to manage rated officers across the Total Force amid the current turbulence. More specifically, we built a linear programming model that specifies the number and types of manned-aircraft pilots, combat systems officers, air battle managers, and remotely piloted aircraft pilots that should be produced annually from the undergraduate training pipeline to fill requirements across the Total Force. Using the model, we then explored the implications of several production and retention scenarios on long-term career field health given a set of rated officer requirements. The report explains the model's main features, underlying content, and data inputs; it also describes key technical aspects of the model.

This report is intended to provide our sponsor and rated career field managers with information about the capabilities of the model and how it can be used in policy analysis. It would also interest those who are involved in the technical modeling aspect of career field planning.

The research reported here was commissioned by the United States Air Force and conducted within the Manpower, Personnel and Training Program of RAND Project AIR FORCE as part of three sequential fiscal year projects (FYs 2014–2017) titled Total Force Aircrew Management Analytic Support. This report documents work shared with the U.S. Air Force as recently as April 20, 2017.

RAND Project AIR FORCE

RAND Project AIR FORCE (PAF), a division of the RAND Corporation, is the U.S. Air Force's federally funded research and development center for studies and analyses. PAF provides the Air Force with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future air, space, and cyber forces. Research is conducted in four programs: Force Modernization and Employment; Manpower, Personnel, and Training; Resource Management; and Strategy and Doctrine. The research reported here was prepared under contract FA7014-16-D-1000.

Additional information about PAF is available on our website: <http://www.rand.org/paf/>

This report documents work originally shared with the U.S. Air Force on April 20, 2017. The draft report, issued on June 6, 2018, was reviewed by formal peer reviewers and U.S. Air Force subject-matter experts.

Contents

Preface.....	iii
Figures.....	vii
Tables.....	viii
Summary.....	ix
Acknowledgments.....	xv
Abbreviations.....	xvi
1. Introduction.....	1
Overview of the Rated Officer Life Cycle	2
Total Force Aircrew Management Charter.....	5
The Importance of Long-Term Career Field Management	5
Our Approach	7
Organization of the Report	8
2. Total Force Blue Line Model Overview.....	9
Model Inputs and Assumptions	9
Model Objective Function and Constraints	15
3. The Impact of Retention on Inventory Levels with Fixed Production	19
Baseline Results.....	19
Major Airline Hiring Results.....	23
Comparing Pilot Shortfall with Baseline and Major Airline Hiring Losses.....	27
Conclusion.....	28
4. The Impact on Inventory Levels of Optimizing Production for Pilots	29
Constraints on Production Quantities	29
Optimized Production Results with Major Airline Hiring Losses	30
Conclusion.....	35
5. The Impact of Optimizing Production on Inventory Levels for CSOs, ABMs, and RPA Pilots.....	36
Overview	36
The Effect of Optimizing Production on CSO Inventories	38
The Effect of Optimizing Production on ABM Inventory	40
The Effect of Optimizing Production on RPA Pilot Inventory	42
6. How the Model Can Be Used to Support Rated Officer Analysis.....	44
Appendix A. Requirements, Fixed Production, and Upper Bounds on Production Data.....	46
Appendix B. TFBL Model Formulation	53
Appendix C. Research Methodology for Determining Major Airline Hiring Influence on Pilot Losses	65
Appendix D. ARP, ACP, and AvB History	77

Appendix E. Regressions	80
References	86

Figures

Figure 2.1. General Overview of the TFBL Model	15
Figure 3.1. Pilot Shortfall, by Component, with Baseline Losses	22
Figure 3.2. Pilot Shortfall, by Component, with MAH Losses.....	26
Figure 3.3. RL/BL for Pilots Across Total Force Under Baseline and MAH Loss Scenarios	28
Figure 4.1. Pilot Shortfall, by Component, with MAH Losses and Optimized Production	31
Figure 4.2. Comparison of Fixed and Optimized Production Scenarios	34
Figure 5.1. CSO Shortfall, by Component, with Optimized Production Scenario	39
Figure 5.2. ABM Shortfall, by Component, with Baseline Losses and Optimized Production ...	41
Figure 5.3. RPA Shortfall, by Component, with MAH Losses and Optimized Production	43
Figure C.1. U.S. Pilot Flow (PF) Model	66
Figure C.2. Total Fixed-Wing Pilot Inventories, USAF and USN	69
Figure C.3. Part 121 Majors, Historical and Forecasted Major Airline Hires	71
Figure C.4. Scatterplot of Separations and Retirements Combined Versus Major Airline Hiring.....	74
Figure C.5. Scatterplot of Total USAF and USN Losses Versus Major Airline Hiring.....	74
Figure C.6. Major Airlines Salaries and QoL	75
Figure E.1. USAF RegAF Losses Versus MAH	80
Figure E.2. ANG Total Losses Versus MAH	82
Figure E.3. AFR Total Losses Versus MAH	83
Figure E.4. ANG Affiliations Within One Year of Separating.....	84
Figure E.5. AFR Affiliations Within One Year of Separating	84
Figure E.6. ARC Affiliations Within One Year of Separating	85

Tables

Table 2.1. Elements Captured in the TFBL Model.....	10
Table 3.1. Aggregate Pilot Baseline Loss Rates for FYs 2017–2028.....	20
Table 3.2. Aggregate Pilot Loss Rates for FYs 2017–2028 with Baseline and Major Airline Hiring Losses.....	24
Table 4.1. Pilot Shortfall, by Component, FYs 2017–2025, FY 2030	32
Table 4.2. Pilot Production, by Component, for Fixed and Optimized Cases.....	33
Table 5.1. Aggregate Baseline Loss Rates for FYs 2017–2028 for CSOs, ABMs, and RPA Pilots.....	37
Table A.1. Relationship of MWSs for Each Component, by Rated Category.....	46
Table A.2. Annual Fiscal Year Requirements for All Components, Rated Categories, and MWSs.....	48
Table A.3. Annual Production Quantities for All Components, Rated Categories, and MWSs ..	50
Table A.4. Annual Upper Bound Production Limits for Pilot and RPA Personnel in the Regular Air Force.....	52
Table A.5. Total Force Production, by Rated Category and Fiscal Year	52
Table C.2. Total Fixed-Wing Pilot Inventories, Civilian.....	70

Summary

Background and Purpose

It has become more complex for the U.S. Air Force (USAF) to manage its rated officer population due to the lengthy and costly training pipelines, declining availability of aircraft to train the rated officer force, and the effects of external factors that affect the retention of Air Force rated officers. The Air Force has always had to manage the rated officers in the Regular Air Force (RegAF) by balancing the flows into the force, distributing them among the various rated officer career fields and aircraft, and monitoring the flows out of the force. However, it has not had to manage the flows into the two reserve components, the Air Force Reserve (AFR) and the Air National Guard (ANG), quite as diligently, because the supply of rated officers into those components was both abundant and cheap. Such recent changes as the overall reduction in the number of aircraft, the pending elimination of the A-10 aircraft, the arrival of the F-35 aircraft, and the increase in civilian pilot hiring from the major airlines have made it more challenging to manage rated officers in all the components. Thus, it has become increasingly important to adopt an overall—or Total Force—perspective on the rated officer force, especially in the manned-aircraft pilot community, where there is a significant shortage of pilots. This report documents our efforts to develop a long-term career field–planning model for all rated officers across the Total Force that can be used to assess policy alternatives and inform decisionmaking in managing the rated officer force.

The Total Force Blue Line Model

The Total Force Blue Line (TFBL) model was developed by RAND Project AIR FORCE (PAF) to satisfy the Air Force Directorate of Operations' (AF/A3) need to have an analytical capability to help manage the rated force across all components—Regular Air Force, ANG, and AFR. TFBL could replace (or run side-by-side with) the Air Force Rated Aircrew Management System (AFRAMS) model that has supported Regular Air Force rated management since fiscal year (FY) 2001 while simultaneously providing a tool that also manages the Air Force Reserve and Air National Guard rated officer forces and captures the interactions among the three components.

To accomplish this goal, this study sought to develop a linear programming model to project the short-term (over the next five years) and long-term (ten or 20 years down the road) consequences of career field planning decisions on the health of the Total Force rated officer force. The essence of the model is to match rated officer inventory to the requirements for each component by determining the annual production and affiliations needed. The model factors in

historical retention and affiliation patterns for all three components, each rated category, and many of the rated career fields.

We defined the majority of the model constraints and inputs by (1) analyzing existing data to include manpower authorizations and personnel data files, (2) discussing with our sponsoring office how the model structure matches reality and the implications on the model results, and (3) meeting with subject-matter experts about data and modeling to improve our model and coordination with the Air Force.

Rated force management models typically use a framework (referred to as red-line/blue-line or RL/BL) where the number of personnel in the current inventory (blue-line) over time is compared to the number of personnel required (red-line) to run the enterprise. When the total inventory equals total requirements, the enterprise is fully staffed. The RL/BL charts enable leadership to identify which categories of rated inventory will experience persistent shortfalls or surpluses and may therefore require additional management attention.

How We Designed the Model

Our approach to building a rated officer career field management model was informed by past (both far and recent) RAND Corporation work developing rated force management models. TFBL is an optimization model that forecasts how career field dynamics, such as production, retention, and affiliation, might unfold over time. Thus, the modeling decisions that simplify the real context of career field planning are critical to the accuracy and usefulness of the model, as are the data analyses from which the model inputs are created. We highlight model inputs and assumptions here; a more detailed explanation appears in the body of the report and the appendixes.

Model Inputs and Assumptions

Put simply, the model is initialized with the current inventory for each component and type of rated officer (11X Pilots, 12X Combat Systems Officers, 13B Air Battle Managers, and 18X Remotely Piloted Aircraft Pilots) at the end of FY 2016 and a set of manpower requirements for FY 2017 and onward. The main goal of the model is to increase or decrease the initial inventory to ultimately match the requirements while limited by some real-world constraints. Important considerations are the schoolhouse capacity, the time it takes to attain an inventory that matches the requirements, and whether the path to attain this inventory is sustainable. The model provides a solution that best matches the inventory to the requirements by determining the production and affiliations needed while factoring in retention patterns of each type of rated officer.

The main elements captured in the model are as follows:

- *Requirements.* The requirements are derived from the Manpower Programming and Execution System (MPES) database and are the summation across all types of jobs for each career field considered in the model.

- *Maximum production capacity.* Production is one mechanism the model uses to increase inventory. Production here is measured as the number of officers who successfully graduate from undergraduate flying training annually. Without constraints, the model maximizes or minimizes production to meet requirements as quickly as possible. But in the model, boundaries are set based on inputs from the Air Force Director of Training and Readiness (AF/A3TF) Total Force Aircrew Management (TFAM) to ensure reasonable production limits each year.
- *Retention.* Retention patterns are defined for each component, career field, and commissioned year of service based on historical data. In the case of the major airline hiring scenario, aggregate pilot retention rates are based off a separate linear regression analysis that shows the linkage between major airline hiring and Air Force pilot separations and retirements.
- *Affiliation rates.* Affiliations are the main mechanism for how the AFR and ANG gain individuals each year. Therefore, we include affiliations in the model, and the affiliation rates used are based on historical affiliation patterns (averaged over a 20-year period).

How the Model Works

The model finds an optimal solution by seeking the best match of inventory to annual requirements, simultaneously determining the needed production and affiliations each year while accounting for retention patterns. To ensure that the model reaches this solution as efficiently as possible, several priorities are encapsulated in the objective function. In general, the model minimizes

- the number of unfilled requirements
- the number of rated officers in excess of requirements
- the number of rated officers produced
- the deviation of model affiliations from the historical affiliation pattern.

What We Explored with the Model

Our research team conducted two excursions that demonstrate how the model functions and potential conclusions resulting from the excursions. One excursion, found in Chapter 3, examines two types of retention scenarios comparing a baseline excursion to a major airline hiring excursion for manned-aircraft pilots. The second excursion examines two types of production cases comparing planned production levels to optimized production levels: Chapter 4 on manned-aircraft pilots and Chapter 5 for combat systems officers (CSOs), air battle managers (ABMs), and remotely piloted aircraft (RPA) pilots. These excursions address some of the issues that decisionmakers are currently grappling with as part of ongoing efforts to improve the health of each rated career field across the Total Force and provide analysis and conclusions that could be drawn from the excursions to influence policy.

Two Retention Scenarios

We used TFBL to examine the effects of different retention levels on the health of each rated career field, as retention is one of the two main levers affecting the inventory in this model. We considered two retention scenarios: (1) loss rates derived from AFRAMS model results,¹ which we refer to as the baseline loss scenario; (2) loss rates derived from a linear regression model (McGee, 2015), which forecasts loss rates for the manned-aircraft pilot community in response to increases in major airline hiring, referred to as the major airline hiring (MAH) scenario. For each of these scenarios, the pilot production levels used were provided to RAND by AF/A3TF.

Currently the major airlines are forecasting an unprecedented level of civilian pilot hiring, which will continue to increase over the next five years. Research indicates that the only significant relationship between forecasted major airline hiring and Air Force separations applies to the manned-aircraft pilot community; CSOs, ABMs, and RPAs currently aren't affected by major airline hiring, and therefore we have two retention scenarios for the manned-aircraft pilot community only.

In the major airline hiring scenario, shortfalls in almost all pilot categories persist, and shortfalls occur earlier and more severely than in the baseline loss scenario. For example, by FY 2022, the RegAF pilot shortfall in the major airline hiring scenario is more than double the amount in the baseline loss scenario (2,008 versus 952). While the RegAF pilot shortfall significantly increases over the following several years, the ANG and AFR meet their pilot requirements earlier than under the baseline loss scenario, due to an increase in affiliations from higher RegAF separations. For instance, the pilot shortfall is less than half by FY 2021 for the AFR in the major airline hiring scenario. While the decreases in the shortage for the AFR and ANG represent a significant portion of the ANG and AFR pilot shortfalls, the increase in the pilot shortage in the RegAF tends to dwarf them, in both the near and long term. A complete presentation of these results is presented in Chapter 3.

Two Production Scenarios

Given that the pilot community faces and will continue to face significant shortfalls across the Total Force under fixed production levels in light of increased major airline hiring, RAND explored production levels required to mitigate these shortfalls. The existing AF/A3TF planned production represents the “fixed” production based on accession targets, training seat capacity, ability for pilots to fly to gain needed experience, and other policy issues. By “fixed” production, we mean adhering rigidly to the planned production. This “fixed” production may vary from year to year but is determined exogenously from TFBL and cannot be adjusted by the model. Varying production to respond more robustly to the demand signal is an obvious approach toward

¹ The AFRAMS model is maintained and run by Human Resources Data, Analytics, and Decision Support Division, Directorate of Plans and Integration (AF/A1XD, formerly AF/A1PF) and has been the program of record for RegAF inventory modeling projections since 2001.

alleviating the shortage. This is especially true because the Air Force has largely an “up-or-out” system in terms of promotions, and there are statutory or policy provisions preventing lateral pilot entries in later points in the career. At best, with 100-percent retention, the number of officers is limited by the number of officers accessed and produced each year. Toward this goal, the TFBL model was employed to optimize pilot production (with realistic production constraints) to reduce the shortfall to the largest extent possible. The purpose of creating an optimized production plan is to provide policymakers with the ability to assess risk and assign resources to those areas of most critical need.

The way TFBL is formulated, production must be bounded above and below to ensure reasonable and realistic production levels. It is unrealistic to assume a training school could shut down for a year, just as it is unreasonable to assume that production could triple from one year to the next. Thus, we bounded production for the RegAF between 90 and 110 percent of planned (or fixed) values and forced production to be smooth (deviating no more than 10 percent from the previous year’s production level to ensure realistic increases or decreases in production in such a small time frame).² AFR and ANG production is capped at the planned production levels, and the Total Force production for each rated category (pilots, CSOs, ABMs, and RPAs) was also limited.

Despite the limited ability to change production, modest production changes from planned levels can have a significant impact on the community specific shortfalls. As we show in Chapters 4 and 5, the ability to optimize production can largely offset the effects of major airline hiring for manned-aircraft pilots and mitigate any shortages for CSOs, ABMs, and RPA pilots. However, we caution the reader that the specific production results presented in this document should be considered in the larger production pipeline context, as the production doesn’t address absorption constraints.

Production results must be taken in the proper context. The production in the model signals the number of pilots who should graduate from undergraduate pilot training each fiscal year. This model then makes an implicit assumption that the number of pilots produced each year can successfully flow through graduate pilot training in the formal training units and then move into the operational squadrons where they gain the experience (also known as absorption) required in the time frame required. This assumption is likely invalid for fighter and special operations pilots, as well as being potentially problematic for other kinds of pilots in specific airframes. However, the intent of TFBL as an RL/BL model specifically gets to inventory and manning levels and was never designed to address absorption or experience levels.

² Please see Appendix A for a more detailed discussion of data used in the model runs.

How the Model Can Support Total Force Rated Officer Analysis

The model results described in this summary and in the body of the report explore issues that affect career field health over time: production levels, affiliation rates, and possible influences of civilian pilot hiring on retention. As it stands, the model reflects the best data and information about the Total Force rated officer community; however, policymakers may wish to change the information in the model in the future. For example, the requirements are provided at an aggregate level, but senior leaders may wish to incorporate more requirement details, such as the type of duty, to include line-flying duties or staff positions, or to incorporate historical assignment patterns to these specific kinds of duties. Anticipating that various types of changes to the model would be needed, we have ensured that it can be adjusted and edited so that it will continue to be useful to policymakers not only today, but for years to come.

The overarching purpose of the model and of the results that are produced is to enable policymakers to visualize the effect of a variety of issues on the health of the rated officer career fields and, accordingly, make decisions about policies for managing the career field that are informed by projections of the policy's effects ten or 20 years in the future. The ability to vary assumptions in the model to depict alternative policy scenarios or reflect current realities and analyze the effects can provide valuable information to Air Force leadership as new initiatives are being considered prior to implementation. Understanding the implications of distinct retention patterns provides insight into the importance of monitoring retention and devising appropriate incentives to maintain the needed experience within each community. These and other analyses can be conducted using the TFBL model to inform Air Force decisionmaking along the path toward attaining healthy Total Force rated career fields.

Acknowledgments

We are grateful to many Air Force personnel who have assisted in this study. Maj Gen Martin Whelan, Directorate of Future Operations (AF/A3X), and Steven (Pounder) Ruehl (then AF/A3X, now AF/A3O with the same name) served as the main sponsors and provided feedback during their tenure before retirement (in the case of Maj Gen Whelan) and reorganization (in the case of Ruehl). Col Terry (Katt) Frady, Lt Col Chris (CMac) McDonald, Col Farley (Sweet) Abdeen, Col Vance (VC) Bateman, Col John (JDub) Welch, Lt Col Mark Wernersbach, Lt Col Dawn Brindle, Lt Col Jeff Clark, and Lt Col Chris (Packman) Pack served as our action officers and points of contact over the three fiscal years this research was conducted. They were instrumental in providing us with data, context, and insights into rated officer management. Primarily due to Lt Col Mark Wernersbach and Lt Col Chris Pack, we maintained consistent communication with Air Force Directorate of Operations (AF/A3), which enabled our work to have greater influence on rated management policy decisionmaking in AF/A3. We'd like to thank several of the officers and analysts who worked in the Rated Force Policy Division of the Air Force, Directorate of Force Management Policy (AF/A1PPR), namely Lt Col Rob Butkovich, Lt Col Chris McDonald (CMac), and Lt Col Andy Beale, and several analysts in AF/A1XD (which used to be AF/A1PF prior to reorganization) over the years as we have worked to improve upon our data and modeling methods.

We would also like to thank several RAND researchers who assisted in the work. Al Robbert, Lisa Harrington, Bart Bennett, and John Crown provided insightful reviews of early versions of the model and output. We ultimately produced a much-improved model as a result of all of their comments, questions, and suggestions. Lastly, we'd like to thank Al Robbert and Gary Massey for their insightful reviews that greatly strengthened the report.

Abbreviations

11U	remotely piloted aircraft pilot (former traditionally manned pilot)
12U	remotely piloted aircraft pilot (former combat systems operator)
18X	remotely piloted aircraft pilot
ABM	air battle manager
ACP	aviation continuation pay
ACIP	aviation career incentive pay
ACTF	Aircrew Crisis Task Force
ADSC	active duty service commitment
ADSO	active duty service obligation
AETC	Air Education and Training Command
AF/A1XD (was AF/A1PF)	Human Resources Data, Analytics, and Decision Support Division, Directorate of Plans and Integration
AF/A3TF	Directorate of Operations, Director of Training and Readiness, Total Force Aircrew Management
AFPC	Air Force Personnel Center
AFR	Air Force Reserve
AFRAMS	Air Force Rated Aircrew Management System
AF/REP	Personnel Directorate, Air Force Reserve
AFROTC	Air Force Reserve Officer Training Corps
AFSC	Air Force specialty code
ALFA	ALO, LIFT, FAC, and AETC (air liaison officer, lead-in fighter training, forward air controller, Air Education and Training Command)
AMEC	Aircrew Management Executive Council
ANG	Air National Guard
ARC	Air Reserve Component
ARP	aviator retention pay
ATP	air transport pilot

AvB	aviation bonus
AWACS	airborne warning and control system
BL	baseline (scenario)
C2ISR	command and control, intelligence, surveillance, and reconnaissance
CEA	Career Enlisted Aviator
CFI	commercial flight instructor
CSAR	combat search and rescue
CSAF	Air Force Chief of Staff
CSO	combat systems officer
CYOS	commissioned years of service
FAA	Federal Aviation Administration
FTU	formal training unit
FY	fiscal year
FYDP	future years defense planning
IFF	introduction to fighter fundamentals
JSTARS	Joint Surveillance and Target Attack Radar System
LoE	line of effort
MAH	Major Airline Hiring (scenario)
MilPDS	Military Personnel Data System
MPES	manpower programming and execution system
MWS	Major Weapon System
NGB/A1MP	Air National Guard Manpower, Organization, and Resources Division
OPNAV	Office of the Chief of Naval Operations
OTS	Officer Training School
PAF	RAND Project AIR FORCE
PF	Pilot Flow (model)
PIC	pilot in command
QoL	quality of life
RDTM	rated distribution and training management

RegAF	Regular Air Force
RIF	reduction-in-force
RL/BL	red-line/blue-line
RPA	remotely piloted aircraft
SME	subject-matter expert
SO	special operations
TFAM	Total Force Aircrew Management
TFBL	Total Force Blue Line (model)
UFT	undergraduate flying training
UPT	undergraduate pilot training
USA	U.S. Army
USAF	U.S. Air Force
USAFA	U.S. Air Force Academy
USCG	U.S. Coast Guard
USMC	U.S. Marine Corps
USN	U.S. Navy
YAS	years of aviation service

1. Introduction

It has become more complex for the U.S. Air Force (USAF) to manage its rated officer population due to the lengthy and costly training pipeline, aircraft availability to provide adequate flying experience to the rated officer force, and the effects of external and environmental factors on Air Force rated officer retention. It has always had to manage the rated officers in the Regular Air Force (RegAF), balancing the flows into the force, distributing newly winged undergraduate flying training graduates among the various rated officer career fields and aircraft, and monitoring the flows out of the force. However, in the past, the Air Force has not had to scrutinize the flows into the two reserve components, the Air Force Reserve (AFR) and the Air National Guard (ANG), as diligently, because the supply of rated officers affiliating into those components was both abundant and cheap. But recent changes, such as the overall reduction in the number of aircraft affecting the Air Force's ability to train and season pilots, the pending elimination of the A-10 aircraft, the arrival of the F-35 aircraft, the increase in civilian pilot hiring from the major airlines, and a growing demand for remotely piloted aircraft missions, have made it more important to take an overall—or Total Force—view of the rated officer force, especially in the manned-aircraft pilot community, which has a significant shortage of pilots across the Total Force.

Managing the flow of rated officers into and out of the Air Force can be difficult. Delivering the right number of trained and experienced aircrew to fill the cockpits requires Air Force personnel managers to look ahead several years and anticipate what the demand will be (requirement) and determine whether the supply (inventory) will be adequate to meet the anticipated demand. Furthermore, the main source of incoming aircrew to the AFR and the ANG are aircrew separating from the RegAF, so Air Force personnel managers must consider AFR and ANG aircrew forces as the RegAF establishes retention policies with due regard for their impact on the AFR and ANG.

The pilot community is dealing with a chronic fighter pilot shortage and an impending mobility pilot shortage. In March 2017, the Air Force Deputy Chief of Staff for Manpower, Personnel, and Services testified before Congress that the Air Force faced a shortage of 1,500 pilots at the end of fiscal year (FY) 2016 across the Total Force, most of which resided in the fighter pilot community (Grosso, 2017). This aircrew crisis, and more specifically the fighter pilot crisis, is likely to worsen and is already having negative consequences on other pilot career fields as pilots are drawn from other fields to fill positions that fighter pilots would normally fill (e.g., instructor pilot or joint and staff positions).

Additionally, the national commercial air fleet business directly affects the Air Force's pilot population, and it has been a growing concern for all manned-aircraft pilot communities. Research has shown that increases in major airline hiring correlate with higher pilot attrition

(McGee, 2015; Sweeney, 2015). Higher salaries and predictable travel schedules are also a draw and affect separation decisions for Air Force pilots. While the Air Force has occasionally faced temporary spikes in major airline demand that draw more pilots out of the RegAF, there is no historical precedent for the sustained level of demand that is projected in the years to come (McGee, 2015). Recent data cited in the March 2017 testimony suggest that, over the next several years, major airline hiring is forecasted to reach unprecedented high levels, and airline pilot salaries have increased (Grosso, 2017). This aircrew crisis, combined with unprecedented major airline hiring, means that the Air Force must consider every avenue available to retain the experienced aircrew currently in the force and, at the same time, determine how to ramp up production and absorption of new pilots quickly and efficiently to address the current pilot shortage.

Overview of the Rated Officer Life Cycle

This work focuses on the rated officer community, personnel whose duties require flying and who include those officers who are 11X Pilots, 12X Combat Systems Officers (CSOs), 13B Air Battle Managers (ABMs), and 18X Remotely Piloted Aircraft (RPA) Pilots.³ Each year, the Air Force must identify the number of personnel needed to continue the steady flow of personnel into the rated community, accessing enough officers into the Air Force to ensure a sufficient number of them complete undergraduate training to fill the career field pipeline. Each year, accessions are needed to replace the total number of rated officers who separate or retire from the Air Force, those who voluntarily or involuntarily leave, those who are promoted to Colonel (O-6) and promote out of the group under consideration (O-1 through O-5), and those who are no longer qualified to fly. This is a complex process that involves art as well as science. We provide a brief description here to convey the complexity of this entire process.

Rated Accessions

U.S. Air Force Academy (USAFA) and Officer Training School (OTS) graduates are commissioned and immediately enter active duty. The Air Force places a top priority on placing these officers into undergraduate training seats as soon as they become available. Because the training pipeline for rated officers is quite long, the Air Force also does its best to get the USAFA and OTS graduates into training seats immediately. Air Force Reserve Officer Training Corps (AFROTC) graduates do not necessarily enter active duty immediately and can be delayed for up to one year to minimize the number of active duty officers awaiting training (minimizing cost) and to create a queue whereby AFROTC cadets can enter active duty just-in-time to fill training seats throughout the year that would otherwise have gone unfilled. Since USAFA and

³ 11X, 12X, and 18X are career field designators, with the X representing a series of specific aviation community designations.

AFROTC graduate the bulk of their cadets in the spring, when training seat availability is limited, it becomes more difficult to schedule training in classes that occur year-round. Thus, the ability to delay AFROTC cadets from entering active duty immediately helps to alleviate some of the training seat congestion and improves training seat utilization over the course of the FY.

At a minimum, the training process contains two main blocs of training: undergraduate flying training (UFT) followed by the formal training unit (FTU). UFT has four specific tracks, one for each rated category: undergraduate pilot training (UPT), undergraduate CSO training, undergraduate ABM training, and undergraduate RPA training. The longest undergraduate training is for the pilots, at 54 weeks. The FTU has training specific to the aircraft that each officer is assigned to and, on average, is about 24 weeks long but can be up to 63 weeks in length—for example, for the CV-22. In between UFT and the FTU, fighter pilots also take an eight-week course called introduction to fighter fundamentals (IFF).

Upon completion of UFT, each officer earns his or her wings, and the clock starts on their active duty service commitment (ADSC): ten years for pilots and six years for CSOs, ABMs, and RPA pilots. Air Force pilot training is so costly that the longer ADSC is required for the Air Force to get a return on investment and to help maintain a certain retention level so as not to drive the number of accessions higher, thereby generating an even larger UFT bill. After the completion of UFT, officers then serve out the remainder of their ADSC, to include aircraft-specific training at the FTU.

While most of the production occurs in the RegAF, the AFR and ANG do have capabilities to produce officers. However, since the production levels are small in number, production is not the main source for personnel entering the Air Reserve Component (ARC). The ARC relies very heavily on officers separating from the RegAF and affiliating, usually within one FY of separating from the RegAF. As RegAF officers are under an ADSC, the ARC receives the bulk of affiliations much later in a rated officer's career: 11 to 14 years later for manned-aircraft pilots, and seven to nine years (or later) for CSOs and ABMs (and, likely, RPAs in the future). An additional complication is that the separating officer must work with the ARC to find an unfilled requirement satisfactory to both parties before the affiliation can be processed.

Once pilots are accessed and trained, the Air Force also must manage retention across the pilot communities, which leads into the next complex aspect of rated officer management.

Retention

Given ongoing pilot shortages, the potential for even greater shortages, and the cost of training new pilots, retaining experienced pilots in the force is an important goal.

To entice rated officers to stay past their initial ADSC, there is an aviation bonus (AvB) program. Thus, when RegAF rated officers face the end of their UFT ADSC, they have three options: leave the Air Force, stay in the Air Force and sign a bonus contract, and stay in the Air Force and do not sign a bonus contract. Aircrew members can sign whatever contracts are available for that given FY, which are subject to change each FY. In FY17, manned-aircraft

pilots (11X) could sign on for an additional one-, two-, five-, or nine-year service commitment and receive an annual bonus ranging from \$28,000 to \$35,000 for a first-time bonus, depending upon the pilot's AFSC. RPA pilots (18X) could sign on for an additional five- or nine-year service commitment and receive an annual bonus of \$35,000. There were other stipulations if the pilot's ADSC expired before FY 2017 or the pilot signed a renewal contract, but those were generally five- or nine-year service commitments, for \$28,000 to \$35,000 annual payments. Additionally, pilots who never signed an aviation bonus contract, or who signed an aviation bonus contract that had expired, were eligible to sign on for a minimum term of 22 years of aviation service and receive an annual bonus ranging from \$28,000 to \$35,000.⁴ CSOs (12X) could sign on for an additional five-year service commitment and receive \$10,000 to \$20,000 annually, depending upon the CSO's AFSC.

For the AFR and ANG, the FY 2017 AvB programs were limited to Active Guard and Reserve officers (AFR and ANG officers who are on active duty status). For AFR, there were two tiers: the first tier contained 11X pilots and 18X RPA pilots, and the second tier contained 12X CSO officers. The Tier 1 AvB program provided \$30,000 annually for one to three years of service commitment for a first-time contract, and it provided \$20,000 annually for one to three years of service commitment for a renewal contract. The Tier 2 AvB program provided \$25,000 annually for one to three years of service commitment for a first-time contract, and it provided \$15,000 annually for one to three years of service commitment for a renewal contract.

The ANG AvB program also had two tiers but was a bit more specific to positions deemed critical. The first tier was for RPA pilots (to include 11Us, 12Us, and 18Xs), 11F fighter pilots, 11X instructor pilots, and 12M C-130 instructor navigators and offered \$30,000 annually for a service commitment of four to six years for a first-time contract or \$20,000 annually for any service commitment contract of less than four years or for any length renewal commitment between two and six years. The second tier focused on pilots (excluding instructor pilots), CSOs (excluding 12M C-130 instructor navigators), and ABMs assigned to the RC-26 only. For each of these Tier 2 categories, a \$25,000 annual payment for a four- to six-year service commitment for a first-time contract was offered; for renewal contracts of two to six years' service commitment or first-time contracts less than four years' service commitment, the offer was \$15,000 annually.

Current legislation mandates that a business-case analysis be used to determine, by aircraft category, the need for an aviation bonus, the associated contract length, and the annual dollar amount to be offered. The Air Force business case analysis includes the following factors for each aircraft category: current and projected manning, retention trends, cost of training a replacement, and length of training. It is important to note that AvB offerings may vary from

⁴ Please see *United States Air Force Fiscal Year 2017 RegAF Aviation Bonus (AvB) Program, Proposal 2* for additional information regarding AvB offering.

year to year due to legislative changes, budget, business case analysis, and perspective of approval authority.

This description has presented some of the complexities of the acquiring, training, and retaining of Air Force rated personnel, which is why a tool that helps to manage this critical human capital is vital to the success of the Total Force Aircrew Management (TFAM) office.

Total Force Aircrew Management Charter

Recognizing that aircrew management throughout the Total Force would benefit from greater coordination among the active and reserve components, the Air Force Chief of Staff (CSAF), at the 2013 Aircrew Summit, directed the formation of a TFAM office. In September 2014, the Secretary of the Air Force and CSAF, Chief of the AFR, and Director of the ANG signed the Total Force Aircrew Management Charter. The mission of the TFAM office is to integrate the management of the RegAF, AFR, and ANG aircrew resources to maximize Total Force combat readiness.

To be successful, the TFAM office needs the capability to conduct and use objective analysis. This analysis includes generating reliable, consistent projections of aircrew requirements and inventories, and the ability to assess how policy changes affect these projections. The RegAF has an analytic capability to generate these projections using the Air Force Rated Aircrew Management System (AFRAMS) model. The capabilities in the reserve component have been more limited, lacking, for example, the capability to project either expected or policy-driven changes in inventories over time.

RAND Project AIR FORCE (PAF) has developed a modeling capability—the Total Force Blue Line (TFBL) model—that provides inventory projections for each of the three Air Force components (RegAF, AFR, and ANG) using consistent parameters and accounting specifically for the flow of pilots among the components. This report describes the development of the TFBL model for projecting Total Force rated officer demand and supply at the level required to manage rated officers (position, component, weapon system, and commissioned years of service).

The Importance of Long-Term Career Field Management

In 2017, the CSAF created the Aircrew Crisis Task Force (ACTF), which provides strategic direction and actionable recommendations to the CSAF on issues regarding the aircrew manning crisis across the Total Force. The ACTF actively manages three divisions that span requirements, accessions, production, absorption, retention, sortie production, and Total Force integration. The goal of the ACTF is to explore every potential short-term, mid-term, and long-term solution within these lines of effort (LoEs) that will mitigate the aircrew crisis (Goldfein, 2017). The ACTF is not solely concerned with the fighter pilot shortage, though that is where the majority of the shortage resides and previous effort was spent. Another important matter that has been scrutinized, and the Air Force has been working on for several years, is the maintenance worker

shortage (Everstine, 2017). Maintenance workers are required to fix aircraft parts, perform routine depot maintenance, and help keep aircraft ready to fly. There also are some concerns that the Career Enlisted Aviators (CEAs) have shortages that can cause sorties to be canceled, grounding planes and pilots. These issues are being addressed by the ACTF as well.

How long these issues persist is dependent on actions taken by the Air Force while under a constrained budget approved by Congress. Increasing the pilot inventory is a multifaceted problem, requiring both attention to production capacity in the undergraduate and graduate training pipeline—incorporating new pilots into operational units and affording them sufficient flying time to gain experience (known as absorption)—and retention of experienced pilots once they complete their initial service commitments.

With respect to the fighter pilot shortage, graduate training and absorption seem to be the two biggest limiting factors in the larger production pipeline currently. Retention is also an issue because inventory levels are at an all-time low, while major airline hiring is projected to grow for the next five years; the Air Force is short-staffed, so it needs every fighter pilot possible, especially to help train the inexperienced pilots. Retention is not the biggest threat to fighter pilot manning (Schulker and Terry, 2018).⁵ However, the research shows production must be increased. The Air Force rated officer career fields aren't able to quickly acquire experience at midgrade levels from outside the Air Force. The Air Force is largely an "up-or-out" system in terms of promotions, and there are statutory or policy provisions preventing lateral pilot entries in later points in a pilot's career. Therefore, the only way to increase inventory is to produce more newly winged pilots each year than the number of pilots the Air Force is losing each year. Anything short of that goal, and the fighter pilot inventory will continue to decrease. Currently, the Air Force is trying to increase production but has faced real execution-year challenges, causing it to fall short of the FY 2017 RegAF production target of 284 new fighter pilots. Even if the Air Force could produce that number of RegAF fighter pilots (or more) through the graduate training pipeline, absorption is an enormous challenge. In past shortages, absorption has been the most acute issue (Taylor, Moore, and Roll, 2000), because operational units cannot function with too many inexperienced pilots and not enough flying hours to go around (Robbert et al., 2015). If the absorption pipeline problem isn't resolved, then the increase in production will cause an influx of inexperienced pilots that will take longer to gain experience, cause the inexperienced-to-experienced ratio to increase beyond healthy levels in each unit, force the experienced pilots to fly more sorties than required, and result in a large number of pilots unable to perform critical duties when they are needed.

While the bonus policies described earlier can have immediate returns, adjusting production and absorption will take years to fix, and it will be years before benefits are realized. The Air Force needs to act now, so that five to ten years down the road, the fighter-pilot manning levels

⁵ See Schulker and Terry (2018) for a retention-based analysis of the fighter pilot crisis.

are healthier than they would be otherwise, while retention efforts in the near term mitigate the current experience-level concerns.

Our Approach

To support Total Force rated officer management, the RAND Corporation developed a rated officer inventory projection model that uses a set of future requirements as the target and then projects the inventory that will be needed over time to fill the requirements. The model is a multigoal linear programming model that projects the short-term (i.e., over the next five years) and long-term (i.e., 15 or 20 years out) consequences of career field–planning decisions for the health of the rated officer force. The model tries to exactly match each rated officer inventory to each rated officer requirement by determining annual production and affiliations. The model factors in retention and affiliation patterns derived from historical data or from previous RAND research that is continually updated (e.g., McGee, 2015).

We defined the majority of the model constraints and inputs by

- analyzing existing data, including manpower and personnel data files. For example, these data were used to identify the historical retention and affiliation patterns for the ARC.
- meeting with aircrew subject-matter experts (SMEs). For example, SMEs helped to identify the number of manned-aircraft pilots performing RPA pilot duties and how to address them in the modeling.

After building preliminary versions of the linear programming model, we refined it by exploring a number of excursions to understand how it was functioning. This involved using a variety of different policy inputs and constraints and then observing the impact of those inputs and constraints on the shape of the career field many years into the future.

The results are typically presented in what is called a red-line/blue-line (RL/BL) chart, with future requirements depicted in red and future inventories in blue. This presentation allows senior leaders to quickly assess which career fields are likely to have systemic overages (blue line is above the red line) or shortages (blue line is below the red line) and may therefore require further management attention.⁶

The novelty in this modeling effort was creating a Total Force model that linked the active and reserve components—recognizing when RegAF separations resulted in ARC affiliations. The model understands that affiliations (in the traditional definition) in the reserves cannot be greater than the number of officers who had previously separated from the RegAF. Thus, affiliation behavior is aligned with RegAF separations and patterns, and this serial linkage is preserved.

⁶ For more explanation on the difficulty of balancing rated personnel requirements and inventories and examples of RL/BL rated force model results, see Bigelow and Robbert (2011). For a high-level description of a Total Force rated RL/BL model and modeling details, see Terry et al. (2017). For a description of a similar modeling approach regarding force-of-the-future policies, see Robbert et al. (2017).

Organization of the Report

This purpose of this report is to explain the inputs, constraints, and model formulation and provide a few examples of the excursions that we explored during model development. Chapter 2 provides an overview of the TFBL model, including model inputs and parameters and the model objective function and constraints. Chapters 3 through 5 present the results of model excursions that illustrate how the model functions. These excursions include two types of retention scenarios (Chapter 3), the impact of production on pilot inventory levels (Chapter 4), and the impact of optimizing production levels (Chapter 5). These scenarios were chosen for inclusion because they address some of the issues that decisionmakers are grappling with as part of the aircrew crisis. Chapter 6 provides the conclusions of the report and how excursions and the results can inform policy analysis.

The report includes several appendixes that provide additional technical information about various elements of the data, model, and support for those elements. Appendix A contains the data provided by the Directorate of Operations, Director of Training and Readiness, Total Force Aircrew Management (AF/A3TF) and used in the modeling. Appendix B describes the TFBL model formulation. Appendix C provides some information on alternate avenues to increase pilots, outside of the usual internal production route. Appendix D provides some history about aviation continuation pay (ACP) and aviation career incentive pay (ACIP). Appendix E contains the statistical regression analysis used in the analysis presented in major airline hiring scenarios.

2. Total Force Blue Line Model Overview

The TFBL model is a linear optimization model that can analyze the effect of a variety of potential Air Force policy decisions affecting the rated officer communities over time by accounting for career field dynamics such as production, retention, and affiliations. The modeling decisions used to represent real-life career field planning are critical to the accuracy and usefulness of the model and its results. However, the modeling decisions are just one important piece; the data analysis from which the model inputs are created is equally important. This chapter provides a conceptual overview of the inputs, assumptions, and decisions in our model. A more technical discussion of the model data and formulation can be found in Appendixes A and B, as well as in the TFBL *User's Guide* (Terry et al., 2017).

Model Inputs and Assumptions

The model is initialized with the current inventory for each component (RegAF, AFR, ANG); each rated category (11X pilots, 12X CSOs, 13B ABMs, and 18X RPA pilots); and each major weapon system (e.g., fighter, mobility, airborne warning and control system [AWACS]) at the end of FY 2016, and the set of projected requirements for FY 2017 and across the future years defense planning (FYDP) horizon. The main goal of the model is to adjust inventory (increasing or decreasing from the initial inventory) until it matches the requirements while limited by some real-world constraints. Important considerations are whether the inventory can match the requirements given certain production levels, what production levels it will take to get the inventory to match the requirements, the timeline associated with achieving the requirements (if feasible), and whether attaining this inventory is sustainable.⁷

The model provides a solution that best matches the inventory to the requirements by determining the production and affiliations needed while factoring in historical or forecasted retention patterns. The main elements that are captured in the model are listed in Table 2.1, along with the information source that forms the basis of the input for each element.

⁷ Sustainability is determined by whether the inventory stabilizes over time, i.e., the annual production is equal to the annual losses. The inventory can be sustainable and not meet the requirements.

Table 2.1. Elements Captured in the TFBL Model

Model Element	Our Approach and Source of the Information
Requirements by component, rated category, major weapon system, and FY	Projected funded requirements on October 1, 2016 Source: AF/A3TF, derived from MPES (Manpower Programming and Execution System database)
Starting (or initial) inventory by component, rated category, major weapon system, and commissioned years of service (CYOS)	Inventory on September 30, 2016 Source: AF/A3TF, derived from personnel data files
Production limitations	Planned production constraints Source: AF/A3TF, derived from Programmed Flying Training Conference products
CYOS distribution of newly produced pilots	Benchmarked on historical patterns of CYOS of rated officer graduating from UFT Source: Personnel data files
Retention by component, rated category, major weapon system, and CYOS	
• Historical retention rates	Benchmarked on historical retention patterns since FY 1996 for the ARC, FY 2001 for the RegAF Source: Personnel data files
• Retention under major airline hiring	Regression analysis based on historical major airline hiring and Air Force separations Source: Updated results from McGee (2015).
Affiliation rates	Benchmarked on historical affiliation patterns since FY 1996 Source: Personnel data files
ALFA* Tour pilots	Current ALFA tour pilots are returned per a return schedule. Any model-generated ALFA tour pilots will serve a four-year tour and then return to home Air Force specialty code (AFSC). Source: Air Force Personnel Center (AFPC) for the current ALFA tour pilot population and the ALFA tour pilot return schedule, rule set for model-generated ALFA tour pilots from AF/A3TF

NOTE: *ALFA tour* is used to describe assignments that are “bills” to be paid by the operational flying community, in this case manned-aircraft pilots performing RPA pilot duties. ALFA is an acronym for ALO, LIFT, FAC, and AETC (air liaison officer, lead-in fighter training, forward air controller, Air Education and Training Command).

For those data for which historical information is required to obtain appropriate distributions (e.g., distribution of production by CYOS, affiliation rates), we utilize the end-of-FY BAE extracts from FY 1996 through FY 2016.⁸ The specific formats of these data fields, as well as recent historical examples, are provided in the user’s guide for TFBL (Terry et al., 2017). The following is a brief, qualitative description of how each data input relates to the greater TFBL analysis capabilities.

⁸ BAE stands for file part b (officer), active extract. This references the parts of the personnel files that contain data on active duty officers. There are similar files for active duty enlisted, and for reserve and guard officers and enlisted airmen as well.

Requirements

The TFBL requires a set of projected requirements. The requirements set the target for the level of inventory that would achieve health in each rated community.⁹ The difference between inventory and requirements is the primary metric from which we assess the health of each modeled rated community. Requirements are specified by

- component (RegAF, ANG, AFR)
- rated category (pilot, CSO, ABM, RPA pilot)
- Major Weapon System (MWS) (e.g., bomber; fighter; command and control, intelligence, surveillance and reconnaissance [C2ISR])
- FY.

Requirements are derived from MPES for all three components. For RegAF requirements, we use a data set that has been modified by AF/A3TF for use in analysis, modeling, and projecting staff shortfalls. The AFR and ANG requirements are typically provided by Personnel Directorate, Air Force Reserve (AF/REP) and the Air National Guard Manpower, Organization, and Resources Division (NGB/A1MP), respectively. The requirements are often specified for the first eight FYs, and they remain at the same level as the last provided fiscal value for the remaining years in the model. In the TFBL model, an officer can be assigned to any requirements with a matching rated category and MWS, irrespective of the CYOS of the officer.

Initial Inventory

The TFBL inventory is initialized using a September 30, 2016 snapshot of the personnel files residing in the Military Personnel Data System (MilPDS)¹⁰ for all three components, all rated categories, and all MWS that are modeled. Obtaining an accurate snapshot of inventory is vital for the near- and midterm analysis of the Total Force rated force and its comparison with requirements. The ARC initial inventory data are provided to RAND by AF/A3TF through appropriate AFR and ANG representatives. In years past, the RegAF inventory data have been provided by the Human Resources Data, Analytics, and Decision Support Division, Directorate of Plans and Integration (AF/A1XD—then AF/A1PF) but can also be provided by AFPC.

Production

The main mechanism available to increase the inventory is production, which in this model refers to the number of officers who successfully graduate from UFT for each component, rated category, and MWS. Without any constraints, the model (and any system in general) would

⁹ While career-field health is a complex concept, in terms of the modeling presented in this document, we simply mean a career field is healthy when the inventory matches the requirement. For those interested in a broader discussion on career field health, see Terry et al. (2018).

¹⁰ FY 2016 data were used in the analyses described in this report, but the model has since been updated to the most current inventory data set.

maximize the production to meet the requirements as soon as possible. If allowed to do so, the model would suggest significantly large production for the first several years until the inventory level approaches the requirements, and then it would significantly decrease production. A widely varying production plan like this is neither stable nor sustainable in reality, ignoring such real-life influences as continuous operation of schoolhouses, hiring of instructors, and year-group dynamics on the future inventory in terms of personnel management.

The Air Force needs a stable and predictable training plan regardless of whether that production plan is suboptimal in terms of meeting requirements. But given budgetary constraints and priorities that often do not meet the resourcing needs of the training pipeline, it is necessary to ensure that resources are aligned with programmed training. Therefore, from a budgetary and stable pipeline perspective, it is necessary to place upper bounds on production in the model to ensure meaningful and reasonable production levels in any given year.

More specifically, this model limits production in three different ways. First, we set production to the planned or programmed levels to see the health of the force under this level of production over time. The planned production levels are provided by AF/A3TF for all components, rated categories, and MWSs.

Second and third, we constrain production for the situation when we (1) optimize production, meaning we let the model determine the production values. When production is optimized, we (2) specify an upper and lower bound that production must satisfy, and we (3) “smooth flow” the production from year to year. The upper bounds usually represent high but realistic limitations on maximum capacity through UFT. The lower bounds are usually some percentage of the fixed production levels. The smooth flow constraint prevents wild deviations in production from year to year by ensuring that production in the following year is within a specified percentage of the previous year. This allows for stable, healthy growth (or reduction) over time, in a manageable manner, to aid in planning. When production is optimized, the upper and lower bounds and smooth-flow percentage are provided by AF/A3TF.

Years of Service at Time of Entry into Rated Officer Force

The length of training and point in time at which a rated officer earns his or her wings depends on several factors, including source of commission, graduation, and training-seat availability. Rated officers complete undergraduate pilot training at various points in their career, and the ADSC commitment does not begin until the rated officer earns his or her wings. The model accommodates for this variability by calculating the CYOS distribution of each newly produced rated officer over time and allocates each to a CYOS according to this distribution.

To calculate these distributions, we used historical annual personnel data snapshots from FY 1996 to FY 2016 and determined which CYOS the rated officer was in upon completion of UFT,

which ranged from zero CYOS to six CYOS.¹¹ The CYOS upon UFT graduation is represented as a probability density function for each component, rated category, and MWS.

Retention

Retention is also a key component of career field planning and health. If retention is high, less production is required to maintain a healthy inventory. If retention is low, more production is required to keep inventory levels steady. Production needs to be adequate to ensure that enough personnel make it to later points in their careers, gain the experiences needed to fill leadership positions, and take advantage of developmental opportunities. Retention is the driver for determining how many personnel make it to later career points. Thus, it is necessary to model retention, the connection between retention and production, and the future impact on career field health.

At a minimum, retention patterns differ by component, career field, and CYOS. For instance, pilots incur a ten-year ADSC while CSOs, ABMs, and RPA pilots incur a six-year ADSC. This results in very different retention rates at six and 12 CYOS for the different career fields. Retention is very difficult to forecast because there are so many factors that influence each rated officer's decision to stay or leave the Air Force, but over time, distinct patterns and trends have evolved. Thus, we apply distinct retention patterns for each component, rated category, and MWS by CYOS to capture these trends.

Retention (or, conversely, loss) rates are based on historical data, forecasted projections involving a variety of economic factors, and Air Force policy. But the model allows the user to change certain factors, such as bonus amounts, and analyzes the impact of such changes on retention. Chapter 3, for example, presents an analysis in which pilot loss rates are assumed to be significantly higher than the norm due to recent increases in major airline hiring. The effects of various policies—such as retention bonuses, changes in the length of the ADSC, and other policies that affect retention rates—can then be analyzed using TFBL to see the projected impact on the health of each career field. Retention rates for the RegAF can come from a variety of sources. In the past, we used AFRAMS loss rates for the RegAF and historically derived loss rates for the ARC.¹² However, we have also used loss rates based on major airline hiring scenarios informed by previous RAND analysis (and explained in greater detail in Chapter 3).

Affiliation Rates

While the ARC does produce officers, it is not the main avenue by which it acquires new personnel. The main mechanism available to the ARC to increase its inventory is affiliations, i.e., those rated officers who separate from the RegAF and transition to the AFR or ANG. Without

¹¹ CYOS is measured like age; upon commissioning into the Air Force, you are in CYOS 0. If you are in CYOS 1, then you have completed one full year, but less than two full years of service since commissioning.

¹² AFRAMS modeling incorporates the most recent five-year average loss rate.

any constraints, the model would maximize the number of affiliations (which is limited by the number of RegAF separations) to better meet requirements in the ARC. However, it is not realistic that 100 percent of the RegAF separations would affiliate to the ARC, so we must consider the historical trends to inform both a realistic expectation of affiliation and which kinds of affiliations are allowed. As an example, a RegAF fighter pilot may affiliate into the ANG or AFR as an 11F (fighter pilot), 11K (trainer), or 11M (mobility pilot), based off patterns we have seen in the data. The historical trends on which kinds of affiliations are allowed is also informed by AF/A3TF.

RAND calculated historical affiliation rates for both the AFR and ANG—by rated category, by MWS, and by CYOS. These rates were developed using RegAF and ARC personnel files from FY 1996 to FY 2016. The average affiliation rate was then used as an upper bound percentage on the number of RegAF separations in any given year. Given the persistent shortages in the ARC, when the model maximizes the number of affiliations allowed, it achieves the historical rate, thereby providing a realistic expectation for the number of affiliations.

ALFA Tours and Crossflow

As not all rated personnel spend their career in one career field, it is common to have crossflow, where one officer in one career field reclassifies into another career field. Historically, 42 RegAF mobility pilots have reclassified into RegAF special operations pilots annually. As their inventories are affected by such changes, we account for this type of crossflow on a case-by-case basis. Additionally, some manned-aircraft pilots were provided on loan temporarily to the RPA pilot community, serving in three- to four-year developmental career-broadening assignments. When such assignments are up, some pilots may return to their original manned-aircraft career fields. Pilots on these assignments, referred to as ALFA tours,¹³ retain their original rated AFSC.

Although some ALFA tour pilots have been sent directly from UPT (referred to as UPT directs), most ALFA tour pilots have years of prior experience in another rated career field. To accurately reflect manned-aircraft pilot inventory levels, we account for these ALFA tour pilots by counting them in the RPA pilot community. After completion of a four-year tour, we then return most of these individuals back to their manned-aircraft pilot communities. AFPC and AF/A3TC provide the current number of ALFA tour pilots and their expected return to their manned-aircraft AFSC.

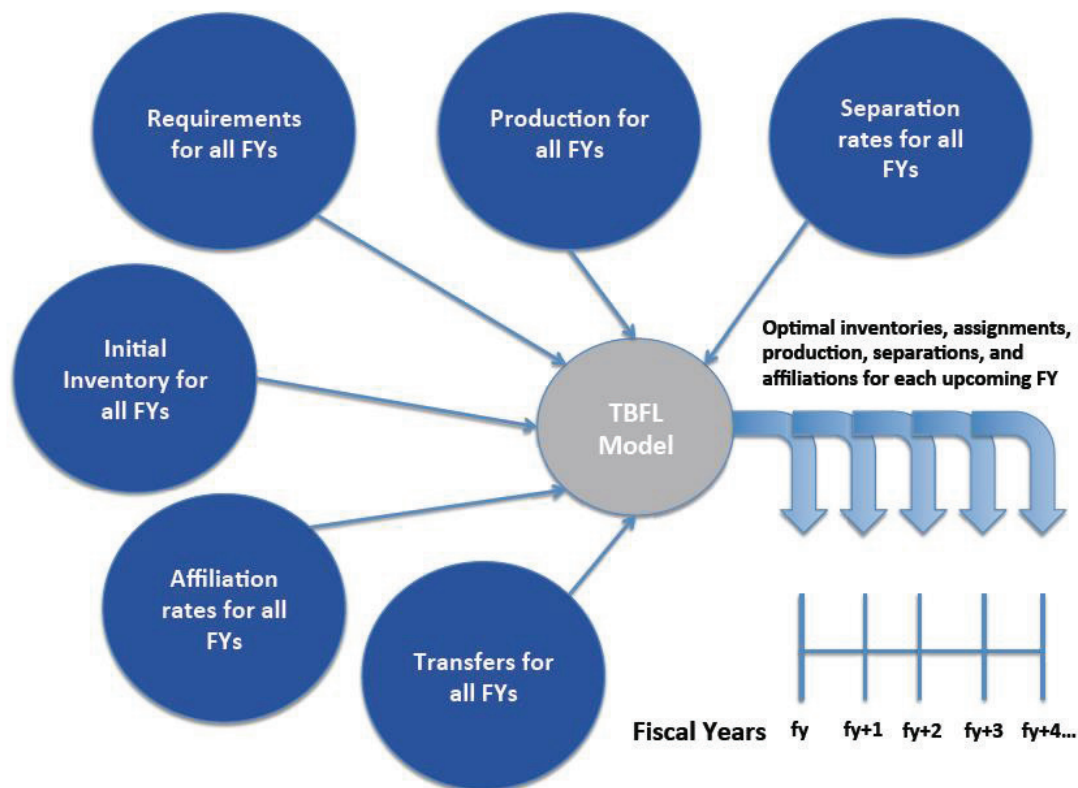
¹³ Though its origin dates back to the Vietnam era, the term *ALFA tour* is still used to describe assignments that are “bills” to be paid by the operational flying community (i.e., experienced aviators) (Air Force Instruction 11-412, 2009).

Model Objective Function and Constraints

TFBL is a linear programming model, implemented in the SAS programming language,¹⁴ that takes a variety of inputs, including user-specified manpower requirements. By varying flows such as production, losses, and affiliations, the model projects rated officer inventories that attempt to match the requirements while also meeting constraints and conditions on either the flows or the inventories.

The TFBL model is then run using specific instances of the inputs described in the previous section and provides optimal inventories, assignments, production (if the model is set to optimize production), losses, and affiliations for each FY over the model horizon, which is typically 30 FYs. Figure 2.1 provides an overview of the TFBL model. Appendix B provides a full description of the TFBL model's data dimensions, variables, constraints, and objective function. However, in the remainder of this chapter, we provide brief descriptions of the main components of the model.

Figure 2.1. General Overview of the TFBL Model



¹⁴ SAS once stood for statistical analysis system. Here we are referring to the SAS programming language and the SAS PC environment, which are products of SAS Institute, Inc.

Objective Function

The objective function is how the linear programming solver identifies an optimal solution. The constraints determine the feasible region containing all possible solutions that satisfy all the constraints. It is this region in which the optimal solution (or solutions) is found. Thus, it is important that the objective function contains a meaningful metric (or metrics) for identifying when one solution is better than another (or all others). In our model, we include four goals in the objective function, which can be thought of as multigoal programming: The first two goals relate to matching the requirements as much as possible (i.e., minimize shortages [first] and minimize surpluses [second]), the third goal is to produce the smallest number of rated officers to accomplish this match, and the fourth goal is to adhere as closely as possible to historical affiliation patterns. The shortages are represented by the sum of all unfilled requirements. The surplus is calculated as the sum of all unassigned officers. To reduce training, salary, and future retirement costs (without directly calculating these costs), the model minimizes the total number of rated officers produced while trying to meet requirements and adhering to the historical affiliation patterns as closely as possible.¹⁵ Taking these goals into consideration, the objective function minimizes the summation of the following:

1. the number of unfilled requirements (this represents a personnel shortage in the rated career field)
2. the number of rated officers who are not assigned to a requirement (this represents a rated officer surplus)
3. the number of rated officers produced (to keep training, pay, and retirement costs at a minimum)¹⁶
4. the model-chosen affiliations deviating from the historical affiliation patterns (this allows the model to deviate when necessary but influences affiliations in the model to adhere to the strong historical affiliation patterns).

Within the unfilled requirements goal, all requirements are equal in weight across all components, all rated categories, and all MWSs. Thus, the penalties for shortages are equal across all components, all rated categories, all MWSs, and all years. There is no priority in terms of rated career fields, and the model tries equally to meet requirements across all rated career fields. Since having surplus personnel is the opposite of unfilled requirements, within the rated

¹⁵ If the model can bring in ten rated officers and meet requirements, it could bring in 20 rated officers and still meet requirements. So, without calculating the true lifetime cost for each additional rated officer, it stands to reason that if one were to minimize the number of produced officers, one would, in fact, reduce the cost to the Air Force. Thus, the model aims to bring in the smallest number of rated officers that still meets requirements. This is relevant only when the model is optimizing production.

¹⁶ Minimizing production tends to add to the weight of overages and subtract from the weight of shortages, giving the model a bias toward underfilling requirements. Given the production constraints on the entire pipeline (from undergraduate flying training to absorption), this seems a better and more realistic option than ramping up production so much as to generate an overage, which would then need to decrease to stabilize and sustain the requirements.

officer surplus goal, all penalties for surpluses are equal. In fact, the penalty for a surplus of one rated officer in a rated career field is equal to one unfilled requirement in another rated career field. It is important to note that excess inventory in one rated career field cannot “fix” the shortage in another rated career field, and that the penalties are additive.

There is a cost to producing an officer. While penalizing excess inventory also deters overproduction, the goal of this piece of the objective function ensures that production takes place (assuming it is feasible to do so) only if the unfilled requirements are reduced over future FYs by more than the penalty of carrying excess inventory and the one-time cost of production. This is true only when production is being optimized. In the fixed-production case, the model is forced to achieve the production levels specified and will incur that penalty no matter what.

The last goal of the objective function ensures that affiliation to the ANG and AFR from the RegAF follows historic patterns, to the extent possible. For example, if there is a significant shortage of 11K (trainers) in the ANG such that affiliating RegAF fighter pilots would become ANG 11Ks instead of ANG 11Fs more than has historically occurred, then a penalty for deviating is incurred. This goal minimizes dramatic shifts away from historical affiliation patterns while recognizing the need and capability for minor deviations when officers affiliate into the ANG or AFR.

It is worth noting that, when optimizing multiple objectives, one typically assigns weights to each of the objectives to assign relative importance to each. In this case, we assign equal weighting to all goals, as the model results behaved as expected with equal weights, and there was no additional need to influence the model outcome to match reality.

Model Constraints

Constraints are mathematical formulations of real-world limitations that should be taken into consideration. Any valid or practical solution in real life should satisfy these limitations, so they are enforced in the model to ensure that any model solution makes sense in real life and to the decisionmaker. As shown in Figure 2.1, the model calculates inventory from one FY to the next in a typical inventory-control model formulation as applied to this specific situation.¹⁷ The major constraints that define meaningful model solutions, given our objective function, are the following:

1. The inventory for each rated officer type for a particular FY and CYOS is equal to the inventory from the previous FY and CYOS, plus total gains in the current FY and CYOS, minus total losses in the current FY and CYOS for each rated officer community.

¹⁷ Inventory theory is a subspecialty within operations research. The inventory-control problem is a classic example in which a company must decide how much of each product to order in each time period to meet demand for its products. Here, the order of products represents the production of rated officers, and the demand is the requirement for a time period of one year.

2. The number of assigned personnel (which is the same as a filled requirement under a “one person to one job” assumption), plus the number of unfilled requirements is equal to the total number of requirements.
3. The number of assigned personnel plus the number of unassigned personnel is equal to the total inventory.
4. Production is either fixed at levels provided by AF/A3TF or is bounded by levels provided by AF/A3TF, if optimizing production.
5. If production is being optimized, we smooth-flow production to ensure that it doesn’t significantly vary from year to year, making production and training capacity planning easier.
6. Losses are a product of the inventory and loss rates.
7. Affiliations into the ANG and AFR are constrained by historical affiliation rates and the number of officers that separate from the RegAF in a particular FY.
8. The model-chosen affiliations are ensured not to differ greatly from historical affiliation patterns, which are dependent upon RegAF losses.

Together, the objective function and the constraints enable the computation of the optimal inventory by component, rated category, MWS, FY, and CYOS for the specified set of requirements. As a result, optimal production is provided, as well as a timeline to career field health. Appendix B presents technical details of the model formulation. In the next three chapters, we illustrate the use of the TFBL model with three different excursions: First, we show how it is used to analyze the effect of two retention scenarios under fixed production on future inventory levels; second, we show how optimizing production under a given retention scenario affects future inventory levels for pilots; third, we show how optimizing production under a given retention scenario affects future inventory levels for CSOs, ABMs, and RPA pilots.

3. The Impact of Retention on Inventory Levels with Fixed Production

As mentioned in previous chapters, the major airlines are hiring pilots at an unprecedented rate. Not only did the airlines hire a substantial number of pilots in 2017, but sustained growth in hiring is forecasted to continue for the next five to seven years. Previous research shows that there is a statistically significant relationship between the number of pilots the major airlines are hiring and the number of pilots that separate or retire from the Air Force. Given the statistical relationship between the two, it is only natural that we consider a retention scenario that best forecasts the impact of major airline hiring on the future pilot inventory. With this in mind, we considered two retention scenarios:

- Baseline (BL) scenario. Baseline loss rates are derived from the AFRAMS model, run using fixed requirement and production inputs from AF/A3TF. We also model each rated category (pilots, CSOs, ABMs, and RPA pilots) across the Total Force.
- Major Airline Hiring (MAH) scenario. In this scenario, we use adjusted loss rates to account for the increase in losses due to the effects of increased major airline hiring and directly incorporate the number of forecasted hires from the major airlines over the next seven years. Because previous work has shown pilot retention is affected by the increased hiring but not by the other rated categories, this scenario applies only to pilots. As in the baseline scenario, we model the Total Force to see the effects on future pilot inventories and use fixed requirement and production inputs from AF/A3TF.

The fundamental differences between the two scenarios, and the results provided in this chapter, are the retention (or loss) rates used for the pilots, which provide vastly different outcomes for future pilot inventories.

Baseline Results

The AFRAMS model, maintained and run by AF/A1XD (formerly AF/A1PF), has been the program of record for RegAF inventory modeling projections since 2001. As part of this work, RAND initially was asked to incorporate AFRAMS results for the RegAF and to use those results to provide the Total Force inventory projections. The baseline results are RAND's replication of AFRAMS results for the RegAF, while accounting for different handling of ALFA tours per AF/A3TF and still providing the Total Force inventory projections that account for the interactions between RegAF separations and AFR and ANG affiliations.

Under this scenario, the requirements and production of all components and rated categories are fixed to match inputs provided by AF/A3TF.¹⁸

Description of TFBL Inputs with Baseline Losses

In general, the inventories and inputs are based on analyses of the historical data. The inventory is based on personnel files through the end of FY 2016. The production values provided by AF/A3TF reflect planned and programmed levels for FY 2017 through FY 2026.¹⁹ The requirement inputs provided by AF/A3TF are the MPES-derived requirements for FY 2017 through FY 2027. (The production and requirements values used in these scenarios are provided in Appendix A.) RegAF loss rates are derived from the AFRAMS model results; loss rates for the AFR and ANG are based on historical average loss rates calculated from the personnel files from FY 1996 to FY 2016 and are fixed at those values for each future year. Table 3.1 displays the aggregate pilot loss rates by component.²⁰ These aggregate pilot loss rates, while informative, are not the loss rates used in the TFBL model. Rather, the loss rates are specified by each major weapon system and CYOS for each component's rated categories (pilot, CSO, ABM, and RPA pilot).

Table 3.1. Aggregate Pilot Baseline Loss Rates for FYs 2017–2028

Component	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
RegAF (%)	6.4	5.7	7.2	7.8	7.1	7.9	7.8	7.3	7.8	7.2	6.7	6.9
AFR (%)	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
ANG (%)	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6

Unfilled Pilot Requirements with Baseline Losses

As noted in Chapter 2, requirements are given by component, rated category, MWS, and FY. When assessing an RL/BL (i.e., requirements versus inventory) chart at an aggregate level (for example, Total Force pilots or RegAF pilots), it is important to understand that excess inventory in one component, rated category, or MWS can hide or negate shortages in another component, rated category, or MWS, even though that is not how the TFBL model operates. More specifically, the RegAF fighter pilot shortage can be negated or diminished by the RegAF mobility pilot overage when you sum across the MWS to provide a RegAF pilot RL/BL. Thus,

¹⁸ The input files that were used in these analyses are outlined in Chapter 2 and described in further detail in the *TFBL User's Guide* (Terry et al., 2017). The model results described in this chapter are similar to those produced for the Aircrew Management Executive Council (AMEC) 17-1, held in November 2016.

¹⁹ All TFBL model inputs are “flat lined” at the last year of input. Thus, production is assumed to remain at FY 2026 levels from FY 2027 onward.

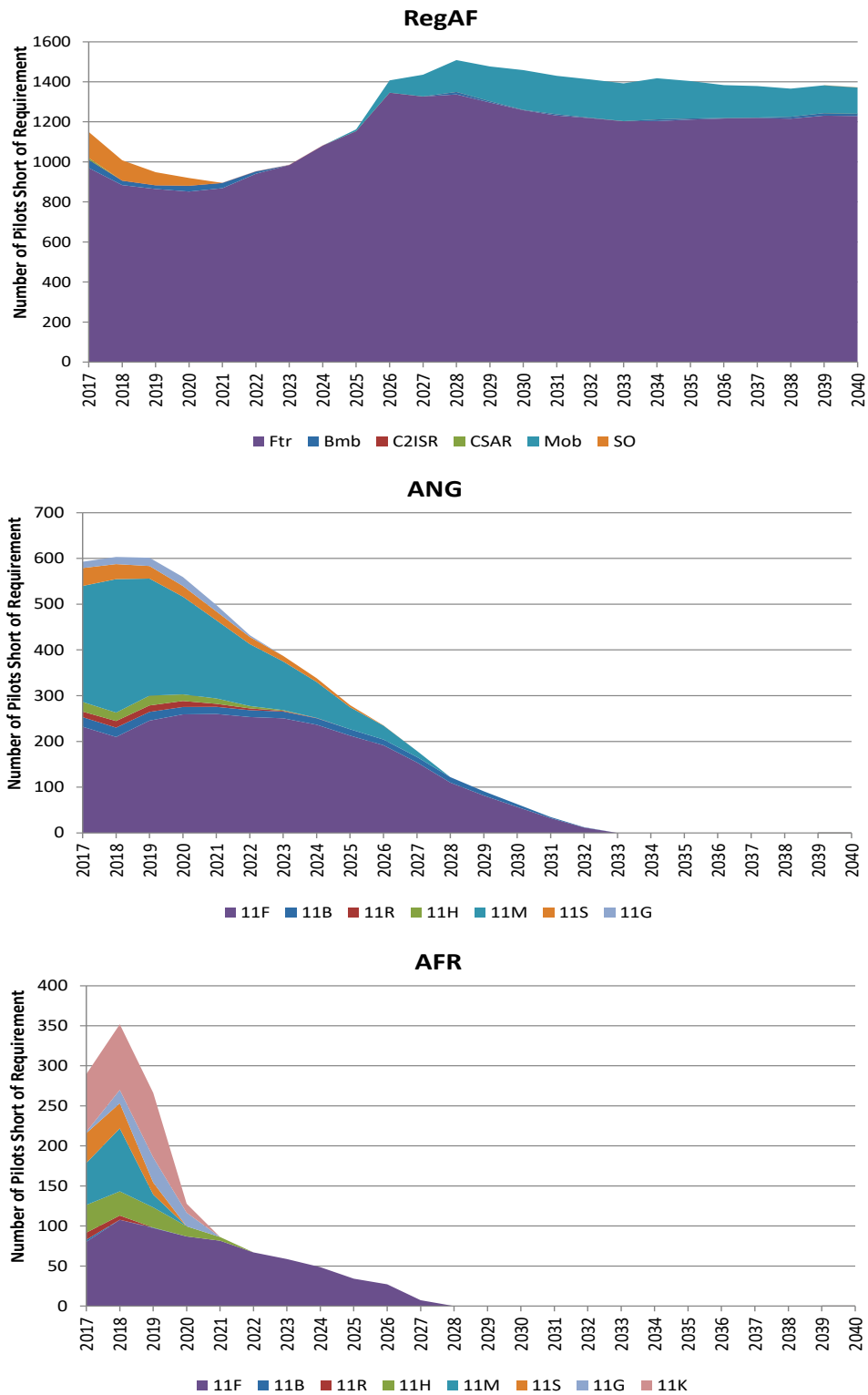
²⁰ Calculated as a weighted average across CYOS and MWS.

while inventory and requirements at the component level and rated category level are important to compare, the unfilled requirements that reflect the MWS-specific shortfalls are useful inputs for career field managers, who make personnel decisions for each career field within a component. Thus, it is important to examine results at both the aggregate level and the MWS level.

Figure 3.1 shows the pilot shortages for each component and MWS. For RegAF pilots, the majority of the shortage resides in the fighter pilot community. Near-term production reduces this shortfall, along with the shortfall for special operations (SO) pilots, but it is insufficient to avoid longer-term losses. The overall shortfall for the RegAF pilots is approximately 8 percent to 10 percent of the requirement, which, in recent years, is typically a little more than 13,000 pilots. For the AFR and ANG, the shortage resides in many of the pilot communities within 11X and improves with time (and rapidly in the AFR) as increased affiliations from the RegAF to the AFR and ANG increase inventory over time due to projected substantial losses in the next few years.²¹ Nevertheless, the shortfall is a significant portion of the pilot requirement for the reserve components (approximately 10 percent and 15 percent for the AFR and ANG, respectively) over the next several years.

²¹ It is important to highlight that the model does not differentiate between various guard and reserve statuses. While overall pilot manning may technically reach 100 percent, this would most likely occur due to overhiring pilots for part-time billets to cover for the full-time support shortfalls.

Figure 3.1. Pilot Shortfall, by Component, with Baseline Losses



SOURCES: See foregoing text for sources of these data.

NOTES: Ftr = fighter; Bmb = bomber; CSAR = combat search and rescue; Mob = mobility.

The shortfall for any rated category depends on factors outlined earlier, most notably requirements, production (and affiliations to the AFR and ANG), and loss rates. A change in any of these factors could influence the shortage significantly. In the next section, we compare the effects of forecasted major airline hiring, which reflect increased pilot losses.

Major Airline Hiring Results

Many airline industry experts have recently predicted crippling shortages in the supply of airline transport pilots. Concern over pilot shortages in the United States arises from recent legislation that changed the mandatory retirement age from 60 to 65, a declining supply of new professional pilots into the pipeline, and forecasts of continuing expansion of the major airlines. The 2014 Boeing *Current Market Outlook 2014–2033* forecasts 7,550 new airliners in the United States and a demand for 88,000 new pilots in North America during the forecast period (Boeing, 2014, p. 43). Because of this increased demand, major airlines have rapidly expanded their hiring, which has a direct implication for Air Force pilot separations and retirements. Therefore, RAND incorporated results from McGee (2015) to account for the increased pilot losses.

Under the MAH scenario, the requirements and production for all components and rated categories are fixed to match inputs provided by AF/A3TF.²²

Description of TFBL Inputs with Major Airline Hiring Losses

Inputs for the MAH scenario are the same as those in the BL scenario except for loss rates. RegAF, AFR, and ANG loss rates are baseline loss rates adjusted to account for the increase in losses due to the effects of increased major airline hiring.

Table 3.2 contains the loss rates for pilots for both the BL and MAH scenarios. Across components, the losses increase under the MAH scenario for the RegAF, as well as for the AFR and ANG. As our model results show, a major airline hiring scenario can *reduce* the shortage within the ARC, due to increased separations in the RegAF, while maintaining historical affiliation rates, despite an increase in ARC losses. This occurs because pilots often affiliate with the ARC while flying for the major airlines. Unlike the rates in the BL scenario, the losses under a MAH scenario change yearly, reflecting the forecasted hiring levels predicted for the next several years.

²² The input files that were used in these analyses are outlined in Chapter 2 and provided in further detail in the *TFBL User's Guide* (Terry et al., 2017). The results provided here are similar to those produced for AMEC 17-1, held in November 2016.

**Table 3.2. Aggregate Pilot Loss Rates for FYs 2017–2028 with Baseline and
Major Airline Hiring Losses**

Scenario	Component	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
BL	RegAF (%)	6.4	5.7	7.2	7.8	7.1	7.9	7.8	7.3	7.8	7.2	6.7	6.9
MAH	RegAF (%)	9.9	9.9	10.1	10.5	11.0	11.1	11.0	11.0	10.9	10.5	10.0	10.2
BL	AFR (%)	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
MAH	AFR (%)	9.2	9.2	9.2	9.4	9.6	9.6	9.6	9.6	9.5	9.4	9.2	9.2
BL	ANG (%)	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
MAH	ANG (%)	6.9	6.9	6.9	7.0	7.1	7.1	7.1	7.1	7.0	7.0	6.9	6.9

Having developed baseline loss rates and knowing the aggregate percentage of pilots who would leave the Air Force under a MAH scenario, we then calculated loss rates for each MWS by CYOS. In short, we took the baseline loss rates by MWS and CYOS and adjusted them to ensure that the aggregate pilot loss rate equaled the rates shown in Table 3.2 for the MAH scenarios.²³

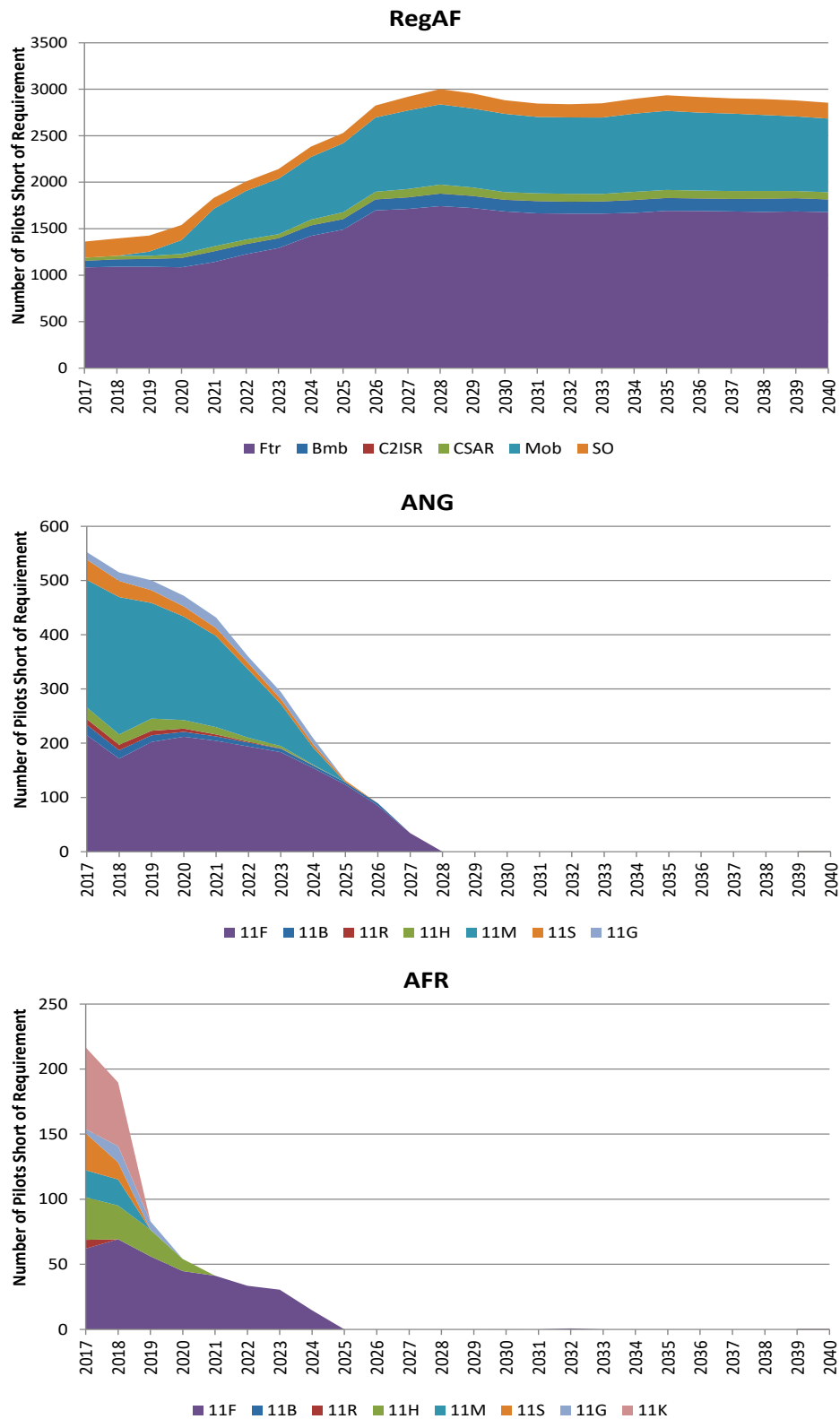
Pilot Shortfall Increases Under a Major Airline Hiring Scenario

As would be expected, increased loss rates due to the effects of increased major airline hiring have a significant effect on the future inventory of pilots in the RegAF and greatly increase the projected shortage. As with the BL scenario (shown in Figure 3.1), the shortage (and thus the inventory, since the requirement is flat-lined) reaches a steady state in the long term in Figure 3.2, despite higher losses, due to production equaling losses.

While the loss rates for the AFR and ANG do increase under the MAH scenario, albeit modestly, the actual shortfall of pilots decreases due to increased losses in the RegAF and subsequent affiliations into the ARC. Regression analysis did not show any change in affiliation patterns due to major airline hiring, only an increase in the sheer number of affiliations, due to the increased number of RegAF separations. In addition, the pilot shortfall in the AFR and ANG disappears faster than under the BL scenario.

²³ The adjustment was done through a mathematical process call perturbation, which finds an approximate solution for a problem by starting from the exact solution for a related problem (Editors of *Encyclopedia Britannica*, undated).

Figure 3.2. Pilot Shortfall, by Component, with MAH Losses



SOURCES: See foregoing text for sources of these data.

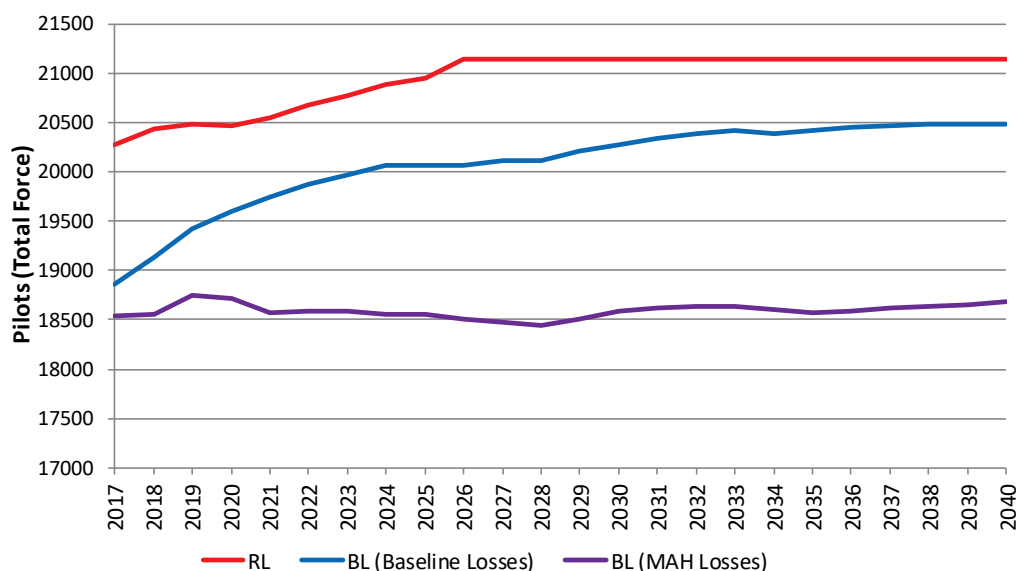
Comparing Pilot Shortfall with Baseline and Major Airline Hiring Losses

Comparing the TFBL model results for the BL and MAH scenarios illustrates the significant effect increased major airline hiring can have on Air Force pilot inventories, especially if it is sustained over the next several years. The results from the BL loss rates (Figure 3.1) show a small reduction in the RegAF shortage in the next few years, and the elimination of that shortage altogether for all MWS (except for fighter pilots from FY 2022 to FY 2025). In the MAH scenario, RegAF shortfalls in all pilot categories (except command and control, intelligence, surveillance, and reconnaissance [C2ISR]) persist, and a mobility pilot shortage appears sooner and is more severe. Of course, it is important to note that the requirements, production, and retention values have greater uncertainty in the long term, but these modeling results show that for the current situation, if the Air Force does not deviate from this set of plans, then a significant and growing shortage is likely to occur. Nevertheless, short-to-mid-term losses are dramatically higher in the MAH scenario. For example, by FY 2022, the RegAF pilot shortfall is double the amount in the BL scenario (2,008 versus 952).

A small counterweight to these significant increases in the RegAF pilot shortfall is that the AFR and ANG inventories match the corresponding requirements sooner than with baseline losses. The ANG is expected to close its shortfall several years sooner (FY 2028 versus FY 2033). Moreover, the near-term severity of the shortfall is reduced considerably, cutting the AFR shortage in half in just a couple of years. While the decrease in AFR and ANG shortages represent a significant portion of the AFR and ANG pilot shortfalls, the increase in the pilot shortfall in the RegAF tends to dwarf them, in both the near and far term. For example, in FY 2020, the Total Force pilot shortfall is 2,065 under the MAH scenario and 1,606 under the BL scenario. By FY 2025, the difference changes to 2,660 and 1,476 in the MAH and BL scenarios, respectively. Indeed, while the Total Force has improved modestly during those years under the BL scenario, its shortfall increases by more than 25 percent in the MAH scenario.

Figure 3.3 provides the RL/BL for all pilots across the total force for both the BL and MAH scenarios. Combining all pilots across the three components can, of course, reduce the perceived shortfalls illustrated in Figure 3.1 and Figure 3.2, as surpluses in some pilot categories or components will increase the Blue Line without reducing the shortfall. Nevertheless, the RL/BL provides an insight into the total force strength at the rated category level. As expected, the Blue Line does considerably worse under the MAH loss scenario. In particular, the gap between the Red Line and the Blue Line with MAH losses widens in the later years, rather than narrowing slightly under BL losses.

Figure 3.3. RL/BL for Pilots Across Total Force Under Baseline and MAH Loss Scenarios



SOURCES: See foregoing text for sources of these data.

Conclusion

This chapter illustrates the way in which the TFBL model can be used to analyze the Air Force’s ability to meet future rated requirements based on varying retention rates. These types of excursions illustrate the range of future inventories and where retention efforts must be focused to help improve career field health (as measured by the inventories matching the requirements). This type of modeling can also help the Air Force assess the effect that future retention policies might have on mitigating pilot losses or providing goals for how many pilots the Air Force should seek to retain each year to offset the effects of increased major airline hiring.

4. The Impact on Inventory Levels of Optimizing Production for Pilots

Results thus far have shown that planned and programmed production levels are not sufficient to combat poor retention levels, especially under increased major airline hiring. As the forecasted major airline hiring losses are greater than production for the first several years of the model horizon, inventory levels keep decreasing until FY 2028 for the RegAF. To maintain the current inventory levels (rather than have the inventory levels decrease), the Air Force must vary (and definitively increase) production to at least match the number of losses under major airline hiring for pilots. With this in mind, we used the TFBL model to determine which production levels would be required to maintain or improve the current pilot inventory levels under major airline hiring.

Instead of fixing production to match inputs from AF/A3TF, we allow production to be optimized (i.e., to become a variable the model determines), constrained by realistic upper and low bound limitations also provided by AF/A3TF. The purpose of creating an optimized production plan is to provide policymakers with the information needed to assign resources to areas where the need is most critical, while balancing the needs and resources across the rated categories and components.

Constraints on Production Quantities

Constraints on production in the TFBL model can be categorized by those affecting the RegAF only, AFR and ANG only, or the Total Force. We have the following constraints, broken down into those categories:

- RegAF-only constraints
 - Annual pilot production by MWS can be no larger than the values specified in Table A.4 in Appendix A, which provides a few years to appreciably increase capacity or reflect other production restrictions.
 - Annual production for each rated category and MWS must be at least 90 percent of its “fixed” (planned) production, shown in Table A.3.
- ARC-only constraints
 - Annual production by rated category and MWS can be no higher than its planned production.
 - There is no lower bound on production (i.e., the lower bound is zero).
- Constraints across the Total Force

- Annual total production by rated category cannot exceed the sum total planned production for that rated category.
- Annual production for a given component, rated category, and MWS is neither less than 90 percent nor greater than 110 percent of its prior year's production.

Taken together, these constraints do not allow for the expansion of production capacity *per se*, since the Total Force production remains the same, but rather allow for production to be reallocated within a rated category, across components and MWS. While these constraints rather narrowly define ranges in which production may occur, this limited additional flexibility can have significant influence on inventory levels.

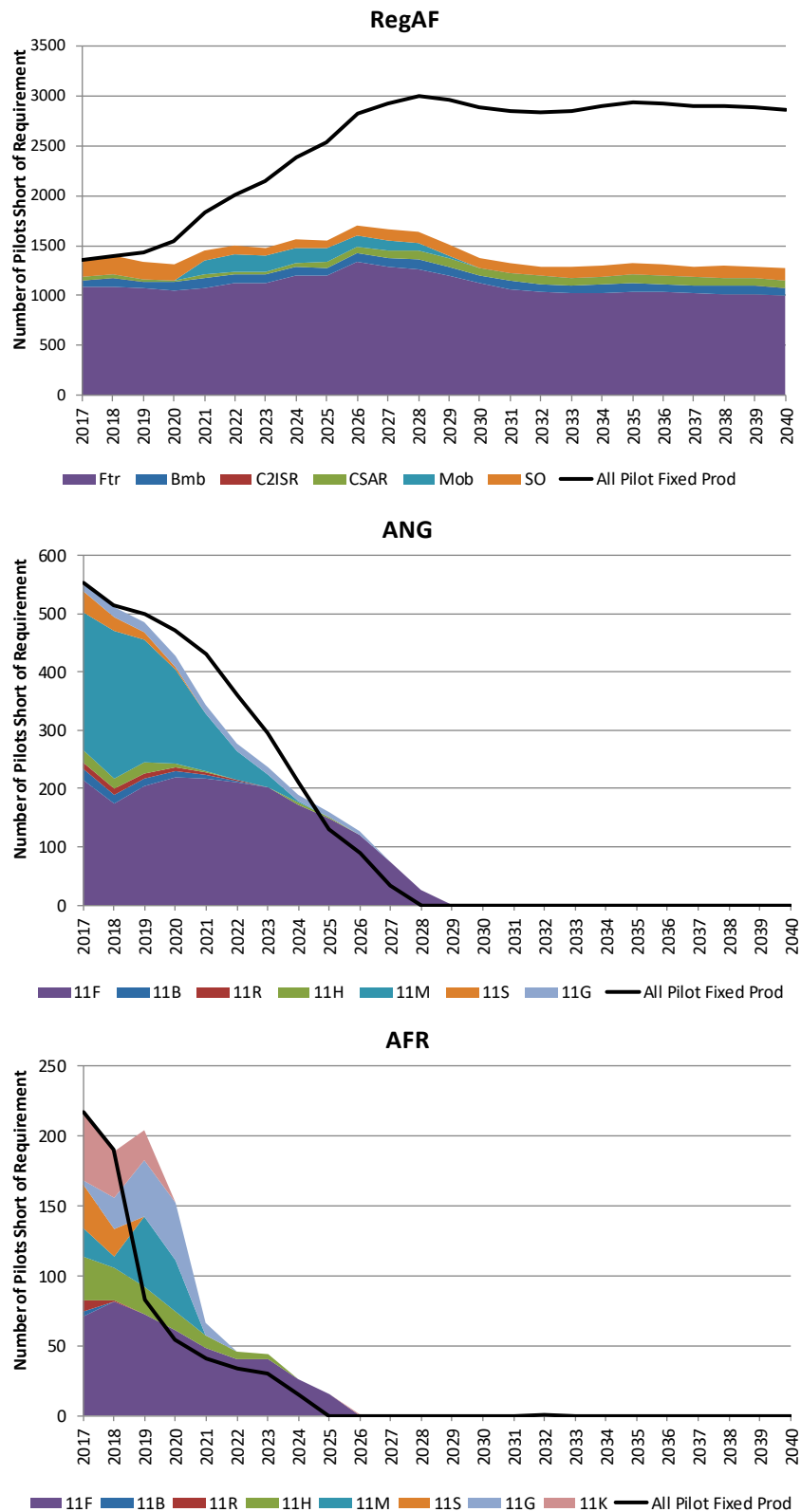
In the analysis that follows, we compare the inventory levels under major airline hiring where production is optimized and the inventory levels under major airline hiring with the fixed AF/A3TF-provided planned production levels, whose results were presented in Chapter 3.

Optimized Production Results with Major Airline Hiring Losses

While it is possible to optimize production for any scenario, the MAH scenario shows the considerable effect an optimal reallocation of production can have on reducing the pilot shortfall (i.e., increasing inventory levels). As stated in Chapter 2, no career field receives greater priority than another. However, since there is more flexibility in the number of rated officers each career field can produce, the TFBL model will favor those career fields with significant shortages in an effort to produce more and to produce earlier, and thereby reduce the shortages earlier, resulting in healthier career field levels overall.

This optimization may include—at times—favoring increased RegAF production, as there is more flexibility to change RegAF production, as well as to consider the capability of reducing ARC shortfalls in later years through affiliations. Figure 4.1 shows the shortfalls for all pilot categories out to FY 2040 for each component, under the MAH scenario with optimized production. Notably, there is a significant decrease in the RegAF pilot shortfall (Figure 4.1, top panel) versus when production is fixed (Figure 3.2), while the ANG and AFR experience only very modest increases in their pilot shortfalls.

Figure 4.1. Pilot Shortfall, by Component, with MAH Losses and Optimized Production



SOURCES: See section on “Description of TFBL Inputs with Baseline Losses” in Chapter 3.

When production is optimized, the shortfall of RegAF pilots drops from over 2,500 in 2025 to approximately 1,500. During that same year, the ARC pilot shortfall is 174 in the optimized production scenario, reflecting a modest increase over 131 for the fixed production scenario. For the fixed production with BL loss rates, the pilot shortfall in 2025 is 1,163 for the RegAF and 313 for the ARC. Indeed, reallocating production, despite the constraints, can mitigate much of the long-term effect of major airline hiring on reduced pilot retention.

Table 4.1 shows the near- and mid-term pilot shortfalls at the rated category level for the three scenarios modeled in this report: fixed production with BL losses, fixed production with MAH loss rates, and optimized production with MAH loss rates. For the MAH scenarios, the differences in the shortfalls between the fixed and optimized production are modest in the first year, but losses quickly become less severe when production is optimized, approaching baseline shortfalls for pilots.

Table 4.1. Pilot Shortfall, by Component, FYs 2017–2025, FY 2030

Production Scenario	Component	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
Fixed, BL loss rates	RegAF	1,149	1,008	948	919	895	952	984	1,081	1,163	1,458
Fixed, MAH loss rates	RegAF	1,361	1,395	1,426	1,539	1,832	2,008	2,142	2,382	2,530	2,882
Optimized, MAH loss rates	RegAF	1,361	1,396	1,335	1,315	1,455	1,495	1,481	1,561	1,552	1,377
Fixed, BL loss rates	ANG	593	603	601	559	498	432	387	338	279	63
Fixed, MAH loss rates	ANG	552	515	500	472	432	359	294	209	131	—
Optimized, MAH loss rates	ANG	552	510	486	427	345	277	236	189	159	—
Fixed, BL loss rates	AFR	287	352	266	128	86	67	59	49	34	—
Fixed, MAH loss rates	AFR	217	190	83	54	41	34	31	15	—	—
Optimized, MAH loss rates	AFR	217	189	204	152	66	46	44	26	15	—

NOTE: — = no shortfall.

Table 4.2 compares the production between the fixed and optimized scenarios. After the initial two years, when production is set by initial conditions, the production for pilots in the RegAF greatly increases in the optimized case. This increased production occurs via a

corresponding reduction in production in the ARC (in particular, in the AFR). Since there are shortfalls in these early years in all three components, it might not be clear why a one-for-one trade of pilots from the AFR to the RegAF makes sense. The reason is that the model seeks to minimize *total* shortages over the 30-year horizon.

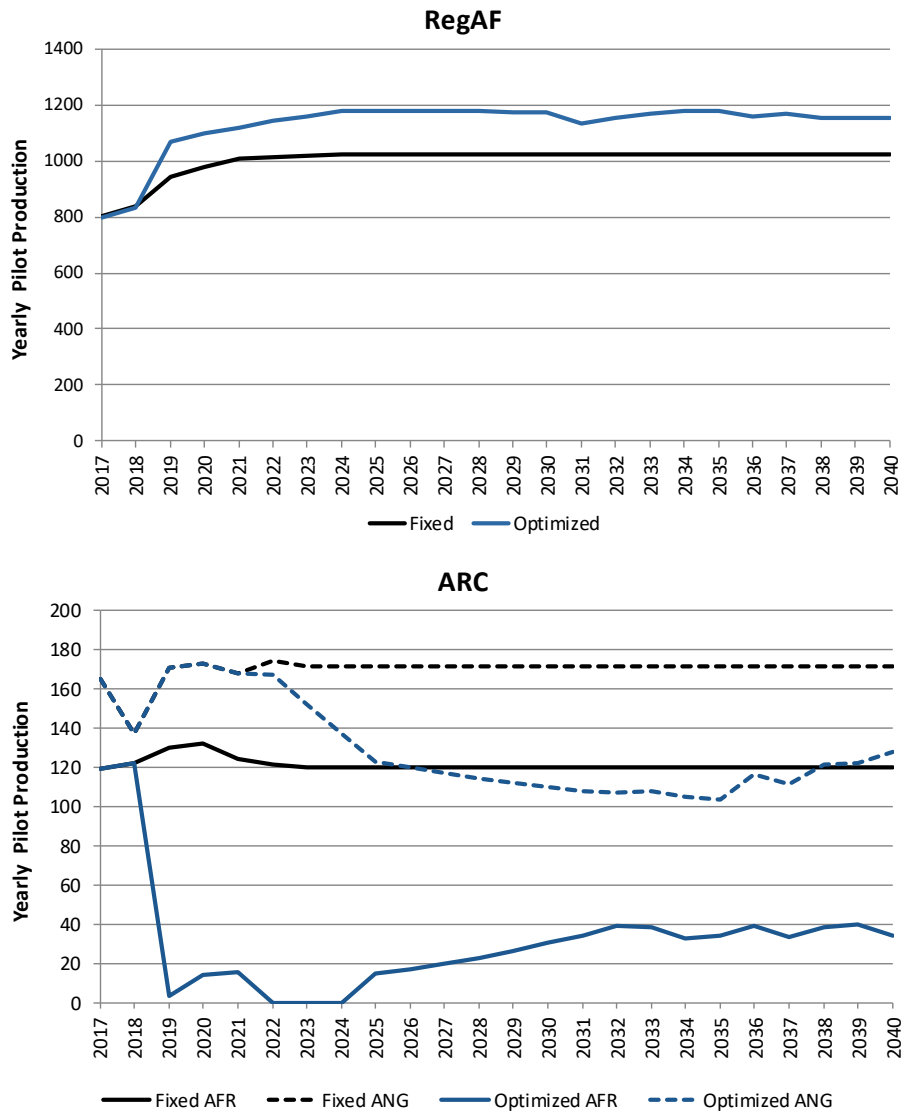
By modestly extending the shortfall in the AFR, the reductions in the RegAF are lessened such that the Total Force shortfall—even in the near term—is lower. For example, in 2020, the pilot shortfall across the Total Force under the fixed -production scenario and MAH loss rates is 2,065 (1,539 + 472 + 54), whereas the shortfall in the optimized production scenario with MAH loss rates is 1,894 (1,315 + 427 + 152). Thus, an increase in the AFR shortfall is “worth” the reduced total force shortfall. Ultimately, the optimized production can be considered as minimizing the “area” of the charts in Figure 4.1, so the long-term projected shortfalls matter too.

Table 4.2. Pilot Production, by Component, for Fixed and Optimized Cases

Production Scenario	Component	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
Fixed	RegAF	801	839	942	979	1,009	1,014	1,020	1,022	1,022	1,022
Optimized	RegAF	796	833	1,069	1,097	1,118	1,142	1,160	1,176	1,176	1,173
Fixed	ANG	165	137	171	173	168	174	172	172	172	172
Optimized	ANG	165	137	171	173	168	167	152	137	123	110
Fixed	AFR	119	122	130	132	124	121	120	120	120	120
Optimized	AFR	119	122	3	14	15	—	—	—	15	30

The overall production differences by component can be seen in Figure 4.2. In general, the total force shortfall is decreased by the increased production in the RegAF that requires a corresponding decrease in the ARC. This decrease improves the objective function further, as the fixed production schedule would produce a surplus in the ARC in the long run. Shifting the production to the RegAF—while modestly extending the shortages in the ARC in the near term—allows for the greatest reduction in pilot shortages (as allowed by the constraints we assumed) over the entire 30-year time horizon. The AFR, in particular, has very little pilot production, which is a result of increased RegAF losses due to major airline hiring (and increased production); the presumed increase in affiliations would result in little need for organic AFR pilot production.

Figure 4.2. Comparison of Fixed and Optimized Production Scenarios



SOURCES: See section on “Description of TFBL Inputs with Baseline Losses” in Chapter 3.

These optimized production levels need to be understood in the proper context. Even though we kept the Total Force production at the same level, we allowed the production to be reallocated across the components and within a rated category within the specified bounds presented in Table A.4 in Appendix A. While these bounds were fairly tight (a 10-percent deviation in either direction from the fixed production), the optimized production levels could still cause graduate training pipeline and/or absorption issues in specific communities. In the fighter pilot instance, if the model optimized production at 110 percent of the fixed level, this additional 10-percent increase could flood the graduate training pipeline, and there might not be enough graduate-level training seats at the formal training units across the various fighter pilot platforms. If there are enough seats in the formal training units, there might not be enough

positions in the operational squadrons for inexperienced pilots to gain the experience required or be absorbed. These optimized production results need to be considered in the context of the entire production pipeline (from the beginning, in terms of accessions, all the way through to absorption) and how best to right-size the entire production pipeline.

Conclusion

In this chapter, we compare the requirements shortfall modeled in TFBL under a major airline hiring scenario under two cases: when production is fixed to match AF/A3TF planned levels, and when it is optimized within the model under various production constraints. Despite limited flexibility of the constraints, they are such that optimizing production allows for some flexibility for reallocating production between components and MWSs.

When optimizing production, it is important to note that the TFBL model implements a large-scale linear optimization where the production is optimized with perfect knowledge of the future loss rates, and with an assumption that the Air Force can execute whatever production levels are either input into the model or suggested by the model results. In reality, actual requirement shortfalls will be based upon actual production, losses, and affiliations—all of which cause errors in the projections. Nevertheless, the TFBL model provides a roadmap for reallocating production to minimize shortages across the rated officer force and illustrates the need to routinely assess whether planned production levels and training capacity should be modified to match production needs to ensure healthy rated career fields.

5. The Impact of Optimizing Production on Inventory Levels for CSOs, ABMs, and RPA Pilots

Overview

Similar to the discussion in Chapter 3, RAND initially was asked to incorporate AFRAMS results for the RegAF and to use those results to provide the Total Force inventory projections. This is true not only for pilots in general, but for CSOs, ABMs, and RPA pilots as well. The baseline results are RAND's replication of AFRAMS results for the RegAF that still provide the Total Force inventory projections that account for the interactions between RegAF separations and AFR and ANG affiliations.

Instead of fixing production to match inputs from AF/A3TF, in this excursion we optimize production. The purpose of creating an optimized production schedule is to provide policymakers the ability to assign resources to those areas of most critical need while balancing needs across the rated categories and components. With that in mind, we used the TFBL model to determine whether a reallocation of production for CSOs, ABMs, and RPA pilots might help improve overall career field health (i.e., increasing or decreasing inventory levels to match requirements).²⁴

Description of TFBL Inputs with Baseline Losses

Research shows that retention patterns for CSOs, ABMs, and RPA pilots are not currently affected by major airline hiring, so the excursions provided in this chapter use baseline loss rates while optimizing production. The requirements, production, and baseline loss rates are derived in roughly the same manner as discussed in Chapter 3, but for CSOs, ABMs, and RPA pilots. The production and requirements values used in these scenarios are provided in Appendix A. Table 5.1 provides the aggregate loss rates by component for CSOs, ABMs, and RPA pilots.²⁵ These rates do not constitute the loss rate inputs to TFBL. Rather, the loss rates are specified by each major weapon system and CYOS for each component's rated categories.

Each model run provides results across the Total Force for all four rated categories at once. Thus, consistent with the analysis done in Chapter 4, the optimized production scenario is performed using losses for pilots from the MAH scenario. However, the loss rates for CSO, ABM, and RPA personnel are unchanged from the BL scenario (as CSO, ABM, and RPA pilot retention rates are currently unaffected by major airline hiring) and are reflected in Table 5.1. However, the MAH scenario affects pilot loss rates, which then affect RPA pilot inventory levels

²⁴ The results provided here are similar to those produced for the AMEC 17-1, held in November 2016.

²⁵ Calculated as a weighted average across CYOS and MWS.

via affiliations from the RegAF. Thus, unlike for CSO and ABM personnel, the inventory levels for RPA pilots are not identical in the MAH and BL cases with fixed production.

Table 5.1. Aggregate Baseline Loss Rates for FYs 2017–2028 for CSOs, ABMs, and RPA Pilots

Component	Rated Category	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
RegAF	ABM (%)	8.1	5.2	6.8	5.9	6.2	7.6	7.2	6.3	6.2	6.5	6.6	6.7
ANG	ABM (%)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
AFR	ABM (%)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
RegAF	CSO (%)	8.3	5.9	6.9	6.2	6.8	7.1	7.7	6.7	7.3	7.3	7.3	7.0
ANG	CSO (%)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
AFR	CSO (%)	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
RegAF	RPA (%)	2.9	2.1	2.6	2.4	2.1	3.2	3.8	4.2	4.6	4.8	4.5	4.9
ANG	RPA (%)	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
AFR	RPA (%)	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4

Constraints on Production for Optimized Production Scenario

Constraints on production in the TFBL model can be categorized by those affecting the RegAF only, AFR and ANG only, or the Total Force. We have the following constraints, broken down by those categories:

- RegAF-only constraints
 - Annual RPA production by MWS can be no larger than the values specified in Table A.4 in Appendix A, which provides a few years to appreciably increase capacity or reflect other production restrictions.
 - Annual CSO and ABM production can be no higher than 110 percent of the planned production by MWS, specified by AF/A3TF (specified in Table A.3 in Appendix A).
 - Annual production for each rated category and MWS must be at least 90 percent of its planned production.
- ARC-only constraints
 - Annual production by rated category and MWS can be no higher than its planned production.
 - There is no lower bound on production (i.e., the lower bound is zero).
- Constraints across the Total Force
 - Annual total production by rated category cannot exceed the sum total planned production for that rated category. For example, the sum total production of CSO personnel across all MWS and the Total Force in FY 2020 must be no more than 325, which is the sum of its planned production that year.
 - Annual production for a given component, rated category, and MWS is neither less than 90 percent nor greater than 110 percent of its prior year's production.

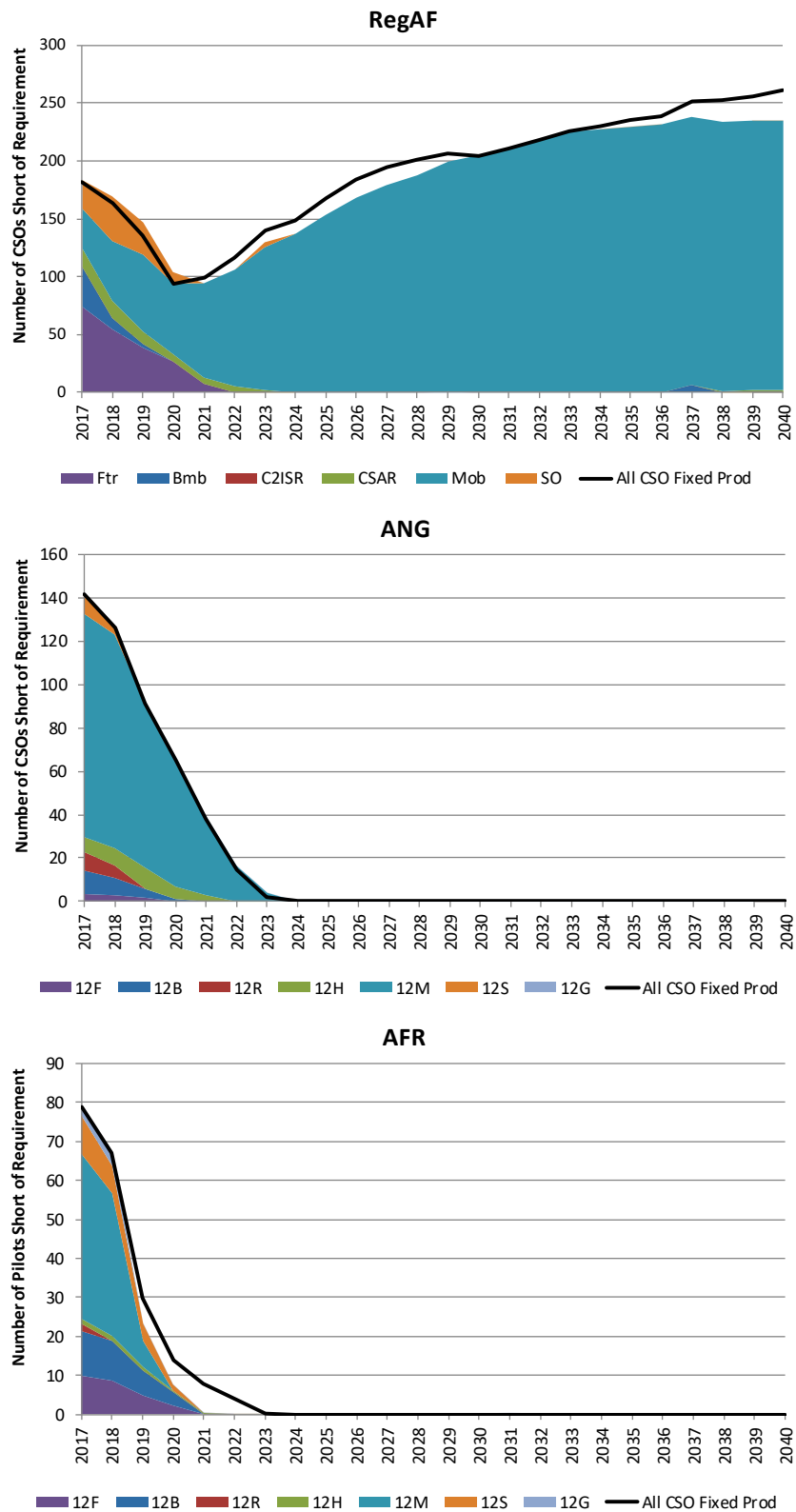
Taken together, these constraints do not allow for the expansion of production capacity in total, since the Total Force production total remains the same, but rather they allow for a reallocation of the production across the components and MWSs, as was allowed with the pilot scenario. In the analysis that follows, we compare the inventory levels in this excursion where production is optimized against the inventory levels with fixed AF/A3TF-provided planned production levels in the BL scenario.

The Effect of Optimizing Production on CSO Inventories

The unfilled requirements for CSOs follow a somewhat similar pattern to those of the pilots, in that the production in the RegAF reduces some of the shortfall in the near term, but the shortfall then increases and remains significant for the longer term. Additionally, as with pilots in the AFR and ANG, the CSO shortfall is predicted to end in the near-to-mid term (2023), an even sooner time frame than for AFR and ANG pilots. On the other hand, while the RegAF pilot shortfall was most significant for fighter pilots, the CSO fighter shortage seems to resolve within five years. The CSO mobility shortage is not seen as an issue, as the line-flying CSO mobility requirements will be obsolete by FY 2025, production is near zero, and the remaining inventory will fill pilot and CSO mobility staff positions and will naturally attrit to zero over time. However, since the requirements have not officially been zeroed out in MPES, the data reflect a significant, yet artificial, shortage. The only remaining issue is for the CSO bomber community, which seems to carry a small number of requirements that go unfilled each year (except FY 2030 to FY 2033).

Figure 5.1 shows the shortfalls for all CSO MWSs out to FY 2040 for each component. The FY2017 shortfall is approximately 5 percent of the RegAF CSO requirement, though it is anticipated that the shortfall will diminish in future years and the only remaining shortage will reside in the bomber community. Unlike for pilots, optimizing production for CSO provides little benefit over the fixed production, due to the strict limits of the production constraints. This result is almost entirely due to combined constraints of (1) no more than 110 percent of planned production in each year for the RegAF and (2) total production across the force cannot be more than 100 percent of the total planned production. Due to the very limited production in the ARC, this effectively limits optimized production so that it is essentially no greater than current planned production.

Figure 5.1. CSO Shortfall, by Component, with Optimized Production Scenario



SOURCES: See section on “Description of TFBL Inputs with Baseline Losses” in Chapter 3.

The Effect of Optimizing Production on ABM Inventory

The unfilled requirements for ABMs are significant in the RegAF, but the TFBL model projects that they will be reduced to zero by 2021, as shown in Figure 5.2. In the RegAF ABM community, there is a Ground career field, but production for the Ground community is zero. The reason the Ground personnel shortage decreases and goes away is that all ABMs receive the same training at Tyndall Air Force Base, and once they are flying qualified, they can be assigned to a ground station requirement. So even though there are no ground personnel produced, ABMs trained to fly the Joint Surveillance and Target Attack System (JSTARS) and AWACS are assigned to ground requirements once the JSTARS and/or AWACS communities are healthy and have a surplus of personnel—thereby enabling the RegAF to achieve overall ABM health by FY 2021.

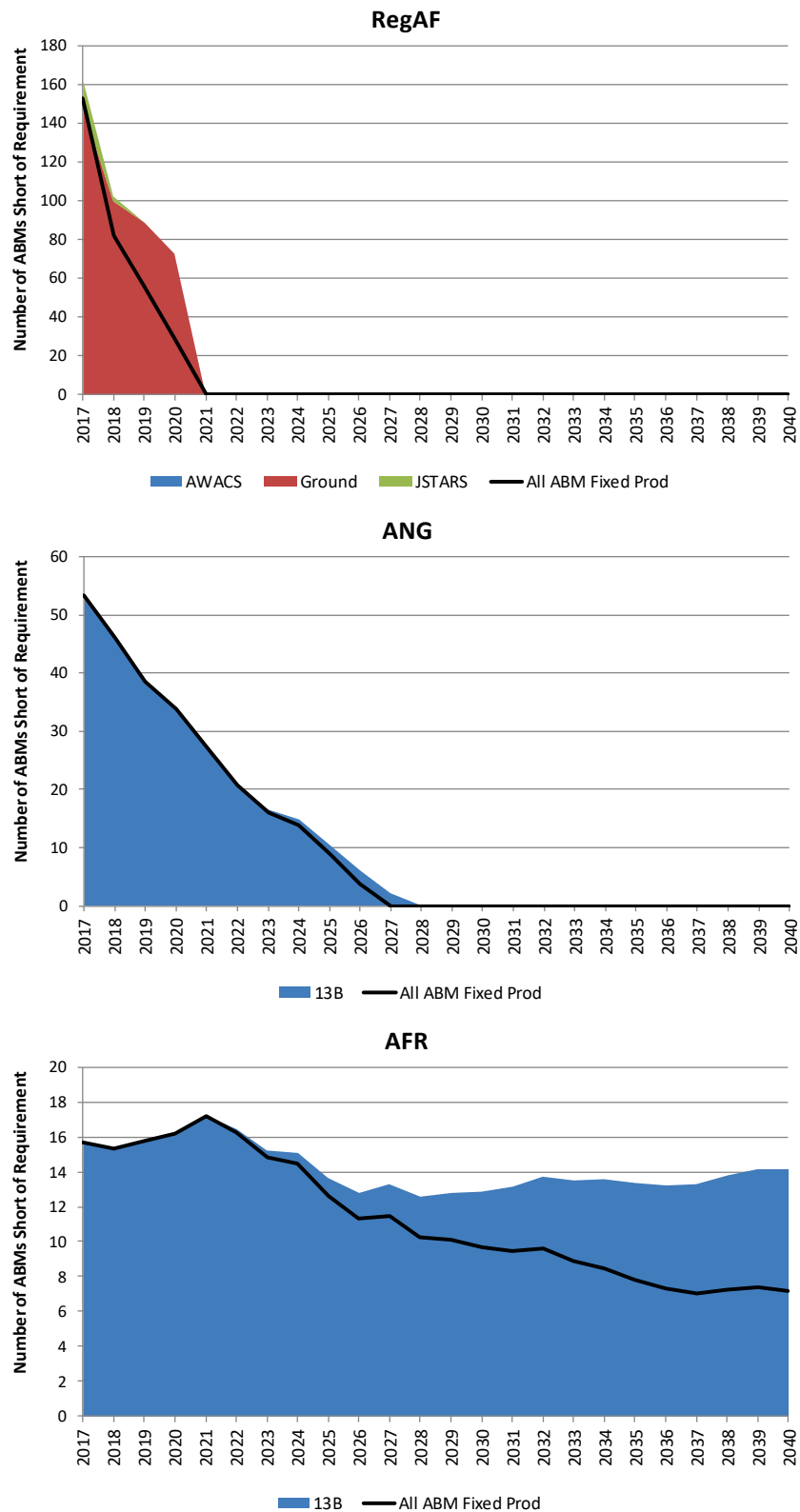
A similar pattern holds for the ANG, though it takes several years longer to eliminate the shortfall. In both cases, the shortfall in FY 2017 is approximately 10 percent of the ABM requirement. Because there are fewer than 100 ABM personnel in the AFR, the shortfall as a percentage of the requirement is also significant at about 15 percent to 20 percent of the requirement. However, the trend for the AFR is that the inventory levels will continue to increase modestly, and the expectation is that the inventory would eventually reach the requirement—or, in a worst-case scenario, be roughly five personnel short. Figure 5.2 shows the shortfalls for all ABM MWSs out to FY 2040 for each component.

It may appear counterintuitive that the shortfall is greater when the production is optimized than under the fixed production scenario. This outcome occurs because of the tight constraints on fixed production: specifically, the “smooth flow” constraints that specify that annual production for a given component, rated category, and MWS be within 10 percent of its prior year’s production. The fixed production schedule would be infeasible under this constraint as, for example, the production of AWACS increases from 67 to 96 from 2017 to 2018 (as shown in Table A.2).²⁶ As a result, the optimized production for AWACS is 86, rather than 96, in 2019.

In addition, because the decrease in production is capped at 10 percent from the prior year’s value, the optimal production schedule must consider possibly underproducing in a year (even if a larger production value is otherwise feasible), lest it be required to vastly overproduce in subsequent years once the inventory is sufficiently larger than requirements. In short, while the “smooth flow” constraints reflect the reality for the pilot categories with large levels of yearly production, the bounds of 90 percent and 110 percent of the prior year’s production are perhaps too restrictive for categories with smaller populations, where annual variations in production (as a percentage of the prior year’s value) could be expected to be greater.

²⁶ The smooth flow assumption, in the case of the AWACS, is more inflexible than planned or fixed production. Without doing a case-by-case analysis for each rated community to assess its ability to increase production from one year to the next (which is likely dependent on the magnitude of production), we made the general assumption of a 10-percent change from one year to the next.

Figure 5.2. ABM Shortfall, by Component, with Baseline Losses and Optimized Production



SOURCES: See section on “Description of TFBL Inputs with Baseline Losses” in Chapter 3.

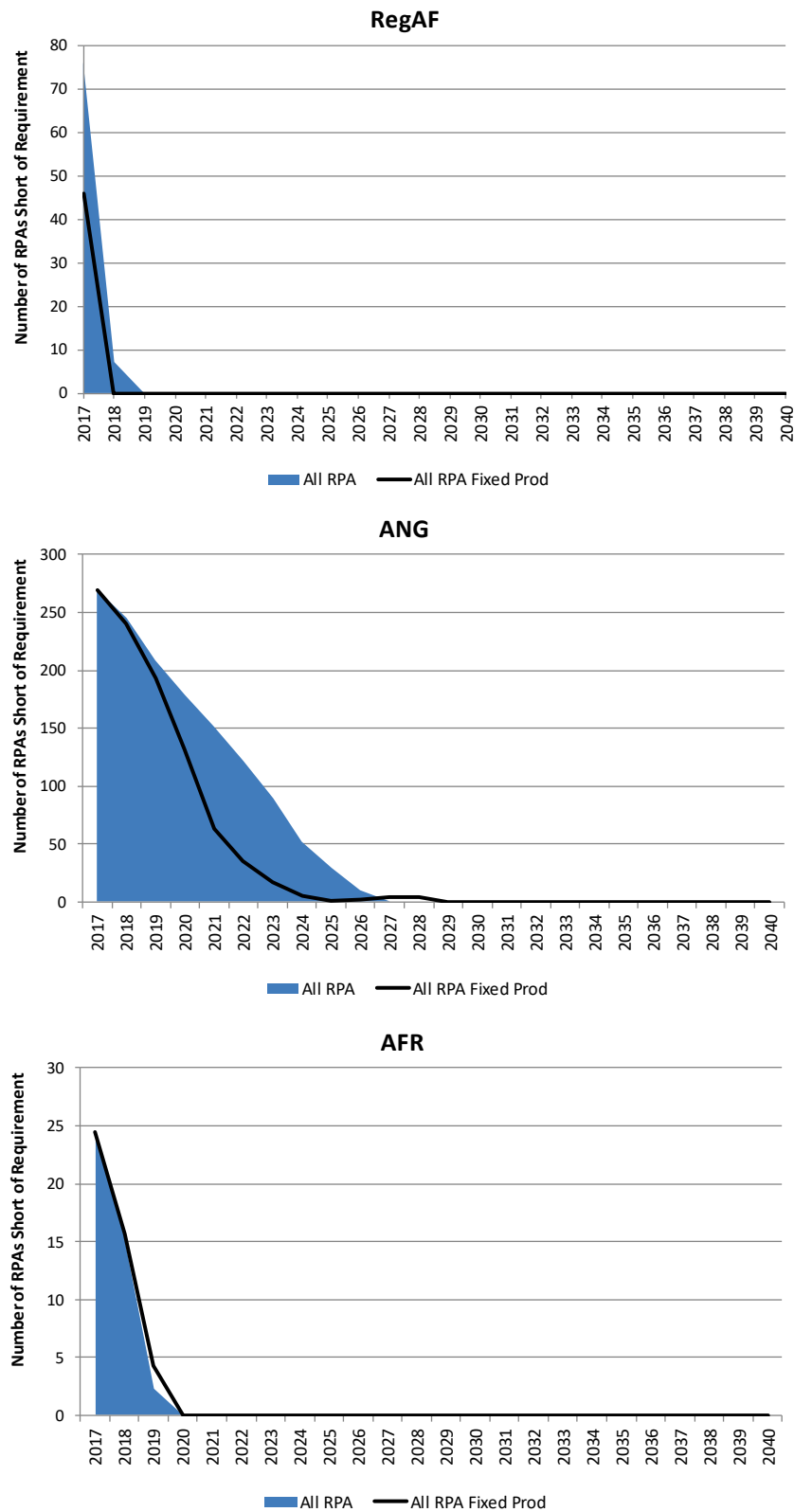
The Effect of Optimizing Production on RPA Pilot Inventory

The unfilled requirements for RPA pilots are relatively modest (approximately 5 percent of total requirement) and limited to FY 2017 within the RegAF. The anticipated production of RPA pilots along with a steady requirement allows for the RegAF to meet its requirements starting in FY 2018 and beyond, according to our TFBL modeling results. The shortfall in the ARC is more dramatic and is particularly significant in the ANG. The shortfall, while decreasing significantly each fiscal year, is one-third of the requirement in FY 2017 and is not expected to diminish until approximately FY 2030. For the AFR, the shortfall appears to be more short-lived, anticipated to end around FY2020. However, the FY2017 shortfall represents almost 15 percent of the AFR RPA pilot requirement. Figure 5.3 shows the shortfalls for RPA pilots out to FY 2040 for each component.

The shortage is partly because the RPA pilot career field is still relatively new. The first 18X RPA pilot cohorts are just reaching the end of their initial ADSC. Retention rates are still unknown for this career field and are being heavily monitored. While the career field is growing, and growing more toward a majority of 18X pilots, those who helped start this career field were prior manned-aircraft pilots or CSOs. The majority of those more senior in the RPA pilot career field currently are from the manned-aircraft community and incurred a ten-year ADSC; they thus have very different retention rates. One reason the ARC may be short-staffed is the limited number of affiliations separating and available each year from the RegAF. The capacity to produce RPA pilots in the ARC might not be sufficient to meet its current needs. Over time, we can expect RegAF separations and ARC affiliations to help increase ARC RPA pilot inventories.

As in the ABM case, the optimized production shows slightly higher shortfalls in the very near term in both the RegAF and the ANG than the fixed production. As with ABMs, the “smooth flow” constraint requires producing fewer than the fixed production to make future decreases in RPA pilot production feasible. However, in addition, the optimized production also recognizes that there will be a surplus of RPA pilots under the planned production scenario in the long term, so it decreases long-term production to its smallest feasible value (90 percent of planned production 2024 production numbers). The fixed production scenario continues to produce, even if there is an oversupply. Thus, while some rated categories may have a slightly higher shortfall under optimized production, the overall objective function value (detailed in both Chapter 2 and Appendix B) is improved when production can be optimized. Greater flexibility in production would, of course, improve the objective value further.

Figure 5.3. RPA Shortfall, by Component, with MAH Losses and Optimized Production



SOURCES: See section on “Description of TFBL Inputs with Baseline Losses” in Chapter 3.

6. How the Model Can Be Used to Support Rated Officer Analysis

The model was designed first and foremost to address the following question: *Given the current set of requirements and planned production levels, will each of our rated career fields be healthy (as measured by the annual difference of requirements and inventory) under realistic retention scenarios?* However, the model can also answer the following research question: *What production levels would eliminate manning shortages (if absorption were not directly addressed)?*

The model results presented in this report begin to address these questions by exploring issues affecting a career field over time—production, crossflow (as captured by ALFA tours currently), potential impacts of retention incentive policies, and requirements. With some small modifications, the model could also address other policies, such as broader crossflow policies, assignment patterns, and determining how many staff (or lower-prioritized requirements) would go unfilled in a given year. The results presented evaluate whether annual inventory numbers look healthy overall as compared with the requirements. The results also allow policymakers to determine which annual production levels would be required to meet the requirement annually or present a timeline to reduce the shortage and eventually match the requirement. With larger modifications, formal training unit constraints and absorption constraints could be introduced as well.

We illustrated the use of the model to help inform decisions about how best to manage the career field by exploring the impact of two retention scenarios (BL and MAH) and two production scenarios (fixed and optimized). The results showed that reallocating production while maintaining the planned Total Force production level has a significant effect on reducing the shortage in the RegAF while combating lower retention levels in the MAH scenario. Given the current state of the Air Force pilot shortage, increased production must be sought now to improve the chance of mitigating increased losses due to the influence of increased major airline hiring. In addition, a reallocation of production has almost the same effect on reducing the shortage as a more optimistic scenario of better retention with planned production levels.

The retention and production excursions results presented were intended to illustrate the capabilities of the model, but they also illustrate how useful the TFBL model can be to policymakers as the aircrew crisis continues. The ability to vary assumptions in the model, modeling the potential effects of policies in terms of retention and production scenarios, can provide valuable information to Air Force leadership as new initiatives are being considered, prior to implementation. As changes in requirements are anticipated, the model can help estimate levels of production that will be needed in future years to inform planning for future training needs. Understanding the implications of different retention patterns provides insight into the importance of monitoring retention and devising appropriate incentives to retain enough rated

officers to stay in the Air Force longer. These and other analyses can be conducted using the model to inform Air Force decisionmakers as they strive to obtain or maintain the health of the rated officer force.

Appendix A. Requirements, Fixed Production, and Upper Bounds on Production Data

This appendix provides the requirements, annual production, and limits on production (for the optimized production scenario presented in Chapter 4) used in the results. Additionally, we provide the relationship between the RegAF, AFR, and ANG MWSs by rated category to help the reader understand the equivalencies between the components.

MWS Equivalencies Between Components

Table A.1 defines the rated communities addressed in the modeling and the equivalencies between MWSs for each component by rated category. The sponsoring office, AF/A3TF, decides which rated communities get modeled and is responsible for assessing whether RAND should add or delete any rated communities each year.

Table A.1. Relationship of MWSs for Each Component, by Rated Category

Rated Category	Component		
	RegAF	AFR	ANG
ABM	AWACS	13B	13B
	Ground	13B	13B
	JSTARS	13B	13B
CSO	Bmb	12B	12B
	C2ISR	12R	12R
	CSAR	12H	12H
	Ftr	12F	12F
	Mob	12M	12M
	SO	12S	12S
Pilot	Bmb	11B	11B
	C2ISR	11R	11R
	CSAR	11H	11H
	Ftr	11F	11F
	Mob	11M	11M
	SO	11S	11S
	N/A	11E	11E
	N/A	11G	11G
RPA	N/A	11K	11K
	RPA11	11U	11U
	RPA12	12U	12U
	RPA18	18X	18X

NOTES: CSAR = combat search and rescue; SO = special operations; N/A = not applicable.

For the RegAF, there is a distinction between core ID and duty Air Force specialty, and the RegAF officers are categorized according to their core ID.²⁷ That is why there is not an equivalent 11E, 11G, or 11K in the RegAF. The AFR and ANG are different in that they don't have a core ID and use rated distribution and training management (RDTM).

Requirement Model Inputs

For all scenarios modeled by TFBL in this report, the requirements are provided by AF/A3TF, AF/REP, and NGB/A1 for the RegAF, AFR, and ANG, respectively. There was only one requirement case analyzed, whose values are provided in Table A.2. Requirements are specified to FY 2026. Post-FY 2026 requirements are assumed to be identical to FY 2026 values. These requirements include an allotment for students and transients and incorporate some of the institutional requirements that are explicitly coded as rated.

²⁷ Core identifier (core ID) is based on the Air Force Specialty Code into which the officer is originally classified.

Component	Rated Category	MWS	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26
			30	30	30	30	30	30	30	30	30	30
		11G	162	162	162	162	162	162	162	162	162	162
		11H	2,335	2,365	2,365	2,365	2,365	2,365	2,365	2,365	2,365	2,365
		11M	109	109	108	108	108	108	108	108	108	108
		11S	136	135	135	135	135	135	135	135	135	135
	RPA	18X	747	747	746	746	746	746	746	746	746	746
AFR	ABM	13B	84	84	84	84	84	84	84	84	84	84
	CSO	12B	71	73	74	74	74	74	74	74	74	74
		12F	24	24	23	23	23	23	23	23	23	23
		12G	23	23	23	23	23	23	23	23	23	23
		12H	13	13	13	12	12	12	12	12	12	12
		12K	0	0	0	0	0	0	0	0	0	0
		12M	187	187	163	161	161	161	161	161	161	161
		12R	40	40	40	40	40	40	40	40	40	40
		12S	47	47	47	47	47	47	47	47	47	47
	Pilot	11B	58	60	62	62	62	62	62	62	62	62
		11E	0	0	0	0	0	0	0	0	0	0
		11F	518	555	555	541	541	541	541	541	541	541
		11G	116	116	116	116	116	116	116	116	116	116
		11H	97	97	97	95	95	95	95	95	95	95
		11K	425	425	424	424	424	424	424	424	424	424
		11M	2,086	2,139	2,127	2,106	2,106	2,106	2,106	2,106	2,106	2,106
		11R	70	70	70	70	70	70	70	70	70	70
		11S	154	154	154	154	154	154	154	154	154	154
	RPA	18X	188	188	188	188	188	188	188	188	188	188

Fixed Production Level Model Inputs

The fixed production schedule scenario is provided by AF/A3TF for all components, rated categories, and MWSs. Table A.3 provides yearly production figures for FY 2017 through FY 2024. After FY 2024, production levels are assumed to follow FY 2024 values.

Table A.3. Annual Production Quantities for All Components, Rated Categories, and MWSs

Component	Rated Category	MWS	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
RegAF	ABM	AWACS	67	96	96	90	90	90	90	90
		Ground	0	0	0	0	0	0	0	0
		JSTARS	18	25	25	25	25	25	25	25
	CSO	Bmb	65	60	58	69	69	69	69	66
		C2ISR	79	67	103	86	98	86	86	71
		CSAR	6	8	8	8	8	8	8	6
		Ftr	46	52	53	53	53	53	53	48
		Mob	0	0	0	0	0	0	0	0
		SO	45	54	60	60	48	60	60	58
	Pilot	Bmb	58	57	56	70	73	73	73	68
		C2ISR	50	55	83	83	83	83	83	88
		CSAR	52	55	55	60	67	67	67	67
		Ftr	284	285	285	285	285	285	285	285
		Mob	269	292	354	370	391	396	402	404
	RPA	SO	88	95	109	111	110	110	110	110
		RPA11	0	0	0	0	0	0	0	0
		RPA12	0	0	0	0	0	0	0	0
		RPA18	300	300	300	300	178	178	178	178
ANG	ABM	13B	22	21	22	20	22	21	21	21
	CSO	12B	0	0	0	0	0	0	0	0
		12F	0	0	0	0	0	0	0	0
		12G	0	0	0	0	0	0	0	0
		12H	3	1	0	5	4	5	4.5	4.5
		12M	19	14	28	20	22	20	21	21
		12R	0	0	1	1	1	1	1	1
		12S	15	8	8	8	8	6	6	6
	Pilot	11B	0	0	0	1	0	1	0.5	0.5
		11F	43	29	25	25	27	26	27	27
		11G	0	0	0	0	0	0	0	0
		11H	17	11	6	16	12	16	14	14
		11M	97	86	127	118	116	118	117	117
		11R	4	0	2	2	2	2	2	2

Component	Rated Category	MWS	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
	RPA	11S	4	11	11	11	11	11	11	11
		11U	0	0	0	0	0	0	0	0
		12U	0	0	0	0	0	0	0	0
		18X	29	33	43	40	40	40	40	40
AFR	ABM	13B	0	0	0	0	0	0	0	0
	CSO	12B	5	1	0	3	3	2	2	2
		12F	0	0	0	0	0	0	0	0
		12G	0	0	0	0	0	0	0	0
		12H	0	0	0	0	0	2	2	2
		12M	10	10	10	10	10	10	10	10
		12R	1	2	2	2	2	2	2	2
		12S	0	0	0	0	0	1	1	1
	Pilot	11B	4	4	4	4	2	2	2	2
		11F	4	6	6	7	7	7	6	6
		11G	0	0	0	0	0	0	0	0
		11H	4	6	4	8	7	4	4	4
		11M	104	104	114	108	103	103	103	103
		11R	0	2	2	2	2	2	2	2
		11S	3	0	0	3	3	3	3	3
	RPA	11U	0	0	0	0	0	0	0	0
		12U	0	0	0	0	0	0	0	0
		18X	8	8	8	8	8	8	8	8

Optimized Production Model Inputs

For an optimized production run, the model constrains the production of RegAF pilots and RPA pilots in the RegAF. These inputs, provided in Table A.4, reflect AF/A3TF's estimate of the near-term limits on how quickly production could ramp up, based on a variety of factors including instructors, aircraft, and training capacity; however, these limits do not include absorption capacity constraints. Post-FY 2024 production constraints are assumed to be identical to the FY 2024 value. The Total Force production constraint is the sum across component and MWS for each rated category and fiscal year. Table A.5 summarizes the Total Force production by rated category for each fiscal year.

Table A.4. Annual Upper Bound Production Limits for Pilot and RPA Personnel in the Regular Air Force

Rated Category	MWS	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Pilot	Bmb	58	58	73	73	73	73	73	73
	C2ISR	50	55	83	83	83	83	83	83
	CSAR	52	55	67	67	67	67	67	67
	Ftr	284	285	302	301	314	330	340	352
	Mob	269	292	465	466	474	482	490	490
	SO	88	93	110	115	115	115	115	115
RPA	RPA18	300	300	300	300	178	178	178	178

Table A.5. Total Force Production, by Rated Category and Fiscal Year

Rated Category	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Pilot	1,080	1,092	1,243	1,284	1,301	1,309	1,312	1,314
CSO	284	265	311	294	283	287	289	258
ABM	99	130	131	124	126	125	125	125
RPA	307	311	321	318	200	201	201	200

Appendix B. TFBL Model Formulation

RAND has developed a family of inventory models, implemented as SAS-based linear programming models, with very similar characteristics. The first one of these inventory models built is the model discussed in this report, which projects Total Force (active and reserve components) rated officer inventories. In Air Force aircrew-management matters, line graphs depicting projected manpower requirements and inventories conventionally use a red line for the requirements and a blue line for the inventories. Consequently, this rated officer inventory projection model became known as the Total Force Blue Line (TFBL) model.

This model has since been adapted for three different projects that all involve projecting inventory against requirements: The first was to extend TFBL, which modeled the rated officer community, to model the aircrew community (rated officers plus career enlisted aviators); the second was to test “Force of the Future” kinds of policies on the Air Force active duty force; and the third adapted the TFBL model to project the short-term and long-term consequences of career field planning decisions on the health of the active duty RPA force. This appendix gives the technical details of the TFBL linear programming model that started off this body of research.

A linear programming model can be specified using the following constructs:

- *Scalars* are single values defined for recurring use in various expressions. For example, the scalar *fyfirst* is defined to have a value of 2016, which is the first fiscal year represented in the model.
- *Indices* identify the various arrays of values—parameters and variables—used in the model. For example, the inventory is indexed by career field, CYOS, and FY dimensions. In the expressions used in this appendix to define the model, indices appear as subscripts.
- An *index set* specifies the members of a multidimensional index or a combination of indices.
- *Parameters* are fixed values provided as inputs to the model. Inputs to the TFBL model include arrays of requirements; historic or forecasted rates; historic distribution by CYOS of production; the initial inventory as of September 30, 2016, and other empirical or policy-related values.
- *Variables* are values that change as the linear programming algorithm seeks an optimal solution.
- By systematically changing the values of the variables, the model minimizes an *objective function*, a value equal to the sum of stated variables.
- *Boundary conditions* fix the values of certain subsets of variables. For example, inventories in the first fiscal year are set equal to the initial inventory, which is entered as a parameter in the model.
- The model adheres to *constraints*—equations expressed using parameters and variables that represent real-world conditions (such as not being able to have negative values of inventory).

For consistency, sets are denoted by an “s_”, parameters are denoted by a “p_”, and variables are denoted by a “v_”.

Data Dimensions

The model includes four dimensions for requirements: component, rated category, MWS, and fiscal year. The model includes five dimensions for officer inventories: component, rated category, MWS, CYOS, and FY. Thus, all requirements can be described by the following four-tuple (component, rated category, MWS, FY), and all inventories can be described by the following five-tuple (component, rated category, MWS, CYOS, FY). These dimensions are defined as follows:

- **Component:** The model includes all three components in the Total Force Air Force. The subscript identifies this dimension.
- **Rated category:** This model includes all four rated officer categories: pilots, CSOs, ABMs, and RPA pilots. The subscript identifies this dimension.
- **MWS:** The model considers 21 officer career fields that span all three components and all four rated categories. In the expressions that follow, the subscript c identifies this dimension.
- **CYOS:** The model includes up to 30 CYOS. This model employs $CYOS = 0$ for inventory with less than one complete year of service. $CYOS = 1$ indicates inventory with service greater than or equal to one but less than two complete years. The subscript y identifies this dimension.
- **Fiscal year:** The model can be extended for any number of fiscal years into the future. For this project, the starting inventory was taken as the end of FY 2016, and projections are made through FY 2046. The subscript f identifies this dimension.

Technical Model Formulation

What follows is a detailed description of the TFBL model. We specify the scalars, index sets, parameters, and variables that make up the objective function and constraints of the TFBL model.

Scalars

- $\text{cyfirst} = 0$, first commissioned year of service modeled
- $\text{cylast} = 30$, last commissioned year of service modeled
- $\text{fyfirst} = 2016$, first fiscal year modeled
- $\text{fylast} = 2046$, last fiscal year modeled
- $\text{npslb} \in [0, 1]$, represents the lower bound on production in any given FY, acting as the percentage multiplier production to enforce a lower bound

Index Sets

The main index sets upon which all other sets are built are the following six sets:

- $\text{s_comp} = \{\text{RegAF}, \text{AFR}, \text{ANG}\}$, the set of all components ($c \in \text{s_comp}$)
- $\text{s_rcat} = \{\text{Plt}, \text{CSO}, \text{ABM}, \text{RPA}\}$, the set of all rated categories ($r \in \text{s_rcat}$)
- $\text{s_icat} = \{\text{Bmb}, \text{C2ISR}, \text{CSAR}, \text{Ftr}, \text{Mob}, \text{SO}, \text{RPA11}, \text{RPA12}, \text{RPA18}, \text{11B}, \text{11E}, \text{11F}, \text{11G}, \text{11H}, \text{11K}, \text{11M}, \text{11R}, \text{11S}, \text{11U}, \text{12B}, \text{12F}, \text{12G}, \text{12H}, \text{12K}, \text{12M}, \text{12R}, \text{12S}, \text{12U}, \text{AWACS}, \text{Ground}, \text{JSTARS}, \text{13B}, \text{18X}\}$, the set of all MWS inventory categories ($s \in \text{s_icat}$)
- $\text{s_bcat} = \{\text{rBmb}, \text{rC2ISR}, \text{rCSAR}, \text{rFtr}, \text{rMob}, \text{rSO}, \text{rRPA}, \text{Unspec}, \text{r11B}, \text{r11E}, \text{r11F}, \text{r11G}, \text{r11H}, \text{r11K}, \text{r11M}, \text{r11R}, \text{r11S}, \text{r11U}, \text{r12B}, \text{r12F}, \text{r12G}, \text{r12H}, \text{r12K}, \text{r12M}, \text{r12R}, \text{r12S}, \text{r12U}, \text{rAWACS}, \text{rGround}, \text{rJSTARS}, \text{r13B}, \text{r18X}\}$, the set of all MWS requirement categories ($s \in \text{s_bcat}$)
- $\text{s_cy} = \{\text{cyfirst}, \dots, \text{cylast}\}$, set of all commissioned years of service (CYOS) modeled ($y \in \text{s_cy}$)
- $\text{s_fy} = \{\text{fyfirst}, \dots, \text{fylast}\}$, the set of all fiscal years (FY) modeled ($f \in \text{s_fy}$)

The remaining index sets used in the model are subsets of the sets above or a Cartesian products of some of the sets listed above.

- $\text{s_ivld} \subseteq \text{s_comp} \times \text{s_rcat} \times \text{s_icat}$, valid three-tuple defining an inventory category
- $\text{s_bvld} \subseteq \text{s_comp} \times \text{s_rcat} \times \text{s_bcat}$, valid three-tuple defining a requirement category
- $\text{s_rqmt} \subseteq \text{s_bvld} \times \text{s_fy}$, valid requirements by FY
- $\text{s_pref} \subseteq \text{s_ivld} \times \text{s_bvld}$, a valid assignment of an officer from an inventory category in s_ivld to a requirement category in s_bvld
- $\text{s_avld} \subseteq \text{s_ivld} \times \text{s_bvld} \times \text{s_fy}$, valid assignments for each FY

- $s_allow \subseteq s_ivld \times s_ivld$, allowed affiliations of an officer from an inventory category in s_ivld to a different inventory category in s_ivld
- $s_hafil \subseteq s_allow \times s_cy \times s_fy$, historical affiliations by CYOS and FY
- $s_r2arc \subseteq s_ivld \times s_ivld \times s_cy \times s_fy$, allowed affiliations by CYOS and FY
- $s_init \subseteq s_ivld \times s_cy$, initial inventory
- $s_cy0 \subseteq s_ivld \times s_fy$, captures any atypical production from special programs
- $s_aginv \subseteq s_ivld \times s_fy$, set of inventory categories by FY
- $s_int \subseteq s_ivld \times s_cy \times s_fy$, set of inventory categories by CYOS and FY
- $s_prod \subseteq s_ivld \times s_fy$, production by inventory category and FY
- $s_DstProd \subseteq s_ivld \times s_cy$, CYOS distribution of when rated officers earn wings
- $s_ireg \subseteq s_ivld \times s_cy \times s_fy$, affiliation set from RegAF to ARC
- $s_afil \subseteq s_ivld \times s_cy$, maximum affiliation rates for allowed affiliation paths
- $s_tx \subseteq s_ivld \times s_ivld \times s_cy \times s_fy$, forced transfers from one inventory category to another inventory category by CYOS and FY
- $s_riftot \subseteq s_ivld \times s_cy \times s_fy$, RIFs by inventory category, CYOS, and FY
- $s_surv \subseteq s_ivld \times s_cy \times s_fy$, survival rates (1-loss rates) by inventory category, CYOS, and FY

Parameters

We will use the following parameters in the model:

- p_rqmt_{rcsf} specifies the requirements for each rated category $r \in s_rcat$ FY, component $c \in s_compo$, requirement category $s \in s_bcat$ and FY $f \in s_fy$
- $p_InitInv_{rcsy}$ is the initial inventory for each rated category $r \in s_rcat$, component $c \in s_compo$, inventory category $s \in s_icat$, and CYOS $y \in s_cy$
- p_cy0_{rcsf} is the initial inventory when CYOS=0 for each rated category $r \in s_rcat$, component $c \in s_compo$, inventory category $s \in s_icat$, and FY $f \in s_fy$
- p_prod_{rcsf} is the number of produced officers for each rated category $r \in s_rcat$, component $c \in s_compo$, inventory category $s \in s_icat$, and FY $f \in s_fy$
- $p_DstProd_{rcsyf}$ is the distribution of produced officers into CYOS for each rated category $r \in s_rcat$, component $c \in s_compo$, inventory category $s \in s_icat$, and FY $f \in s_fy$

- p_surv_{rcsyf} is 1-loss rate for each rated category $r \in s_r\text{cat}$, component $c \in s_compo$, inventory category $s \in s_icat$, and FY $f \in s_fy$
- $p_afrrate_{rcsy}$ is the upper bound on affiliation rate for the AFR for each rated category $r \in s_r\text{cat}$ FY, component $c \in s_compo$, requirement category $s \in s_bcat$ and FY $f \in s_fy$
- $p_angrate_{rcsy}$ is the upper bound on affiliation rate for the ANG for each rated category $r \in s_r\text{cat}$ FY, component $c \in s_compo$, requirement category $s \in s_bcat$ and FY $f \in s_fy$
- $p_arcrate_{rcsy}$ is the upper bound on affiliation rate for the ARC for each rated category $r \in s_r\text{cat}$ FY, component $c \in s_compo$, requirement category $s \in s_bcat$ and FY $f \in s_fy$
- $p_atran_{r_1c_1s_1r_2c_2s_2}$ is the historical affiliation rate from one rated category $r_1 \in s_r\text{cat}$, component $c_1 \in s_compo$, and inventory category $s_1 \in s_icat$ to another rated category $r_2 \in s_r\text{cat}$, component $c_2 \in s_compo$, and inventory category $s_2 \in s_icat$
- $p_tx_{r_1c_1s_1r_2c_2s_2yf}$ is the number of forced transfers from one rated category $r_1 \in s_r\text{cat}$, component $c_1 \in s_compo$, and inventory category $s_1 \in s_icat$ to another rated category $r_2 \in s_r\text{cat}$, component $c_2 \in s_compo$, and inventory category $s_2 \in s_icat$ for each CYOS $y \in s_cy$ and FY $f \in s_fy$
- p_riftot_{rcsyf} is the number of Reductions In Forces (RIFs) that will be executed for each rated category $r \in s_r\text{cat}$, component $c \in s_compo$, inventory category $s \in s_icat$, and FY $f \in s_fy$

Variables

While the previous subsections described the sets and parameters that are input to the model, this section describes decision variables whose values are determined when the linear programming solver finds an optimal solution. As the variables represent rated officers, filled or unfilled requirements, or the assignment of rated officers to requirements, all the variables must be greater than or equal to zero. We will use the following variables in the model:

- $v_inv_{rcsyf} \geq 0$ is the number of officers for each rated category r , component c , inventory category s , CYOS y , and FY f for $(r, c, s, y, f) \in s_inv$.
- $v_gains_{rcsyf} \geq 0$ is the number of gains for each rated category r , component c , inventory category s , CYOS y , and FY f for $(r, c, s, y, f) \in s_inv$.
- $v_prod_{rcsf} \geq 0$ is the number of produced officers for each rated category r , component c , requirement category s , and FY f for $(r, c, s, f) \in s_prod$.
- $v_losses_{rcsyf} \geq 0$ is the number of losses for each rated category r , component c , inventory category s , CYOS y , and FY f for $(r, c, s, y, f) \in s_inv$.
- $v_sep_{rcsyf} \geq 0$ is the number of separations for each rated category r , component c , inventory category s , CYOS y , and FY f for $(r, c, s, y, f) \in s_inv$

- $v_{rif_{rcsyf}} \geq 0$ is the number of RIFs for each rated category r , component c , inventory category s , CYOS y , and FY f for $(r, c, s, y, f) \in s_{inv}$
- $v_{asgn_{r_i c_i s_i r_r c_r s_r f}} \geq 0$ is the number of officers assigned from an inventory rated category r_i , component c_i , and inventory category s_i to a requirement rated category r_r , component c_r and requirement category s_r for each FY f for $(r_i, c_i, s_i, r_r, c_r, s_r, f) \in s_{avld}$.
- $v_{unasgn_{rcsf}} \geq 0$ is the number of unassigned officers for each rated category r , component c , inventory category s , and FY f for $(r, c, s, p, f) \in s_{aginv}$.
- $v_{unasgn_{rcspf}} \geq 0$ is the number of officers unassigned for each rated category r , component c , inventory category s , population segment p , and FY f for $(r, c, s, p, f) \in s_{aginv}$.
- $v_{unfill_{rcsf}} \geq 0$ is the number of unfilled requirements for each rated category r , component c , requirement category s , and FY f for $(r, c, s, f) \in s_{rqmt}$.
- $v_{afil_{r_1 c_1 s_1 r_2 c_2 s_2 y f}} \geq 0$ is the number of affiliations from one rated category r_1 , component c_1 , and inventory category s_1 to another rated category r_2 , component c_2 , and inventory category s_2 for each CY c and FY f for $(r_1, c_1, s_1, r_2, c_2, s_2, y, f) \in s_{2arc}$
- $v_{unafil_{rcsyf}} \geq 0$ is the number of separations that do not affiliate and leave the AF for each rated category r , component c , inventory category s , CYOS y , and FY f for $(r, c, s, y, f) \in s_{inv}$
- $v_{afpos_{r_1 c_1 s_1 r_2 s_2 c_2 f}} \geq 0$ is the number of positive deviations when calculated using the historical affiliation rate from one rated category r_1 , component c_1 , and inventory category s_1 to another rated category r_2 , component c_2 , and inventory category s_2 for each FY f for $(r_1, c_1, s_1, r_2, s_2, c_2, f) \in s_{hafil}$
- $v_{afneg_{r_1 c_1 s_1 r_2 s_2 c_2 f}} \geq 0$ is the number of negative deviations when calculated using the historical affiliation rate from one rated category r_1 , component c_1 , and inventory category s_1 to another rated category r_2 , component c_2 , and inventory category s_2 for each FY f for $(r_1, c_1, s_1, r_2, s_2, c_2, f) \in s_{hafil}$

Objective Function

In this model, we include four goals in the objective function, which can be thought of as multi-goal programming: minimize the unfilled requirements (jobs that can't be filled by a rated officer), minimize the excess number of inventory (the number of rated officers who don't have a job), and minimize production of rated officers. Separately, we incentive affiliations to happen much like they have historically happened by MWS. Since the objective function reflects multiple goals, it is necessary to determine the relative importance of each goal in order to produce meaningful results.

$$\begin{aligned}
\min \quad & \sum_{(r,c,s,f) \in \text{s_aginv} \ni f > \text{fyfirst}} \text{v_unasn}_{rcsf} \\
& + \sum_{(r,c,s,f) \in \text{s_rqmt} \ni f > \text{fyfirst}} \text{v_unfill}_{rcbf} \\
& + \sum_{(r,c,s,f) \in \text{s_aginv} \ni f > \text{fyfirst}} \text{v_prod}_{rcsf} \\
& + \sum_{(r_1,c_1,s_1,r_2,c_2,s_2,f) \in \text{s_hafil} \ni f > \text{fyfirst}} \text{v_afpos}_{r_1c_1s_1r_2c_2s_2f} \\
& + \sum_{(r_1,c_1,s_1,r_2,c_2,s_2,f) \in \text{s_hafil} \ni f > \text{fyfirst}} \text{v_afneg}_{r_1c_1s_1r_2c_2s_2f}
\end{aligned}$$

Constraints

Constraints are mathematical formulations of real-world limitations that should be taken into consideration or, at the very least, the best approximation to the real-world limitations that we are able to model. Any valid or practical solution in real life should satisfy these limitations so they are enforced in the model to ensure that any model solution makes sense in real life and to the decision-maker. As previously mentioned, the model calculates inventory from one fiscal year to the next in a typical inventory control model formulation as applied to this specific situation. We will briefly describe the constraints that define meaningful model solutions given our objective function:

1. Unfilled requirements plus filled requirements (assigned personnel) equal total requirements.

$$\sum_{(r_i,c_i,s_i) \in \text{s_ivld} \ni (r_i,c_i,s_i,r_r,c_r,s_r,f) \in \text{s_avld}} \text{v_asgn}_{r_i c_i s_i r_r c_r s_r f} + \text{v_unfill}_{r_r c_r s_r f} = \text{p_rqmt}_{r_r c_r s_r f}$$

$$\forall (r_r, c_r, s_r, f) \in \text{s_rqmt} \wedge f > \text{fyfirst}$$

2. Assigned personnel plus unassigned personnel equals total inventory.

$$\begin{aligned}
& \sum_{(r_r,c_r,s_r) \in \text{s_bvld} \ni (r_i,c_i,s_i,r_r,c_r,s_r,f) \in \text{s_avld}} \text{v_asgn}_{r_i c_i s_i r_r c_r s_r f} \\
& + \text{v_unasn}_{r_i c_i s_i f} \\
= & \sum_{(y) \in \text{s_cy} \ni (r_i,c_i,s_i,f) \in \text{s_inv}} \text{v_inv}_{r_i c_i s_i y f}
\end{aligned}$$

$$\forall(r_i, c_i, s_i, f) \in \text{s_aginv} \wedge f > \text{fyfirst}$$

3. Inventory flow stating the inventory in the current period is equal to the inventory at the end of the previous period plus gains in the current period minus losses in the current period.

$$\text{v_inv}_{rcsyf} = \text{v_inv}_{rcsy-1f-1} - \text{v_losses}_{rcsyf} + \text{v_gains}_{rcsyf}$$

$$\forall(r, c, s, y, f) \in \text{s_inv} \wedge y > \text{cyfirst} \wedge f > \text{fyfirst}$$

4. Total losses are equal to separations plus total forced transfers.

$$\text{v_losses}_{r_1c_1s_1yf} = \text{v_sep}_{r_1c_1s_1yf} + \sum_{(r_2, c_2, s_2) \in \text{s_ivld} \ni (r_1, c_1, s_1, r_2, c_2, s_2, y, f) \in \text{s_tx}} \text{p_tx}_{r_1c_1s_1r_2c_2s_2yf}$$

$$\forall(r_1, c_1, s_1, y, f) \in \text{s_inv} \wedge f > \text{fyfirst}$$

5. Production is bounded below by a minimum percentage of production capacity.

$$\text{v_prod}_{rcsf} \geq \text{npslb} * \text{p_prod}_{rcsf} \quad \forall(r, c, s, f) \in \text{s_prod} \wedge f > \text{fyfirst}$$

6. Production is bounded above by production capacity.

$$\text{v_prod}_{rcsf} \leq \text{p_prod}_{rcsf} \quad \forall(r, c, s, f) \in \text{s_prod} \wedge f > \text{fyfirst}$$

7. Separations are equal to the inventory at the end of the previous period times the loss rate in current period plus RIFS

$$\text{v_sep}_{rcsyf} = \text{v_inv}_{rcsy-1f-1} * (1 - \text{p_surv}_{rcsyf}) + \text{v_rif}_{rcsyf}$$

$$\forall(r, c, s, y, f) \in \text{s_inv} \wedge y > \text{cyfirst} \wedge f > \text{fyfirst}$$

8. Total Gains are equal to distribution of produced officers times the production plus the total affiliations plus the the total forced transfers

$$\begin{aligned}
v_gains_{r_2 c_2 s_2 y f} = & p_DstProd_{r_2 c_2 s_2 y f} * v_prod_{r_2 c_2 s_2 y f} \\
& + \sum_{r_1 \in s_rcat, s_1 \in s_icat \ni (r_1, 'RegAF', s_1, r_2, c_2, s_2) \in s_allow} v_afil_{r_1 'RegAF' s_1 r_2 c_2 s_2 y f} \\
& + \sum_{(r_1, c_1, s_1) \in s_ivld \ni (r_1, c_1, s_1, r_2, c_2, s_2, y, f) \in s_tx} p_tx_{r_1 c_1 s_1 r_2 c_2 s_2 y f}
\end{aligned}$$

$$\forall (r_2, c_2, s_2, y, f) \in s_inv \wedge f > fyfirst$$

9. Affiliations from RegAF to AFR are bounded above by maximum affiliation rate times the number of RegAF total losses.

$$\begin{aligned}
\sum_{r_2 \in s_rcat, s_2 \in s_icat \ni (r_1, 'RegAF', s_1, r_2, AFR, s_2) \in s_allow} v_afil_{r_1 'RegAF' s_1 r_2 'AFR' s_2 y f} & \leq \\
p_afrrate_{r_1 'RegAF' s_1 y} * v_sep_{r_1 'RegAF' s_1 y f} & \\
\forall (r_1, s_1, y, f) \in s_ireg \wedge f > fyfirst &
\end{aligned}$$

10. Affiliations from RegAF to ANG are bounded above by maximum affiliation rate times the number of RegAF total losses.

$$\begin{aligned}
\sum_{r_2 \in s_rcat, s_2 \in s_icat \ni (r_1, 'RegAF', s_1, r_2, ANG, s_2) \in s_allow} v_afil_{r_1 'RegAF' s_1 r_2 'ANG' s_2 y f} & \leq \\
p_afrrate_{r_1 'RegAF' s_1 y} * v_sep_{r_1 'RegAF' s_1 y f} & \\
\forall (r_1, s_1, y, f) \in s_ireg \wedge f > fyfirst &
\end{aligned}$$

11. Affiliations plus unaffiliated separations equals total separations from the RegAF.

$$\begin{aligned}
v_sep_{r_1 'RegAF' s_1 y f} = & \sum_{r_2 \in s_rcat, s_2 \in s_icat \ni (r_1, 'RegAF', s_1, r_2, ANG, s_2) \in s_allow} v_afil_{r_1 'RegAF' s_1 r_2 'ANG' s_2 y f} \\
& + \sum_{r_2 \in s_rcat, s_2 \in s_icat \ni (r_1, 'RegAF', s_1, r_2, AFR, s_2) \in s_allow} v_afil_{r_1 'RegAF' s_1 r_2 'AFR' s_2 y f} \\
& + v_unafil_{r_1 'RegAF' s_1 y f}
\end{aligned}$$

$$\forall(r_1, s_1, y, f) \in \text{s_ireg} \wedge f > \text{fyfirst}$$

12. Calculating the deviation of affiliations of model chosen affiliations from affiliations calculated using historical affiliation rates. The deviation of affiliations is then penalized in the objective function, thereby incentivizing model affiliations to adhere to historical patterns.

$$\begin{aligned} v_afpos_{r_1 c_1 s_1 r_2 c_2 s_2 y f} - v_afneg_{r_1 c_1 s_1 r_2 c_2 s_2 y f} = \\ p_atran_{r_1 c_1 s_1 r_2 c_2 s_2} * \sum_{y \in \text{s_cy}} v_sep_{r_1 c_1 s_1 y f} \\ - p_atran_{r_1 c_1 s_1 r_2 c_2 s_2} * \sum_{y \in \text{s_cy}} v_unafil_{r_1 c_1 s_1 y f} \\ - \sum_{y \in \text{s_cy}} v_afil_{r_1 c_1 s_1 r_2 c_2 s_2 y f} \end{aligned}$$

$$\forall(r_1, c_1, s_1, r_2, c_2, s_2, f) \in \text{s_hafil} \wedge f > \text{fyfirst}$$

$\text{hist_afil}[\text{ivld}_1, \text{ivld}_2]$ is the historical fraction of affiliating officers from ivld_1 that end up as officers in ivld_2 . Multiply this by $\sum_{\text{cy}} (v_sep[\text{ivld}_1, \text{cy}, \text{fy}] - v_unafil[\text{ivld}_1, \text{cy}, \text{fy}])$. The difference between $v_sep[\cdot, \cdot, \cdot]$ and $v_unafil[\cdot, \cdot, \cdot]$ is, of course, the total number of officers from ivld_1 that affiliated in year fy . This multiplication leaves us with the number of officers from ivld_1 that we want to end up as officers in ivld_2 in year fy . The next term is the number of officers from ivld_1 that actually did end up as officers in ivld_2 in year fy in the model. The difference between what we wanted (historical affiliations) and what we received (model affiliations) is expressed as $v_afpos[\cdot, \cdot, \cdot] - v_afneg[\cdot, \cdot, \cdot]$, the difference of two non-negative numbers. Since the model is minimizing, only one of $v_afpos[\cdot, \cdot, \cdot]$ and $v_afneg[\cdot, \cdot, \cdot]$ will be non-zero and the sum $v_afpos[\cdot, \cdot, \cdot] + v_afneg[\cdot, \cdot, \cdot]$ is the absolute value of the difference, which appears in the objective function.

Boundary Conditions

The following constraints initialize certain variable values in the model that we know to be fixed or set variables that are at the boundaries of certain constraints to values to make sure the model behaves properly.

13. Setting the inventories at $\text{CYOS}=0$ to match whatever atypical production is expected.

$$v_inv_{rcs'cyfirst'f} = p_cy0_{rcsf} \quad \forall(r, c, s, f) \in \text{s_aginv} \wedge f > \text{fyfirst}$$

14. Setting the initial inventory to match the 30 September data.

$$v_inv_{rcsy'fyfirst'} = p_InitInv_{rcsf} \quad \forall (r, c, s, y) \in s_init$$

15. Separations at CYOS=0 are zero.

$$v_sep_{rcs'cyfirst'f} = 0 \quad \forall (r, c, s, y, f) \in s_aginv \wedge f > fyfirst$$

16. Force management actions resulting in RIFs loaded into the system.

$$v_rif_{rcsyf} = p_riftot_{rcsyf} \quad \forall (r, c, s, y, f) \in s_inv \wedge f > fyfirst$$

Optimized Production Version

The optimized production version is very close to the fixed production version. With a few exceptions listed below, the modeling is nearly identical. For the optimized production, we use the following scalars to address the upper and lower bounds on production.

- $npslb=0.9$ represents the lower bound on production in any given FY, acting as the percentage multiplier of production to enforce a lower bound
- $npsub=1.1$ represents the upper bound on production in any given FY, acting as the percentage multiplier of production to enforce an upper bound
- $prod_pct_delta=0.1$ represents the percent changes allowed in production from one FY to the next

In the optimized production case, replace constraints 5-6 with the following constraints.

17. Production is bounded below by a minimum percentage of production capacity.

$$v_prod_{rcsf} \geq npslb * p_prod_{rcsf} \quad \forall (r, c, s, f) \in s_prod \wedge f > fyfirst$$

18. Production is bounded above by production capacity.

$$v_prod_{rcsf} \leq npsub * p_prod_{rcsf} \quad \forall (r, c, s, f) \in s_prod \wedge f > fyfirst$$

19. Smoothflow upper bound production for consistency in production from year to year

$$v_prod_{rcsf-1} - v_prod_{rcsf} \leq prod_pct_delta * p_prod_{rcsf} + 1 \quad \forall (r, c, s, f) \in s_prod \wedge f - 1 > fyfirst+8$$

20. Smoothflow lower bound production for consistency in production from year to year

$$v_prod_{rcsf-1} - v_prod_{rcsf} \geq -prod_pct_delta * p_prod_{rcsf} - 1 \quad \forall (r, c, s, f) \in s_prod \wedge f - 1 > fyfirst+8$$

21. Total Force production constraint

$$\sum_{cs} v_prod_{rcsf} \leq p_TotalProd_{rf} \quad \forall (r, f) \in s_TotalProd \wedge f > fyfirst$$

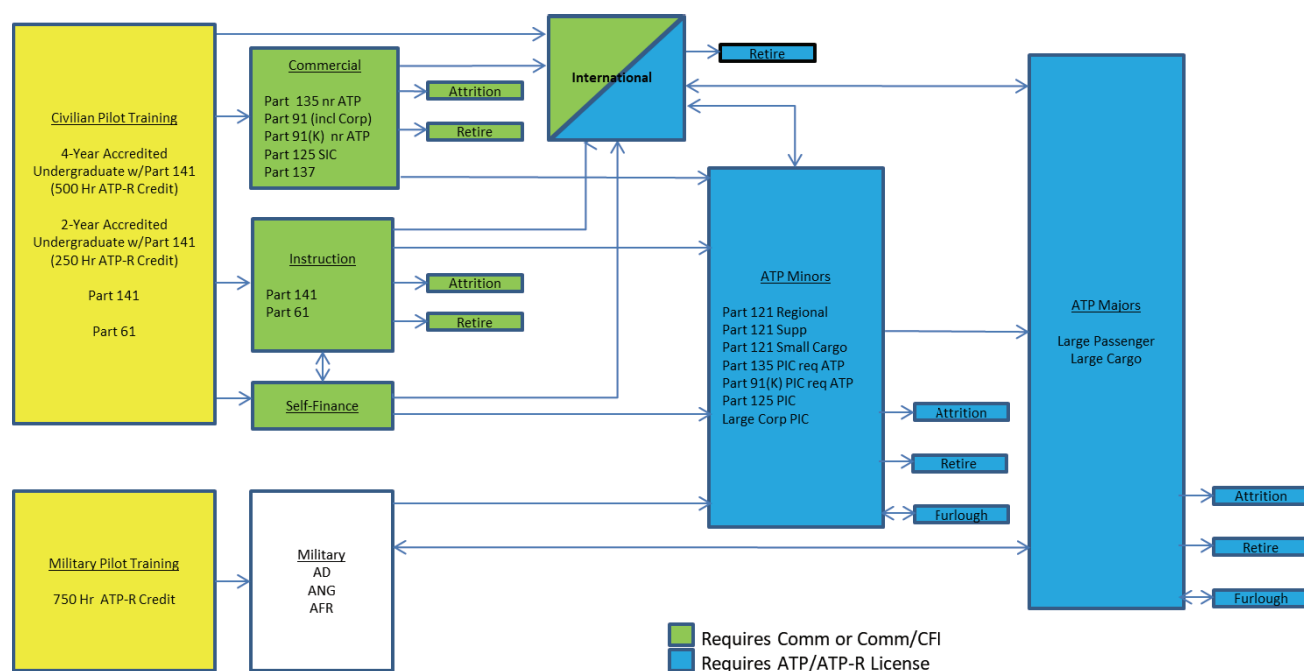
Appendix C. Research Methodology for Determining Major Airline Hiring Influence on Pilot Losses

Prior to the McGee (2015) study, a comprehensive model of pilots flowing through the civilian airline network within the United States did not exist. The first step in this methodology was to determine the flow and create a model to represent this flow of pilots within the United States. After the pilot flow model was created, we performed a regression analysis on historical data analyzing civilian and military pilot production and pilot flow to generate models of behavior based on exogenous factors— mainly major airline hiring. These data were used to inform future forecasts of pilot flow behavior.

Pilot Flow Model

The first step in determining the supply and demand for pilots in the United States was to develop a comprehensive model of the environment itself. This model starts with pilots attending either civilian or military pilot training and ends with pilots leaving the major airlines. Figure C.1 graphically depicts the overall pilot flow used in the U.S. pilot flow model. We will walk through both the civilian pilot training pipeline and the military pilot training pipeline, as depicted in Figure C.1.

Figure C.1. U.S. Pilot Flow (PF) Model



NOTES: *Part* followed by a number refers to the federal regulation governing a particular activity, authority, or certification. ATP = air transport pilot; ATP/R = air transport pilot, restricted; AD = active duty; SIC = second in command; PIC = pilot in command.

Civilian Pilot Training (Yellow Block)

Students begin their careers via one of three tracks: a four-year university-affiliated flight-training program, a two-year college-affiliated flight-training program, or an independent Part 61 or Part 141 flight-training program.²⁸ Students can jump between tracks, though in most cases the quickest and most economical method is to stay within the initial track until achieving the desired certificate. Student pilots begin by obtaining a private pilot certificate. This certificate enables pilots to act as PIC for any plane in which they are qualified and to carry passengers, but not for hire.

Building Experience/Flying for Hire (Green Block)

The next two certificates typically obtained are a commercial certificate or a commercial flight instructor (CFI) certificate. The commercial certificate allows pilots to carry passengers

²⁸ Flight training under Part 61 or being a Part 141–approved school refers to the federal regulations under which the training school has the authority to train pilots. Both sets of regulations define minimum requirements for pilot training and certification. Any FAA-approved flight instructor, whether associated with a flight school or not, may train a student under Part 61 regulations. Part 141 regulations are related to the structure and approval of flight schools. Training under Part 141 regulations is permitted only by instructors associated with an FAA-approved flight school. To become approved, a flight school must meet certain requirements and submit each curriculum it wishes to have approved to the FAA for review. Part 141–approved schools are subject to regular surveillance audits by the FAA and must meet minimum pass rates on the practical exams.

and cargo for hire, and a CFI certificate allows pilots to instruct student pilots. With the commercial certificate, pilots can fly as captains for certain Part 135 (air taxi) operators that do not require an ATP and as first officers for all Part 135 operators, Part 137 (agricultural operations such as spraying) operators, and Part 91 (catch-all category, including everything from U.S. Customs to banner towing and small corporate) operators. With the CFI certificate, pilots can instruct for Part 141 or Part 61 flight instruction companies. These two certificates allow pilots to seek flying employment, and thus the opportunity to build flight hours toward the next certificate, the ATP certificate. While a third route is to self-finance flight instruction and the accruing of flight hours, this route is cost-prohibitive to all but a few. The number of pilots who choose this route will not affect the model results, and thus this route is not accounted for in the model.

An additional route is for pilots to fly for an international airline (the green/blue box in Figure C.1). These international pilot jobs range from corporate flying to small regionals to major airlines, such as Emirates. These airlines typically require a pilot to live outside the United States and to sign a multiyear contract (or training bond). Pay and benefits are usually substantially better than beginning salaries for equivalent flying jobs in the United States. Although the number of U.S. pilots who choose to take this career path is currently low, the major competition for hiring is with regional airlines, as discussed in the following section. Some pilots leave to fly for the international airlines and never return to the U.S. system, though these numbers are very low compared with the total population.

Airlines (Blue Blocks)

The ATP certificate allows pilots to fly for Part 121 operators (airlines) as a captain or as a first officer,²⁹ as a captain for Part 135 operators in aircraft requiring an ATP certificate, or for Part 91K operators (Fractionals) requiring an ATP. Additionally, some operators regularly require ATP certificates for employment, such as Part 125 (large corporate turbine) operators.³⁰ Once obtaining the ATP/restricted ATP (R-ATP) certificate, pilots who desire to fly for the majors typically apply for a minor Part 121 carrier. These include regional airlines, small Part 121 cargo carriers, or small Part 121 charter carriers, to build time and experience to qualify as a competitive candidate for a major airline.

As discussed earlier, another option for U.S. pilots to accumulate experience is flying for international airlines. New ATP-certified pilots with close to the minimum hour requirements are not currently competitive for major airline employment. Instead of flying with a regional airline

²⁹ Part 121 first officers can fly for the airlines with a restricted ATP (R-ATP) certificate (14 C.F.R. 121, 2013).

³⁰ Although Part 125 operations require a commercial license, the common practice for Part 125 operators is that the captains need to have at least an ATP license. Part 125 is unique in that the FAA requires the pilots in command of a Part 125 operator to have at least 1,000 total flight hours and 500 hours of cross-country time, which is more than most R-ATP requirements. Thus, Part 125 captains are accounted for in the R-ATP required accounting block, whereas first officers are accounted for in the commercial-required block of the model.

(low starting pay and a 50- to 90-passenger aircraft), a new ATP pilot can choose to fly for an international airline. These airlines fly the same equipment as the U.S. major airlines and offer much higher starting wages than U.S. regionals. The drawback for some is the need to live overseas, but it is another option for young pilots and allows them to gain experience flying large aircraft, which makes them very competitive for future U.S. major airline employment. There are also some opportunities for pilots with new commercial certificates to fly with charter and corporate operations overseas to build flight time and experience, though the salaries and benefits offered are much less than for ATP pilots.

The final step for most pilots flying professionally is the move to the major U.S. airlines. The majors are thought of as destination airlines, which pilots will stay with for a career, if possible, primarily because of the lucrative pay scales, profit sharing benefits, and retirement plans. Some pilots choose to spend their entire Part 121 career at a company listed in the minors.³¹ This is often for reasons other than pay, such as seniority and quality of life. Although most major airline pay scales top out at over \$300 per flight hour for captains, this study used \$150 per flight hour as the cutoff between majors and minors. Additionally, some companies, such as Part 125 operators, pay salaries similar to the majors'; they were included in the minors because of lack of industrywide pay data. The other minors category operators consist of Part 135 operators, whose PICs require an ATP; Part 91(K) operators, whose PICs require an ATP; and Part 125s.³²

Losses

At every step of the model, a certain number of pilots drop out of the system. These are depicted by the "Retire," "Attrition," and "Furlough" boxes. Retirement is self-explanatory. Attrition encompasses dropouts because of a loss of medical qualification, a release from employment as a result of disciplinary actions, or a self-initiated change in career. Furloughs are most common for Part 121 operators and are included as potential flows at that level. Furloughs occur when airlines contract in size; they lay off pilots without pay until they start hiring again, at which point they offer those positions back to the furloughed pilots first.

Military Training Pipeline (Yellow Block)

Chapter 1 of this report described how officers enter the Air Force, get assigned into rated career fields, and serve out their initial ADSC. We also discussed retention efforts designed to retain pilots past their ADSC. That description provides the framework for the military training pipeline. However, while pilots are serving their time in the military, they are performing missions, flying sorties, and accumulating the flight hours necessary to make them experienced

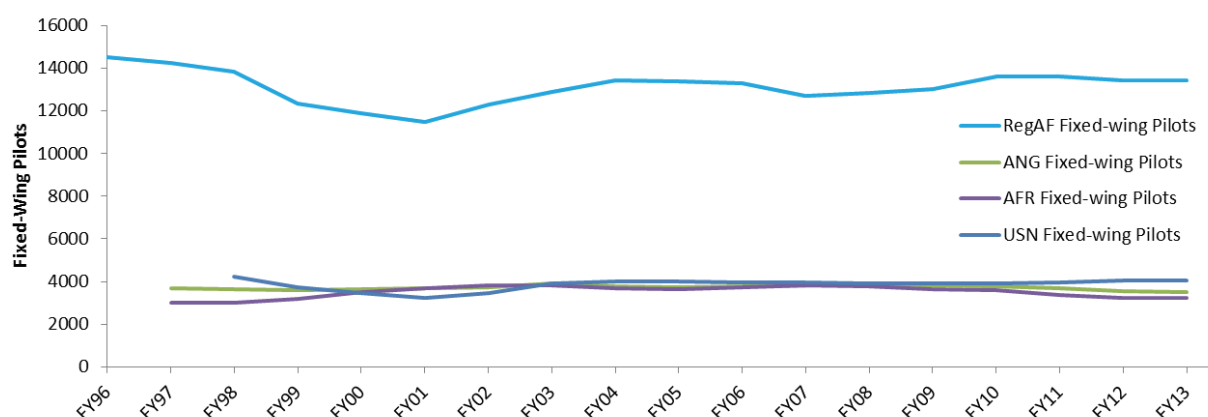
³¹ *Minors* means airlines that are smaller, typically regional, with lower pay.

³² Although Part 125 operations require a commercial license, the common practice for Part 125 operators is for at least the captains to have an ATP license. Thus, Part 125 captains are accounted for in the R-ATP-required accounting block, whereas first officers are accounted for in the commercial-required block of the model.

Air Force pilots. Military pilots qualify for FAA commercial and instrument certificates after pilot training graduation (U.S. Department of Transportation, 2015). Military instructor pilots qualify (after taking a written test) for CFI, CFI-instrument, and multiengine instructor certificates (U.S. Department of Transportation, 2015).

The baseline for the numbers of military pilots was built from numerous sources. The current and historical numbers of USAF pilots were derived using the BAE personnel files and broken down by component. The current and historical numbers for the U.S. Navy (USN) were provided by the Office of the Chief of Naval Operations (OPNAV). The U.S. Marine Corps (USMC) and U.S. Army (USA) fixed-wing pilot data were generated from information provided by the services to the U.S. Government Accountability Office at the end of calendar year 2013. Military pilots are, and will continue to be, a steady source of new hires for the major airlines. Figure C.2 shows the numbers of fixed-wing pilots (exclusive of RPA or drone pilots) in the USAF and USN over the past 18 years.³³ The numbers of fixed-wing pilots in both the USAF and USN were higher at the end of 2013 than they were in 2000.

Figure C.2. Total Fixed-Wing Pilot Inventories, USAF and USN



SOURCES: Calculated from AF personnel files for USAF, OPNAV for USN.

The civilian pilot pipeline dwarfs the military pilot pipeline, both in size and in requirements. Table C.2 shows the 2017 populations of civilian pilots currently in the U.S. pilot pipeline.

³³ USA and USMC numbers are not included here because their contribution to the pipeline is minimal, and the data on these two services were not as precise as the data from the USAF and USN.

Table C.2. Total Fixed-Wing Pilot Inventories, Civilian

Active CFI	Commercial	ATP and ATP-R		
		Minors		Majors
Total Part 141/61 CFIs	Part 135, Part 137, Part 125, Part 91, Corporate	Part 135/91(K) PIC Req ATP /Part 125 PIC	Part 121 Minors	Part 121 Majors
Total	Total	Total	Total	Total
21351	33355	18605	22485	65088

SOURCE: McGee, 2015.

Pilot Demand

At each level of the PF model, four factors drive pilot demand:

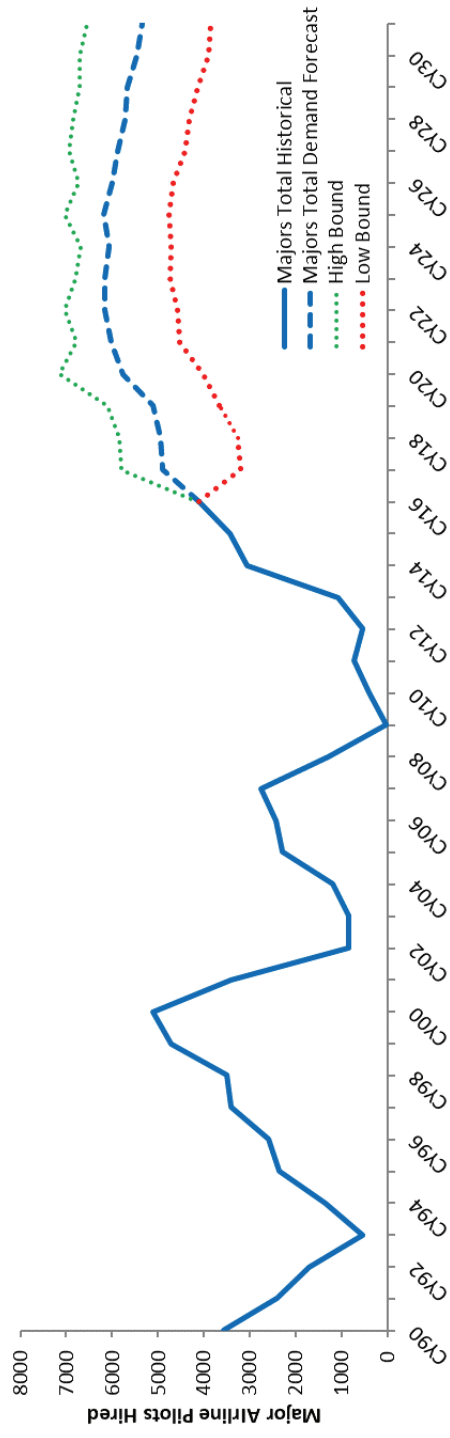
1. fleet growth (or contraction)
2. retirements
3. loss because of career progression (e.g., regional pilots leaving to the majors)
4. attrition (e.g., loss of medical certification, termination, change of career).

We use a variety of data sources from the major airlines, the regional airlines, online sources (fapa.aero and airlinepilotcentral.com), and published FAA data to determine the growth or contraction of each of the blocks or nodes in the PF Model presented in Figure C.1.

Demand for ATPs

Figure C.3 displays the historic and forecast major airline hiring determined by the PF model. The low band is based on 0-percent growth, 50 percent of planned attrition, and 100 percent mandatory retirements. The high band is based on 250-percent forecast growth, 100 percent planned attrition, and 100 percent mandatory retirements.

Figure C.3. Part 121 Majors, Historical and Forecasted Major Airline Hires



SOURCES: PF model and Future and Active Pilot Advisors, undated.

The majors is by far the largest category of ATPs, consisting of 61.3 percent of the ATP population. The demand signal has increased significantly in recent years. By 2016, demand at the majors surpassed 4,000 new pilots per year, and by 2021 it passes the 6,000 pilots per year threshold. The 15-year projected average is over 5,000 pilots per year, creating uncharted territory for major airline hiring. Historically, the industry has seen hiring spikes at these levels for three-to-four-year periods (in both the late 1980s and the late 1990s) but has never experienced sustained hiring at these levels. Most of the future growth is in the passenger sector of the majors, with mandatory retirements driving the majority of growth, followed by passenger fleet growth. Thus, even if the fleet growth prediction is cut in half, this still represents an unprecedented demand in scope and duration.

Military Pilot Supply

As discussed earlier, this model supplies the demand in the majors from two pools of pilots, the minors and separating or retiring pilots from the military. As the forecasted demand from the majors is well above the potential supply coming from the military each year, the PF model assumes that all military pilots desiring a career with the majors will find employment. In 2016, Delta Airlines hired 1,237 new pilots. Of those pilots, 47 percent had prior military experience, even though less than 20 percent of the annual potential supply pool is prior military. For the PF model, the military supply is calculated first, and the minors supply is the difference between the total majors demand and the pilots supplied by the military.

Military pilots are supplied from the USAF, the USN, the USMC, and the USA.³⁴ The majority of fixed-wing pilots in the military are in the USAF, followed by the USN, the USMC, and then the USA. This model considers only fixed-wing pilots in the supply chain. Although some helicopter pilots will transition into professional fixed-wing careers, they are required to gain the same amount of fixed-wing experience as any other pilot to become competitive for employment. Thus, these pilots are captured in the civilian pipeline, which is where they will be required to gain their fixed-wing experience. The majority (89 percent) of fixed-wing pilots fly in the USAF or the USN: 74 percent reside in the USAF and 15 percent in the USN (U.S. Government Accountability Office, 2014; Headquarters Department of the Army, 2014; OPNAV, 2014; USAF/A1 and Bigelow, 2014). Over half of the pilots in the USMC fly rotary-wing aircraft, as do almost 90 percent of USA pilots.

Correlation of Military Pilot Losses and Major Airline Hiring

Multiple studies have concluded that not only are military pilot losses highly correlated with major airline hiring, such hiring is the most significant variable in predicting military pilot losses to the major airlines. The following are the studies and their main findings:

³⁴ Includes active duty, National Guard, and reserves. U.S. Coast Guard (USCG) also flies fixed-wing aircraft. This study did not have access to USCG data. The USCG has only 79 fixed-wing aircraft, so lacking this data will not significantly change the model results.

- The RAND Pilot Retention study: predicted a 35-percent increase in separations for the USAF and an 11-percent increase for the USN, for an increase of 2,500 airline hires.
- United States Air Force Academy (USAFA) study: found that every 1-percent increase in airline hiring increases the probability of separating 1.13 percent for a given USAF pilot population.
- Center for Naval Analysis (CNA) study: calculated a 2.3-percent to 2.7-percent reduction in retention rates for jet and propeller pilots for every 1,000-person increase in hires by the major airlines.

These previous studies have found a significant correlation between major airline hiring and USAF and USN pilot losses: “Exit surveys for the Air Force indicate that for those officers separating from the service, airline hiring is the number one factor in the decision to leave” (Dalonzo, 1999). The previous RAND study found no significant correlation between USMC pilot losses and airline hiring. The results of this analysis coincide with the studies listed here.

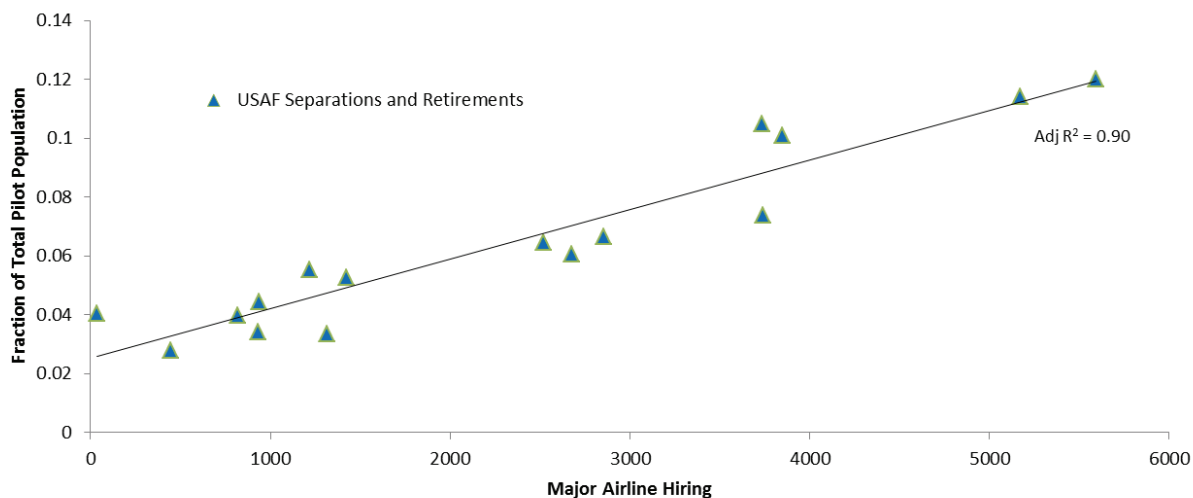
In this study, annual pilot loss and separations and loss rate data for the USAF RegAF, AFR, and ANG, and the pilot loss for the USN, showed a significant relationship to major airline hiring;³⁵ the annual pilot loss data from the USMC and the USA did not show a significant relationship. The fixed-wing pilot pools for the USMC and USA are relatively small, and their losses do not have a significant influence on the supply of pilots to the major airlines.

The potential pool of military pilots for the major airlines includes the annual separations and retirements. A statistically significant relationship was found between MAH and the number of annual separations in the RegAF, the combined total of RegAF separations and retirements, the total RegAF losses, ANG total losses, AFR total losses, and USN total losses. MAH also explained a significant proportion of variance in these outcomes.

Figure C.4 is a scatterplot of USAF separations and retirements along with major airline hiring. Although retirement numbers rise slightly with increased major airline hiring, separations account for the vast majority of losses at higher levels of major airline hiring. In short, as the major airlines step up their hiring, separations of pilots from the USAF increase.

³⁵ While the relationship is between loss rates and major airline hiring, loss rates are a function of losses and the total inventory.

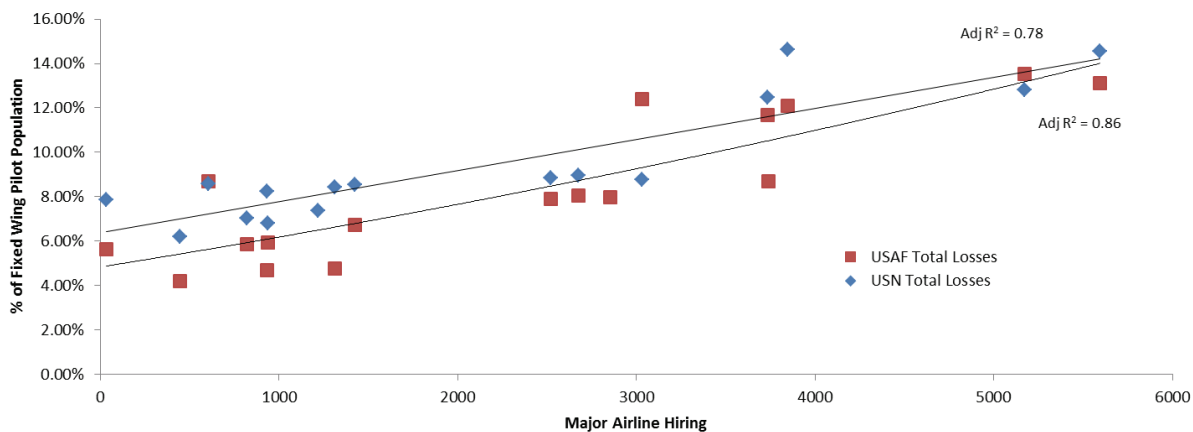
Figure C.4. Scatterplot of Separations and Retirements Combined Versus Major Airline Hiring



SOURCE: AFPC/Research, Analysis and Data Division, 1997–2013. Controls for Air Force force-shaping years.

For the USN, this study had total numbers only of annual losses, so the study was unable to separate out the different types of losses: resignations (similar to separations in the USAF), retirements, and crossflow to other career fields. The combined data for both the USAF and the USN still indicated a significant relationship to major airline hiring, as shown in Figure C.5.³⁶

Figure C.5. Scatterplot of Total USAF and USN Losses Versus Major Airline Hiring

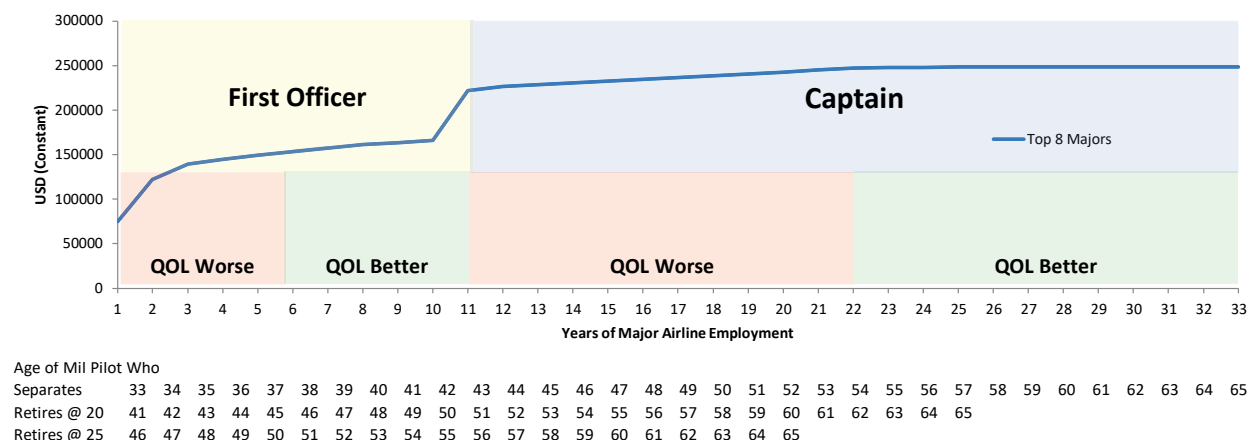


SOURCES: AFPC/Research, Analysis and Data Division, 1997–2013; OPNAV, 2014.

³⁶ FY 2007, FY 2012, and FY 2014 were force-shaping years for the USAF, meaning it offered voluntary separation board or temporary early retirement authority or conducted a reduction-in-force (RIF) board to selectively downsize the force (AFPC/Research, Analysis and Data Division, 2013). These artificially affect the correlation of the data between separations and airline hires.

Figure C.6 presents a rationale for why separations correlate with major airline hiring and retirements do not. Most pilots who desire a career with the airlines separate at the end of their active duty service obligation (ADSO), instead of waiting until retirement. There are two important factors when considering employment at the major airlines: the financial benefits and quality of life (QoL). One of the products of the airline seniority system is that the more-senior pilots at both the first officer and captain levels get to bid first on which flights they like to fly. That policy leaves the junior pilots to fly the weekend, holiday, and red-eye flights, which are considerably less desirable. Another perk for more-senior pilots is the ability to choose leave for family functions, vacations, and holidays. These QoL issues all come together in Figure C.6. The displayed salary (no retirement or other benefits included) and upgrade timing from first officer to Captain are weighted averages of Delta, United, American, Southwest, and FedEx.

Figure C.6. Major Airlines Salaries and QoL



NOTES: Salary data do not include additional pay, such as international override or per diem, nor do they include any retirement benefits for each of the top airlines. Built from airlinepilotcentral.com with the following assumptions: Majors = United, Delta, American, FedEx, and Southwest. Calendar year 2017 dollars, 75 hours per month (pay based on hourly wage). No interest and no scheduled pay raises were factored into this analysis. Regionals – SkyWest, American Eagle/Envoy, ExpressJet, Republic, and Endeavor. Calendar year 2017 dollars, 80 hours per month (pay based on hourly wage). No interest and no scheduled pay raises were factored into this analysis.

A military pilot who separates at age 33 begins drawing the higher pay scale of a captain around age 43 and enjoys both a substantial salary and improved QoL in his or her 50s and 60s (to include reaching the highest salary plateau). A military pilot who retires does not join the majors until age 41 at the earliest. That pilot will not reach the higher pay scales until an age in the early 50s and will not benefit from seniority as a captain (better QoL) until their 60s. The military pilot will never reach the highest salary plateau, as a result of hitting the mandatory age-65 retirement prior to reaching the highest salary plateau. Those pilots who stay in the military until 25 years of service and then transition to the major airlines are forced to choose between lower pay and better QoL or higher pay and worse QoL. As hiring accelerates, these benefits of seniority will shift to the left, but the concept still holds.

How the Pilot Flow Model Results Feed into the Total Force Blue Line Model

For the next 15 years, major airline hiring is forecasted to remain above 4,500 pilots per year. This annual number far exceeds the maximum number of military pilots eligible for separation or retirement. As discussed earlier, the PF model uses regression analysis to model the historic separation and retirement behavior of military pilots to generate overall loss rates that feed into the TFBL model. As inputs, these regressions use (1) historic major airline hiring levels³⁷ and (2) the historic USAF RegAF, ANG, and AFR loss numbers generated from the USAF-supplied active duty, reserve, and guard personnel files and AFPC annual Retention Reports. These regressions are shown in Appendix E. The relationships determined by the regressions are then multiplied by the forecasted major airline hiring levels (produced by the PF Model)³⁸ to determine the total RegAF, ANG, and AFR loss rates due to major airline hiring.³⁹

Regression analysis is also used to determine the affiliation rates for the ANG and AFR, based on historic relationships, by comparing historic RegAF separations and affiliation data generated from the USAF-supplied personnel files.⁴⁰ These rates and affiliation data are then fed into the TFBL model, as discussed earlier.

³⁷ Baselined on Future and Active Pilot Advisors data, undated.

³⁸ Inputs include FAA forecasts, multiple FAA Air Operator Tables, and Flight School data (FAA, 2011a, 2011b, 2012a, 2014a, 2014b, 2014c; 2012b), and data received directly from the major airlines, the regional airlines, and major pilots unions (Air Line Pilots Association, Allied Pilots Association, Southwest Airlines Pilot Association).

³⁹ Control variables included for (1) force-shaping in FY 2007, FY 2012, and FY 2014, (2) post-September 11th terrorist attacks, and (3) recent aviator retention pay (ARP)/ACIP increases.

⁴⁰ AFPC annual Retention Reports.

Appendix D. ARP, ACP, and AvB History

The following details actions the Air Force took that affected the ARP/ACP/AvB policies for the specified fiscal year.

FY 1989: Original ARP offered at \$12,000 per year to commit pilots to 14 CYOS following expiration of their seven-year UPT ADSC.

FY 1996: Helicopter pilots added to ARP eligibility.

FY 1998: National Defense Authorization Act funds \$22,000 bonus with variable contract length and amount; FY 1997 eligible pilots permitted to renegotiate contracts. Take rate: 28 percent.

FY 1999: ARP offered to prior-service (i.e., late-rated) officers. Take rate: 42 percent.

FY 2000: Increased maximum annual payment to \$25,000 with 50-percent up-front option capped at \$100,000. UPT ADSC increased to ten years; ABMs added to rated force. Take rate: 32 percent.

FY 2001: Capped 50-percent up-front option at \$150,000. Airline hiring slowed in the post-September 11th environment; stop-loss and rated recall program initiated to meet rated demands in support of Global War on Terror. Take rate: 30 percent.

FY 2003: Program restructured to target specific AFSCs (pilot, navigator, ABM). Retirement-eligible navigators and initial-eligible ABMs offered ARP for the first time (\$10,000–\$15,000 per year, depending on contract length); pilots offered ARP in variable lengths to 25 years of aviation service (YAS). Take rate: 65 percent.

FY 2004: Lowered the max agreement to 20 YAS for pilots and added navigators with nine YAS. The low-production years of the 1990s (coupled with increased airline hiring) led to peak spending of \$218 million in FY 2004 to meet Operation Enduring Freedom and Operation Iraqi Freedom requirements. Take rate: 76 percent.

FY 2005: Pilots offered a five-year (\$25,000 per year) agreement with 50-percent up-front option; continued navigator and ABM eligibility (\$15,000 per year) at nine and six YAS, respectively. Take rate: 65 percent.

FY 2006: Eliminated navigator ARP and pilot's 50-percent up-front option; renewed ABM eligibility (\$15,000 per year for five years). Take rate: 66 percent.

FY 2010: Due to massive expansion in the RPA career field to 65 combat air patrols, ARP offered to CSOs who cross-trained as RPA pilots (\$15,000–\$25,000 per year with three-to-five-year contract lengths). Take rate: 77 percent.

FY 2011: Eliminated ABM ARP; limited eligibility to pilots (including RPA) and CSOs trained as RPA pilots (12U). Uncommitted 12Us offered a three-, four-, or five-year agreement at \$15,000 per year. Take rate: 70 percent.

FY 2012: Program targeted low-inventory fighter pilot and RPA numbers with a 50-percent up-front option; fighter CSOs offered five-year ARP option for \$15,000 per year, all other CSOs and ABMs excluded. Uncommitted pilots offered three-to-five-year contract at \$15,000 per year. Take rate: 67 percent.

FY 2013: Program, again, targeted low fighter pilot inventory with “To 20 YAS” and 50-percent up-front option; RPA pilots offered 50 percent up-front on five-year offering. Fighter CSOs offered five-year ARP option for \$15,000 per year. RPA CSOs and uncommitted pilots offered three-to-five-year contract at \$15,000 per year. All other CSOs and ABMs excluded. Take rate: 67 percent.

FY 2014: Similar to the FY 2013 ARP program, fighter pilots are eligible for longer contracts of up to nine years. The program permits airmen who will complete their ADSC commitment anytime in FY 2015 to lock in a contract for the next year. FY 2014's ARP program applies to O-5 and below who will not reach 16 years of Total Active Federal Military Service by the end of the FY when their UFT ADSC expires. Depending on the aviator category and length of the ARP contract, incentives vary from \$15,000 to \$25,000 per year, with some categories eligible to receive 50 percent of the ARP total payable up front. Pilot take rate: 53 percent.

FY 2016: Pilots, to include those who entered the Air Force in FY 2015, have the opportunity to accept an agreement of five years or one that will commit them until they reach 20 YAS. Those pilots who are uncommitted and have not previously accepted an ARP agreement are offered the same five-year or 20-YAS commitment at a reduced rate. CSOs from the combat search and rescue, RPA, and fighters may accept an ARP agreement for five or nine years, not to exceed 20 YAS; CSOs and ABMs in the RPA enterprise are also eligible for ARP at the same level as other RPA pilots. Depending on the aviator category and length of the ARP contract, incentives will vary from \$15,000 to \$25,000 per year with some categories eligible to receive 50 percent of the ARP total payable up front. Pilot take rate: 49 percent.

FY 2017: AvB cap raised from \$25,000 per year to \$35,000 per year. Contract options include one-year, two-year, and five-year options for all eligible 11X aviators, with the amounts tiered by the most critical needs. Bomber, special ops, and mobility pilots have a nine-year contract option, while fighter pilots have nine-year and 24-YAS (13-year maximum) options. RPA pilots, along with combat systems operators from various flying communities, are eligible for five-year contracts at varying amounts, tiered by critical needs. Pilot take rate: 47 percent.

Appendix E. Regressions

Figure E.1. USAF RegAF Losses Versus MAH

<i>Regression Statistics</i>	
Multiple R	0.937880403
R Square	0.879619651
Adjusted R Square	0.849524564
Standard Error	0.010751481
Observations	21

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	4	0.013514372	0.003378593	29.22801472	3.54435E-07
Residual	16	0.001849509	0.000115594		
Total	20	0.015363881			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	0.07802645	0.010222941	7.632485252	1.01517E-06	0.056354782	0.099698118
MAH	9.79747E-06	2.23762E-06	4.37852818	0.00046764	5.05393E-06	1.4541E-05
Force Shaping	0.045894868	0.00702213	6.535747875	6.86176E-06	0.031008619	0.060781118
Post-9/11	-0.022844433	0.007953781	-2.872147442	0.011061841	-0.039705696	-0.00598317
ARP Increase	-0.020412424	0.013448927	-1.517773434	0.148581373	-0.048922875	0.008098027

NOTES: *df* = degrees of freedom; *SS* = calculated sum of squares terms; *MS* = mean square terms; *F* = *F* statistic; *Significance F* = significance of *F* in relation to chance.

In terms of the regressors, force-shaping years, post-9/11, and ARP are dummy variables indexed by year to indicate the years in which these conditions applied. The reasons these are important to include and address are the following:

1. Force-shaping is important to include because losses in force-shaping years were artificially high due to policy implementation, not as a result of individual choices.
2. Post-9/11 was chosen because that was a transition of increased patriotism and mission satisfaction. Unfortunately, we did not find enough quality data to specifically model either of those variables, so they were added as dummy variables. Elliott noted in his 2004 RAND study that “less-enjoyable activities and missions, and the sense that military careers are likely to become less appealing in the near future were commonly reported as sources of dissatisfaction with the military.” He also did not specifically model “less enjoyable missions” in the pre-9/11 time frame (Elliott, Kapur, and Gresenz, 2004, p. 86).
3. ARP increases were included because those also change the decision matrix to separate or stay.

We did not find any methodology we felt was accurate enough to model this effect directly, so we addressed it by adding it as a dummy variable. Those predicted separation rates were used as the aggregate loss rates for the RL/BL model. To get to specific MWS and CYOS loss rates, we used the historical loss rate and the current inventory snapshot to get to a weighted aggregate loss rate and then used a perturbation factor to multiply MWS and CYOS loss rates to match the increased aggregate loss rate, from this regression analysis.

Figure E.2. ANG Total Losses Versus MAH

<i>Regression Statistics</i>	
Multiple R	0.731597807
R Square	0.535235352
Adjusted R Square	0.483594835
Standard Error	0.010983458
Observations	21

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	2	0.002500705	0.001250352	10.36463979	0.001011807
Residual	18	0.002171454	0.000120636		
Total	20	0.004672159			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	0.078941689	0.009111705	8.663766708	7.7344E-08	0.059798707	0.098084672
MAH	2.35357E-06	1.90346E-06	1.2364682	0.232176117	-1.64545E-06	6.35259E-06
Post-9/11	-0.019568811	0.006971961	-2.806787227	0.011665769	-0.034216358	-0.004921265

NOTE: Total losses include both full-time and part-time reservists.

Figure E.3. AFR Total Losses Versus MAH

Regression Statistics	
Multiple R	0.793743759
R Square	0.630029155
Adjusted R Square	0.588921284
Standard Error	0.014274797
Observations	21

ANOVA				
	df	SS	MS	Significance F
Regression	2	0.006246051	0.003123026	15.32624119
Residual	18	0.003667857	0.00020377	0.00012987
Total	20	0.009913908		

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.09860307	0.011842149	8.326450767	1.38008E-07	0.073723638	0.123482502
MAH	4.76838E-06	2.47386E-06	1.927507464	0.069848257	-4.29003E-07	9.96575E-06
Post-9/11	-0.027647697	0.009061202	-3.051217411	0.006874168	-0.046684575	-0.008610818

Figure E.4. ANG Affiliations Within One Year of Separating

<i>Regression Statistics</i>	
Multiple R	0.94419403
R Square	0.891502366
Adjusted R Square	0.885791965
Standard Error	19.98909406
Observations	21

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	62379.52435	62379.52435	156.1190269	1.30556E-10
Residual	19	7591.713749	399.5638815		
Total	20	69971.2381			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	20.17177999	8.790024402	2.294849146	0.033302115	1.774047478	38.5695125
RegAF Separations	0.177580048	0.014212362	12.49475998	1.30556E-10	0.147833233	0.207326863

NOTE: Dependent variable is number of affiliations. Independent variable is number of RegAF separations.

Figure E.5. AFR Affiliations Within One Year of Separating

<i>Regression Statistics</i>	
Multiple R	0.933256951
R Square	0.870968537
Adjusted R Square	0.864177408
Standard Error	46.98269783
Observations	21

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	283097.7055	283097.7055	128.2509076	6.84608E-10
Residual	19	41940.10401	2207.373895		
Total	20	325037.8095			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	2.106683617	20.66021897	0.101968117	0.919850431	-41.1356517	45.34901889
RegAF Separations	0.378304332	0.03340497	11.32479172	6.84608E-10	0.308386925	0.448221738

Figure E.6. ARC Affiliations Within One Year of Separating

<i>Regression Statistics</i>	
Multiple R	0.944903015
R Square	0.892841708
Adjusted R Square	0.887201798
Standard Error	62.13841727
Observations	21

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	611255.3344	611255.3344	158.3077907	1.15947E-10
Residual	19	73362.47512	3861.182901		
Total	20	684617.8095			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	22.27846361	27.32481034	0.815319972	0.424992236	-34.91302171	79.46994893
RegAF Separations	0.55588438	0.044180775	12.58204239	1.15947E-10	0.463412955	0.648355804

References

AFPC—*See* Air Force Personnel Center.

Air Force Instruction 11-412, *Aircrew Management*, Department of the Air Force, December 10, 2009.

Air Force Personnel Center, Research, Analysis and Data Division, *Rated Officer Retention Analysis*, various years.

Berry, T., *Pilot Supply Outlook*, Washington, D.C.: MITRE Corporation, 1963.

Boeing, *Current Market Outlook 2014–2033*, Seattle, Wash., 2014.

Bigelow, J. H., A. A. Robbert, *Balancing Rated Personnel Requirements and Inventories*, Santa Monica, Calif.: RAND Corporation, TR-869-AF, 2011.

Carey, S., “American Pilots, Management Agree to Keep Talking on a New Labor Deal,” *Wall Street Journal*, November 23, 2014.

Carey, S., J. Nicas, and A. Pasztor, “Airlines Face Acute Shortage of Pilots,” *Wall Street Journal*, November 12, 2012.

Cleveland, F., *American Eagle Pilot Source Study*, presented at Aviation Accreditation Board International Winter Meeting, Auburn, Alabama, February 19–20, 2013.

Code of Federal Regulations, Title 14, Chapter 1, Subchapter D, Part 121, Operating Requirements: Domestic, Flag, And Supplemental Operations, 2013b.

Dalozzo, W. J., “A Comprehensive Look at Rated Management in the ’90s and Beyond,” Maxwell Air Force Base, Alabama: Air University, 1999.

Davis, C., “Pilot and Technician Hiring Forecast,” Boeing, Seattle, Wash., 2012.

Delta Airlines, *North America Mainline Carrier’s Pilot Age Study*, 2012.

Editors of Encyclopedia Britannica, “Perturbation: Mathematics,” article, undated. As of February 22, 2015:

<http://www.britannica.com/EBchecked/topic/453134/perturbation>

Elliott, M. N., K. Kapur, and C. R. Gresenz, *Modeling the Departure of Military Pilots from the Services*, Santa Monica, Calif.: RAND Corporation, MR-1327-OSD, 2004. As of October 16, 2018:

https://www.rand.org/pubs/monograph_reports/MR1327.html

- Everstine, Brian, “Fixing the ‘Quantity Problem’ in Maintenance,” *Air Force Magazine*, February 3, 2017. As of January 25, 2018:
<http://www.airforcemag.com/DRArchive/Pages/2017/February%202017/February%2003%202017/Fixing-the-“Quantity-Problem”-in-Maintenance.aspx>
- FAA—See Federal Aviation Administration.
- Federal Aviation Administration, “Overview—Title 14 of the Code of Federal Regulations (14 CFR),” Washington, D.C.: U.S. Department of Transportation, 2011a, p. 46.
- , *The Economic Impact of Civil Aviation on the US Economy*, Washington, D.C.: U.S. Department of Transportation, 2011b.
- , “Appendix A.: Methodology for the 2012 General Aviation and Part 135 Activity Survey,” *General Aviation and Part 135 Activity Survey*, Washington, D.C.: U.S. Department of Transportation, 2012a.
- , “Data Downloads,” webpage, U.S. Department of Transportation, updated January 22, 2014a. As of October 15, 2018:
https://www.faa.gov/data_research/aviation_data_statistics/data_downloads/
- , “Airmen Certification System: Active Pilots Summary,” database, U.S. Department of Transportation, 2014b. As of September 24, 2014:
http://registry.faa.gov/activeairmen/M70_Active_Pilots_Summary.pdf
- , *FAA Aerospace Forecast Fiscal Years 2014–2034*, Washington, D.C.: U.S. Department of Transportation, OK 14-0723, 2014c.
- Fullerton, R. L., “An Empirical Assessment of US Air Force Pilot Attrition,” *Defence and Peace Economics*, Vol. 5, No. 14, 2003, pp. 343–355.
- Future and Active Pilot Advisors, “Pilot Job Market and Interview Prep,” database, updated 2018. As of October 12, 2018:
<http://fapa.aero/hiring-all.asp>
- Garamone, Jim, “Schwartz, Welch Pay Tribute to Airmen at Air Force Transition,” press release, American Forces Press Service, August 10, 2012.
- Garton, D., “Impact and Consequences of the ‘1500 Hour Rule’ and the NPRM,” American Eagle Airlines, 2011.
- Goldfein, David L., “Charter for Air Force Aircrew Crisis Task Force,” February 2017.
- Grosso, Gina M., “Military Pilot Shortage,” testimony before the Subcommittee on Military Personnel, Committee on Armed Services, U.S. House of Representatives, March 29, 2017.
- Headquarters, Department of the Army, “The Supply and Demand of Aviation Professionals,” 2014a.

———, “Pilot Supply and Demand,” 2014b.

Higgins, J., K. Lovelace, E. Bjerke, N. Lounsberry, R. Lutte, D. Friedenjohn, S. Pavel, B. Chase, and P. Craig, *An Investigation of the United States Airline Pilot Labor Supply*, published by authors, 2013.

Lovelace, K., and J. Higgins, “U.S. Pilot Labor Supply,” presentation at the 35th Annual FAA Aviation Forecast Conference, Washington D.C., March 9–10, 2010. 71.

McGee, M., *Air Transport Pilot Supply and Demand: Current State and Effects of Recent Legislation*, Santa Monica, Calif.: RAND Corporation, RGSD-351, 2015. As of August 11, 2017:

https://www.rand.org/pubs/rgs_dissertations/RGSD351.html

National Transportation Safety Board, *Loss of Control on Approach, Colgan Air, Inc., Operating as Continental Connection Flight 3407, Bombardier DHC-8-400, N200WQ, Clarence Center, New York, February 12, 2009*, Washington, D.C., 2010.

Public Law 111-216, Airline Safety and Federal Aviation Administration Extension Act of 2010, August 1, 2010. As of April 11, 2019:

<https://www.congress.gov/111/plaws/publ216/PLAW-111publ216.pdf>

Office of the Chief of Naval Operations, “Aviation Data Compiled,” email to authors, 2014.

OPNAV—See Office of the Chief of Naval Operations.

Robbert, A., A. D. Rosello, C. R. Anderegg, J. A. Ausink, J. H. Bigelow, B. Taylor, and J. Pita, *Reducing Air Force Fighter Pilot Shortages*, Santa Monica, Calif.: RAND Corporation, RR-1113-AF, 2015. As of August 08, 2017:

https://www.rand.org/pubs/research_reports/RR1113.html

Robbert, A., T. L. Terry, A. D. Rothenberg, A. Lawrence, and N. B. Carey, *Air Force Officer Management Flexibilities: Modeling Potential Policies*, Santa Monica, Calif.: RAND Corporation, RR-1921-AF, 2017. As of September 9, 2018:

https://www.rand.org/pubs/research_reports/RR1921.html

Schulker, D., T. L. Terry, *Evaluating the Impact of a Total Force Service Commitment Policy on Air Force Pilot Manning: An Exploratory Application of Inventory Modeling*, Santa Monica, Calif.: RAND Corporation, RR-2400-AF, 2018. As of December 5, 2018:

https://www.rand.org/pubs/research_reports/RR2400.html

Smith, G. M., D. A. NewMyer, E. Bjerke, M. Niemczyk, and R. A. Hamilton, “Pilot Source Study: An Analysis of Pilot Backgrounds and Subsequent Success in US Regional Airline Training Programs,” *International Journal of Applied Aviation Studies*, Vol. 10, No. 1, 2010. pp. 73–96.

- Smith, G. M., D. Herchko, E. Bjerke, M. Niemczyk, R. Nullmeyer, J. Paasch, and D. A. NewMyer, “The 2012 Pilot Source Study (Phase III): Response to the Pilot Certification and Qualification Requirements for Air Carrier Operations,” *Journal of Aviation Technology and Engineering*, Vol. 2, 2013.
- Stanley, D. W., *Predicting Pilot Retention*, Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology, 2012.
- Skowronski, W., “Pilot Shortage, Back with a Vengeance,” *Air Force Magazine*, August 2016. As of August 8, 2017:
<http://www.airforcemag.com/MagazineArchive/Pages/2016/August%202016/Pilot-Shortage-Back-With-a-Vengeance.aspx>
- Sweeney, N., *Predicting Active Duty Air Force Pilot Attrition Given an Anticipated Increase in Major Airline Pilot Hiring*, dissertation, Santa Monica, Calif.: The Frederick S. Pardee RAND Graduate School, RGSD-338, 2015. 120. As of August 3, 2017:
https://www.rand.org/pubs/rgs_dissertations/RGSD338.html
- Taylor, B., C. Moore, and C. R. Roll, *The Air Force Pilot Shortage: A Crisis for Operational Units?* Santa Monica, Calif.: RAND Corporation, MR-1204-AF, 2000. As of August 3, 2017:
https://www.rand.org/pubs/monograph_reports/MR1204.html
- Terry, T. L., J. H. Bigelow, J. Pita, J. Sollinger and P. Emslie, *User’s Guide for the Total Force Blue-Line (TFBL) Model*, Santa Monica, Calif.: RAND Corporation, TL-233-AF, 2017. As of August 3, 2017:
<https://www.rand.org/pubs/tools/TL233.html>
- Terry, T. L., C. M. Hardison, D. Schulker, A. C. Hou, L. A. Payne, *Building a Healthy MQ-1/9 RPA Pilot Community: Designing a Career Field Planning Tool*, Santa Monica, Calif.: RAND Corporation, RR-2018-AF, 2018. As of December 5, 2018:
https://www.rand.org/pubs/research_reports/RR2018.html
- USAF—See U.S. Air Force.
- USAF/A1—See U. S. Air Force, Manpower, Personnel and Services.
- U.S. Air Force, *United States Air Force Fiscal Year 2017 RegAF Aviation Bonus (AvB) Program, Proposal 2*, June 5, 2017.
- U.S. Air Force, Manpower, Personnel, and Services, “AFRAMS Output,” 2014.
- U.S. Air Force, Manpower, Personnel, and Services, and J. Bigelow, “TFBL_NoA10_BigMAH_140724,” computer file compiling model results, 2014.

U.S. Department of Transportation, Federal Aviation Administration, “Pilot Certification and Qualification Requirements for Air Carrier Operations; Technical Amendment,” *Federal Register*, 81 F.R. 1, Washington, D.C., 2012b.

———, “Pilots,” webpage, Washington, D.C., updated March 10, 2015. As of October 12, 2018: <https://www.transportation.gov/careers/veterans/pilots>

U.S. Government Accountability Office, “Aviation Workforce: Current and Future Availability of Airline Pilots,” GAO-14-232, February 2014.