



PROJECT AIR FORCE

Independent Review and Assessment of the Air Force Ready Aircrew Program

A Description of the Model Used for Sensitivity
Analysis

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Preface

The Ready Aircrew Program (RAP) sets continuation training requirements for pilots of combat aircraft. The National Defense Authorization Act (NDAA) for Fiscal Year 2017 directed the Secretary of the Air Force to arrange for an independent review of the RAP and its effectiveness in managing aircrew training requirements. The Air Force turned to RAND Project AIR FORCE to conduct the review and to make recommendations for improvements.

As part of the analysis, we created a computational model to examine whether flying units can feasibly meet the continuation training requirements set by RAP and other training requirements when various constraints, such as the length and frequency of temporary duty assignments or deployment schedules, are taken into account.

This report describes the model, its specifications, and how it was used in our assessment of the RAP. An expanded discussion of the RAND Corporation assessment and recommendations in response to the NDAA-mandated review is in John A. Ausink, Tracy C. Krueger, Sean Robson, Susan G. Straus, William W. Taylor, Craig Vara, Matthew Walsh, William A. Williams, and C. R. Anderegg, *Independent Review and Assessment of the Air Force Ready Aircrew Program: A Report Prepared for the Secretary of the Air Force in Compliance with Section 351 of the FY 2017 National Defense Authorization Act*, Santa Monica, Calif.: RAND Corporation, RR-2630-AF, 2018 (not available to the general public).

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Summary

U.S. Air Force pilots must undergo continuation training to maintain flying proficiency and improve their capabilities to perform assigned missions. For combat aircraft pilots, continuation training is governed by the Ready Aircrew Program (RAP), which defines how many aircraft sorties and simulator missions a pilot must complete annually and how this training should be distributed among missions, events, and skills. Squadrons must also accomplish other, non-RAP types of flying training; new pilots must be trained to accomplish the squadron's mission; "inexperienced" pilots must fly enough to become "experienced"; as pilots gain more experience, they need to undergo training to become flight leads; and the best pilots receive additional formal training to become instructor pilots and mission commanders. This training may occasionally interfere with opportunities for "pure" continuation training. For example, experienced pilots who participate in a four-ship mission meant to train a new pilot may not have the time to practice the more-advanced skills needed to fulfill a RAP requirement. As a result, the number of new pilots who enter a squadron each year, the number of sorties that can be flown each month, the ratio of inexperienced to experienced pilots in the squadron, and other factors all affect how rapidly pilots can become experienced, how many flight leads and instructors can be maintained, and how much unconstrained continuation training can be accomplished.

Understanding the capacity of squadrons to complete required training activities is important. This is particularly true as the Air Force conducts a review and assessment of the assumptions underlying annual continuation training requirements and as the Air Force seeks to increase annual pilot production. Yet the relationships between myriad crew management factors and their effects on pilot absorption and training completion are complex and often counterintuitive. We developed a computational model to systematically explore the effects of varying these factors on aircrew management. Simulations using the computational model revealed the potentially negative effects of increasing the number of new pilots entering a squadron each year or decreasing the squadrons' aircraft utilization rates. Simulations also showed that the new, sortie-based definition of experience adopted in 2018 may increase the amount of time needed for pilots to become experienced. More broadly, the model can be used to prospectively simulate the outcomes of a wide range of policy modifications, to understand their implications in terms of pilot absorption and squadron health, and to inform selection between potential policy options.

Abbreviations

AFI	Air Force Instruction
AOR	area of responsibility
API	Aircrew Position Indicator
ARMS	Aviation Resource Management Program
ASD	average sortie duration
B-Course	Basic Course
BMC	Basic Mission Capable
CMR	Combat Mission Ready
FAIP	first-assignment instructor pilot
FL	flight lead
FLUG	flight lead upgrade training
FL	flight lead
FS	fighter squadron
FTU	formal training unit
FW	fighter wing
FY	fiscal year
GAO	Government Accountability Office
IP	instructor pilot
IPUG	instructor pilot upgrade training
MQT	mission qualification training
MTC	Mission Training Center
NDAA	National Defense Authorization Act
OG	operations group
PMAI	primary mission aircraft inventory
RAP	Ready Aircrew Program
RTM	RAP Tasking Message

SCM	sorties per crewmember per month
TDY	temporary duty assignment
TOS	time on station
TTE	time to experience
UFL	upgrade flight lead
T	undergraduate pilot training
UTE rate	utilization rate
WM	wingman

1. Introduction

Flying continuation training in the U.S. Air Force ensures that pilots maintain proficiency and improve their capabilities to perform a unit's assigned mission. For pilots of combat aircraft, this training is governed by the Ready Aircrew Program (RAP), which defines how many aircraft sorties and simulator missions a pilot must complete annually and how the training should be distributed among missions, events, and skills. In addition to continuation training, flying squadrons must accomplish other types of training that enable a unit to function: new pilots must be trained to accomplish the squadron's mission; "inexperienced" pilots (generally, those with fewer than 500 hours in a fighter aircraft) must fly enough to become "experienced"; as pilots gain more experience, they need to undergo training to become flight leads (FLs); and the best pilots receive additional formal training to become instructor pilots (IPs) and mission commanders.

Required training helps define how much annual flying time is needed by pilots. Consequently, it affects how much money is required to provide the training. This makes the RAP a program of interest for Congress; the Government Accountability Office (GAO) has recently issued reports on managing the costs of flying training in simulators and on the need for better analysis to improve the effectiveness of continuation training.¹

Most recently, the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2017 directed the Secretary of the Air Force to contract an independent entity to (1) conduct a review and assessment of the assumptions underlying annual continuation training requirements in the Air Force and the overall effectiveness of the RAP in managing aircrew training requirements and (2) make recommendations for the improved management of such training requirements.² The Air Force contracted with RAND Project AIR FORCE to conduct the review and assessment.

The NDAA language directed that the report examine several specific topics as part of its review:

1. For the aircrews of each type of combat aircraft, and by mission type:
 - a. the number of sorties a pilot needs to reach minimum and optimal levels of proficiency, respectively
 - b. the optimal mix of live and virtual training sorties during continuation training
 - c. the optimal mix of experienced aircrews versus inexperienced aircrews in a unit.

¹ GAO, *Air Force Training: Actions Needed to Better Manage and Determine Costs of Virtual Training Efforts*, Washington, D.C., GAO-12-72772, July 19, 2012; GAO, *Air Force Training: Further Analysis and Planning Needed to Improve Effectiveness*, Washington, D.C., GAO-16-864, September 2016.

² Pub. L. 114-328, National Defense Authorization Act for Fiscal Year 2017, § 351, December 23, 2016.

2. The availability of assets and infrastructure to support the achievement of aircrew proficiency levels and an explanation of any requirements relating to such assets and infrastructure.
3. The use of accumulated flying hours as the metric for determining whether an aircrew member should be designated “experienced” and whether different criteria should be used.

The results of our assessment of the RAP are described in detail in John A. Ausink, Tracy C. Krueger, Sean Robson, Susan G. Straus, William W. Taylor, Craig Vara, Matthew Walsh, William A. Williams, and C. R. Anderegg, *Independent Review and Assessment of the Air Force Ready Aircrew Program: A Report Prepared for the Secretary of the Air Force in Compliance with Section 351 of the FY 2017 National Defense Authorization Act*, Santa Monica, Calif.: RAND Corporation, RR-2630-AF, 2018 (not available to the general public). Some of those results are based on a mathematical model of the flow of pilots through a squadron; this document provides more details about how that model functions and how it can be used to analyze the potential impact of Air Force policy decisions.

The Importance of Modeling Squadron Flow

Pilot upgrade training and continuation training occasionally conflict. For example, experienced pilots may participate in a four-ship mission to train a new pilot instead of practicing the more advanced skills that they need to fulfill a RAP requirement. As a result, the number of new pilots who enter a squadron each year, the number of sorties that can be flown each month (determined by the utilization rate [UTE rate] of aircraft in the unit), the squadron experience level (i.e., the percentage of assigned line pilots who are experienced), and other factors all affect how rapidly pilots can become experienced, how many FLs and instructors can be produced, and how much continuation training can be accomplished.³

Understanding the capacity of a flying squadron to accomplish different types of training has recently become more important for two reasons. First, due to a shortage, the Air Force aimed to increase its annual production of fighter pilots, from 150 in FY 2010 to 260 in FY 2018.⁴ The Air Force needs to understand the potential impact of this increase on a squadron’s ability to accomplish its training. Second, Section 351 of the FY 2017 NDAA directs the Secretary of the Air Force to conduct a review and assessment of the assumptions underlying the annual continuation training requirements of the Air Force and the overall effectiveness of the RAP. The Air Force needs to understand the ability of a fighter squadron to accomplish RAP training requirements under different conditions to address this directive.

³ The UTE rates used throughout this document are adapted from available maintenance data and represent the sorties that are *actually flown* by the squadron. This differs from *scheduled* UTE rates, which are decremented by sortie attrition.

⁴ Annual production figures are based on Air Education and Training Command Guidance Letter allocations, which were compiled and provided by the Air Force Total Force Aircrew Management office.

To examine whether flying units can feasibly meet the RAP continuation training requirements under various circumstances, we created a computational model of three fighter squadrons that composed an operations group (OG). The model incorporates details about the upgrade training requirements and the RAP continuation training requirements shared by the squadrons, along with their temporary duty assignments (TDYs) and deployment schedules within the squadron’s area of responsibility (AOR). The model also incorporates detail about the inflow of first-tour and follow-on tour (“*n*th-tour”) pilots into the squadron. We use the model in two ways:

1. **Baseline dynamics.** We use the model to examine the squadrons’ abilities to complete live and simulator upgrade training and live and simulator continuation training against a backdrop of frequent TDYs and deployments. The baseline case is structured around current unit manning levels and accessions from formal training units (FTUs).
2. **Policy excursions.** After establishing the baseline dynamics of the squadrons, given current manning levels and accessions, we use the model to conduct prospective computational simulations. We examine the squadrons’ ability to complete training and to absorb new pilots given increased Basic Course (B-Course) production, varied aircraft UTE, and changes in the definition of an “experienced” pilot.

The results of the baseline simulations underscore the demands placed on combat units. Under optimistic assumptions about sortie generation capacity, squadron manning levels, and the availability of experienced *n*th-tour pilots, squadrons still have difficulty completing all live and simulator training requirements. Aside from highlighting issues related to the *quantity* of training completed (i.e., number of sorties or hours completed), the simulations call into question the *quality* of training (i.e., pilot roles, mission types, conditions).⁵ In the baseline case, more than 60 percent of home station sorties are dedicated to upgrade training. Thus, less than half of home station training involves “true” continuation training—that is, sorties flown only for the purpose of practice and improvement of skills and not as part of a formal upgrade program.⁶ Finally, the simulation shows that even a small increase in B-Course production without a corresponding increase in aircraft UTE rates will exceed units’ capacities to absorb new pilots.⁷

⁵ By quality of training, we mean the ability of the squadron to support the distribution of the mission types required by the RAP. See Chapter 3 of Ausink et al., 2018.

⁶ This includes sorties dedicated to Red air support, which provide less effective training.

⁷ We call this “breaking” a squadron and define the term later.

2. Models of Fighter Pilot Absorption Capacity

Absorption is the process of accepting new fighter B-Course graduates into fighter units and turning these graduates into experienced fighter pilots.¹ The concept of absorption is multifaceted and involves acquiring the skills and experience needed to perform well in subsequent flying and nonflying assignments. The Air Force has historically assumed that a pilot will have acquired the requisite skills once he or she acquires the equivalent of 500 flying hours in his or her primary fighter.²

The work described in this report builds on past efforts to create and use mathematical models to examine the capacity of combat units to absorb pilots.³ Those models established the role of key parameters in determining a squadron's absorption capacity. The first class of parameters is related to a squadron's *training capacity*—i.e., the pool of sorties that the unit can generate and dedicate to training. The second class of parameters is related to a squadron's *composition*—i.e., the squadron's manning level and the percentage of experienced and inexperienced Aircrew Position Indicator (API)–1 pilots assigned.⁴ The final class of parameters is related to fighter B-Course FTU *production* and the accompanying change in the number of inexperienced pilots arriving at a squadron annually.

Dynamic models of pilot absorption revealed the sensitivity of the aircrew management enterprise to small changes in these parameters. For example, a small increase in B-Course production could increase unit manning levels and lengthen the time to experience (TTE). These

¹ Air Force Instruction (AFI) 11-412, *Aircrew Management*, Washington, D.C., December 10, 2009, paragraph 3.1.

² The historical experience definition adjusted the primary fighter flying hour requirement to 300 hours for pilots with a total of 1,000 hours in Air Force aircraft (these are normally first-assignment IPs [FAIPs], who had a previous tour as undergraduate pilot training [UPT] instructors) and 100 hours for pilots who were previously experienced in another Air Force fighter. In 2006, an Air Force Smart Operations for the 21st Century initiative proposed that simulator training hours could account for up to 20 percent of the total hours required to meet the experience threshold (see AFI 11-2F-16, *F-16 Pilot Training*, Vol. 1, Washington, D.C., U.S. Air Force, April 20, 2015, paragraph 1.5.5). In February 2018, however, the Air Force introduced new definitions of “experience” for fighter pilots based on the fact that pilots may accumulate significant flying hours during deployments that focus only on secondary mission tasking, thus limiting the training. We will use the model to examine potential consequences of this change later in this report.

³ William W. Taylor, S. Craig Moore, and C. Robert Roll, Jr., *The Air Force Pilot Shortage: A Crisis for Operational Units?* Santa Monica, Calif.: RAND Corporation, MR-1204-AF, 2000; William W. Taylor, James H. Bigelow, S. Craig Moore, Leslie Wickman, Brent Thomas, and Richard Marken, *Absorbing Air Force Fighter Pilots: Parameters, Problems, and Policy Options*, Santa Monica, Calif.: RAND Corporation, MR-1550-AF, 2002; and William W. Taylor, James H. Bigelow, and John A. Ausink, *Fighter Drawdown Dynamics: Effects on Aircrew Inventories*, Santa Monica, Calif.: RAND Corporation, MG-855-AF, 2009.

⁴ A squadron's line or primary mission pilots are designated *API-1 pilots*, and supervisory pilots and overhead staff are designated *API-6 pilots*.

changes subsequently affected the squadron's composition by decreasing the percentage of experienced API-1 pilots. The ratio of experienced API-1 pilots to the total number of assigned API-1 pilots is called the squadron's "experience level." Once the percentage of experienced pilots falls below a critical threshold, the squadron will no longer be able to distribute sorties uniformly to all assigned pilots, leading to situations in which inexperienced pilots fly less than they need to and experienced pilots fly more than necessary to provide in-flight supervision to increasing numbers of inexperienced wingmen (WMs).⁵ Policy alternatives to avoid (or halt) such a "death spiral" include increasing squadrons' training capacity (i.e., flying hours) or limiting B-Course production.

Existing models of pilot absorption are specified at a level of abstraction needed to study the fighter pilot inventory from a *longitudinal* point of view (i.e., following each cohort of pilots throughout their careers) and from a *cross-sectional* point of view (i.e., across the entire inventory of Air Force pilots at a single point in time). The current modeling effort focuses on the training and absorption dynamics within a set of squadrons that compose an OG. Such a focus was necessary to address questions related to the desired allocation of sorties between upgrade and continuation training and the actual allocation possible given the squadrons' resources. The current model deviates from existing dynamic models in the following ways:

- In addition to accounting for Combat Mission Ready (CMR) and Basic Mission Capable (BMC) pilots, the model tracks WMs, FLs, and IPs.⁶ This accounts for the needs of pilots undergoing upgrade training and the availability of pilots to lead and support upgrade training.
- To calculate the desired monthly allocation of sorties between upgrade and continuation training, this model schedules and tracks activity associated with upgrades, continuation training, and simulator training.
- To understand how training is affected by exercises and deployments, the model includes TDYs and deployments, with their different associated flying activities.

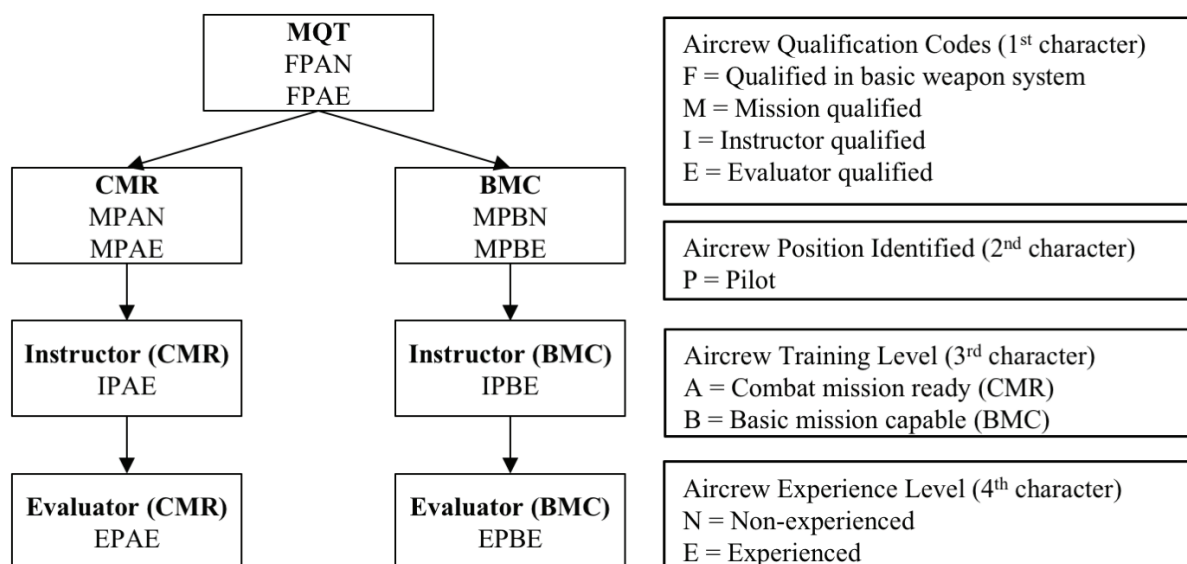
Background Definitions of Squadron Composition

In this model, we considered squadron composition in terms of flight authorization duty codes. Figure 2.1 shows these codes and how they relate to one another.

⁵ Taylor, Moore, and Roll, 2000, found that this problem began in fighter squadrons when the unit experience level fell below 55–60 percent.

⁶ All inexperienced pilots will normally be API-1 CMR pilots. In unusual circumstances, such as a unit conversion from one fighter aircraft to another (e.g., F-16 to F-35), some BMC API-6 pilots may be technically considered as inexperienced for brief periods. Units also have evaluator pilots and mission commanders. The model does not include these designations because neither requires additional upgrade sorties in the 20th OG training syllabus, which the model is based on (20th OG Commander, *20th OG Training Syllabus*, Shaw Air Force Base, N.C., December 14, 2017).

Figure 2.1. Flight Authorization Duty Codes



SOURCE: AFI 11-401, *Aviation Management: Flying Operations*, Washington, D.C.: U.S. Air Force, December 10, 2010.

Upon arriving at the squadron, pilots are enrolled in mission qualification training (MQT). Pilots whose primary job is performing wing supervision or staff functions that directly support the flying operation are generally in positions that require them to maintain only BMC status. BMC pilots accomplish continuation training that maintains familiarization with all, and proficiency in some, of the primary missions of their unit.⁷ Following the right-hand branch of Figure 2.1, an experienced mission-qualified pilot who maintains BMC status after MQT will have a duty code of “MPBE.”

CMR positions require that a pilot be qualified and proficient in all of the primary missions of his or her unit; following the left-hand branch of Figure 2.1, an experienced mission-qualified pilot who maintains CMR status after MQT will have a duty code of MPAE.

Historically, by accumulating flying hours, pilots progress from being inexperienced to experienced.⁸ By completing upgrade training syllabi, they may progress from mission qualified to FL to instructor status.

Two additional elements of squadron composition are not captured in flight authorization duty codes. First, the Air Force describes a squadron’s authorized manning in terms of API. The two APIs relevant for our purposes are API-1 and API-6. A squadron’s line, or primary mission,

⁷ AFI 11-2F-16, 2015, paragraph 1.4.4.

⁸ Forthcoming editions of the AFI 11-2 Mission Design Series, Vol. 1, publications for fourth-generation fighters will incorporate a new definition for experienced pilots, based on number of sorties flown and completion of FL upgrade training.

pilots are designated API-1 pilots.⁹ A squadron's supervisory pilots and overhead staff are designated API-6 pilots. These designations are not reflected in flight authorization duty codes. However, the majority of API-6 pilots are assigned to BMC status; a small number are assigned to CMR status. In contrast, all API-1 pilots are assigned to CMR status. Second, flight authorization duty codes also do not reflect whether a pilot is a WM or a four-ship flight lead (FL), an additional qualification gained after completing MQT but before completing instructor pilot upgrade training (IPUG).¹⁰

Overview of Model

Many specifications in our model were based on training documents and historical training data gathered from three F-16 Block 50 Fighter Squadrons (FSs) in the 20th Fighter Wing (FW) at Shaw Air Force Base: the 55th FS, the 77th FS, and the 79th FS. We relied on four primary data sources.

The first data source was the 20th OG training syllabus, which specifies upgrade training requirements associated with MQT (completed when a pilot first arrives at the squadron), FL upgrade training (FLUG) (completed before a pilot can lead a formation), and IPUG (completed before a pilot can instruct other upgrade pilots).¹¹

The second data source was the F-16CM Blk 50/52 RAP Tasking Message (RTM), which specifies the number of sorties and simulator missions (officially referred to as Mission Training Center [MTC] missions) that pilots must complete on a monthly, quarterly, and annual basis as part of continuation training.¹² Together, these two documents establish the flight training that must be accomplished throughout the year. The upgrade training can only be accomplished during home station operations.

The third data source was compiled information on crew compositions and training accomplished by squadrons in the 20th FW during FY 2016–2017.¹³ The fourth key data source was compiled information about sortie generation by squadrons in the 20th FW during FY 2016–2017.¹⁴ Together, these two spreadsheets established the personnel available to complete training and the squadrons' sortie generation capability.

⁹ The number of API-1 authorizations by squadron is set by multiplying crew ratio by the unit's primary mission aircraft inventory (PMAI), although squadrons can be overmanned or undermanned, depending on the number assigned.

¹⁰ The current inability to differentiate WM or a four-ship FL in Air Force Aviation Resource Management Program (ARMS) or in any automated system hinders proper management of this important qualification. It appears that a data field for these designations is possible.

¹¹ 20th OG Commander, 2017.

¹² Air Combat Command, Flight Operations Division, "Memorandum for F-16CM Block 50/52 Operations Group Commanders," April 2017.

¹³ Data provided by the 20th Operations Support Squadron.

¹⁴ Data provided by the 20th Aircraft Maintenance Squadron.

Based on these data sources, our model most directly corresponds to the training and absorption dynamics of the 20th FW. With only minor changes, however, the model can be extended to other F-16 squadrons and to other fighter aircraft mission-design series.

The model simulated the flying activities of three FSs in a wing. The squadrons operated independently except for when one squadron was deployed, during which time its nondeployed pilots were temporarily attached to sister squadrons. This is illustrated in Figure 2.2, which shows pilots assigned to each squadron with solid arrows and nondeployed pilots attached to other squadrons with dotted arrows. For example, the 55th FS deployed for six months in year 1, after which the majority of its pilots (represented by the thick black line) remained at home station. During the deployment, nondeployed pilots from the 55th FS (represented by the dotted black lines) were temporarily attached to the 77th and the 79th FSs.¹⁵

Figure 2.2. Organizational Dimension of the Fighter Squadrons in an Operational Group



NOTE: Solid arrows show pilots assigned to each squadron; dotted arrows show nondeployable pilots temporarily attached to squadrons during deployments.

The model simulated the sequence of activities that occurred in each squadron on a monthly basis, such as receiving new pilots, scheduling upgrade and continuation training, completing training, and updating pilots' certifications. Simulation results were generated and recorded for individual pilots in the squadrons on a monthly basis. Thus, the simulation could be used to study the cross-sectional composition of the squadrons in each month or to track pilots longitudinally across months during their time with the squadron.

The model was implemented as a set of conditional statements and run as a stochastic simulation using MATLAB.¹⁶ Sources of uncertainty in the model included the squadrons' starting compositions, pilots' arrival times, *n*th-tour pilots' previous qualifications, and the timing of pilots' enrollments into upgrade training. Including stochastic elements allowed us to quantify the ranges of outcomes possible given these realistic sources of uncertainty.

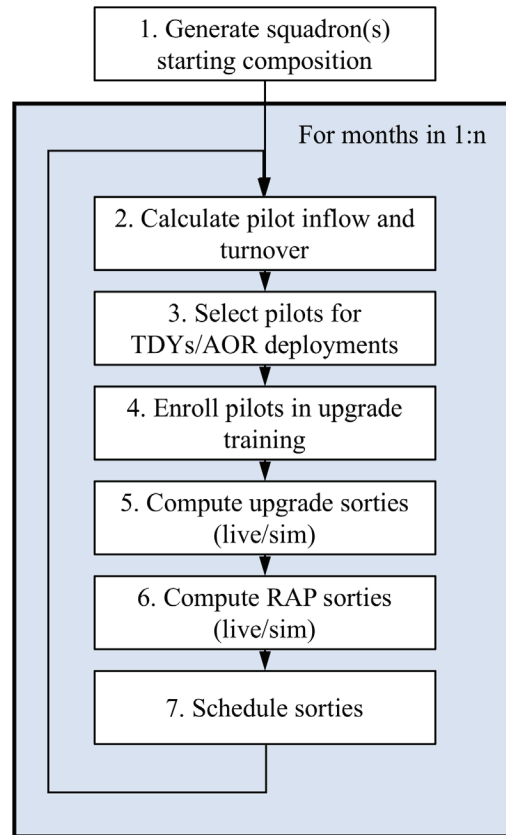
¹⁵ Pilots deploying to an AOR must be CMR or BMC, so most mission qualified pilots assigned to a squadron will deploy. Therefore, the majority of assigned pilots that do not deploy will not have completed MQT, but some mission-qualified pilots may remain at home station under extenuating circumstances.

¹⁶ MATLAB and Statistics Toolbox Release, The MathWorks, Inc., Natick, Massachusetts, 2012.

Model Implementation

The model consists of seven subroutines, shown in Figure 2.3, which we describe in turn.

Figure 2.3. Temporal Dimension Denoting Sequence of Events Completed on a Monthly Basis



NOTE: Live/sim = live/simulated.

1. Generate Squadron Starting Composition

Table 2.1 shows the number of crew members by flight authorization duty code averaged across the 55th, 77th, and 79th FSs during FY 2016 and FY 2017. Certain flight authorization duty codes are not represented in the table because some combinations of aircrew qualification and experience level are rare or nonexistent (e.g., instructors who are inexperienced), as are some combinations of training level and experience level (e.g., inexperienced pilots assigned to BMC status). The experience definition in the data, and in our baseline model, is based on number of hours completed. In a subsequent excursion, we modify the experience definition to reflect number of sorties completed.

Additional data contained in the 20th FW spreadsheets indicated that squadrons included an average of 31 API-1 pilots and nine API-6 pilots.¹⁷ Flight authorization duty codes do not reflect whether a pilot is a WM or an FL, a qualification gained after completing MQT but before completing IPUG.

Table 2.1. Observed and Simulated Squadron Composition by Flight Authorization Duty Code

Duty Code	Observed		Simulated
	FY 2016	FY 2017	
FPMN	5	3	4
MPAN	10	10	10
MPAE	7	9	8
MPBE	2	2	2
IPAE	6	6	6
IPBE	2	2	2
EPAE	6	5	5
EPBE	2	3	3
Total	40	40	40

NOTE: See Figure 2.1 for explanations of the duty codes.

At the start of each simulation, the model randomly drew 40 pilots for each squadron with the following flight authorization duty codes: FPMN, MPAN, MPAE, MPBE, IPAE, IPBE, EPAE, and EPBE. Duty codes were sampled in proportion to their observed frequencies in the 20th FW during FY 2016 and FY 2017, producing the mean number of pilots by flight authorization duty code reported in the “Simulated” column of Table 2.1. Thus, the mean number of pilots by duty position across 1,000 simulations reflected the observed distributions, but the actual numbers during each simulation varied. Each squadron supported 31 API-1 billets and nine API-6 billets. API-6 billets were assigned first to pilots in BMC status, and any remaining API-6 billets were assigned to experienced pilots in CMR status. At the onset of the simulation, all experienced pilots were also designated as FLs. This is a simplifying assumption

¹⁷API-1 crew ratios are directed in AFI 65-503, *U.S. Air Force Cost and Planning Factors*, Washington, D.C.: U.S. Air Force, February 4, 1994, in Table A36-1. Given the squadrons’ PMAI of 24, the expected number of API-1 billets equals 30 (1.25 x 24). Thus, the squadrons were overmanned by one API-1 pilot on average. Each squadron also has two assigned API-6 pilots (i.e., the commander and operations officer) and other attached API-6 pilots assigned to the operations support squadron, OG, or wing.

because the empirical data do not distinguish between experienced WMs versus FLs—in the simulations reported later, pilots occasionally become FLs before reaching 500 hours, and they occasionally reach 500 hours before completing FLUG. Values for time on station (TOS) were generated for each pilot by randomly sampling from a uniform distribution ranging from one to 24 months for inexperienced pilots, and from 25 to 32 months for experienced pilots. Number of hours of live and simulator flights for first-tour pilots were proportional to TOS, meaning that experienced first-tour pilots had been in squadrons for longer than inexperienced ones. All n th-tour pilots had accumulated more than 500 hours before joining the squadron, in addition to the hours accumulated with the squadron.

2. Calculate Pilot Inflow and Turnover

Sources of pilot inflow were varied, as seen in Table 2.2. A mixture of first-tour and n th-tour pilots arrive to fill API-1 billets. Of the first-tour pilots, 90 percent arrive after completing UPT and FTU.¹⁸ The remaining 10 percent consist of FAIPs who, after completing UPT, served their first tour as IPs in UPT before attending FTU. All UPT and FAIP pilots complete approximately 80 hours in the F-16 at FTU before arriving at the operational unit. Those pilots who went directly to FTU after UPT must accumulate a total of 500 hours in their primary aircraft (20 percent of which may be in simulators) before they are designated as “experienced.” FAIPs are assumed to have completed 1,000 hours as IPs and are given some credit for their experience: They only need 300 hours in their primary aircraft (20 percent of which may be in simulators) to become experienced.¹⁹ FAIPs therefore tend to become experienced sooner than UPTs.

Of the n th-tour API-1 pilots arriving at the squadron, 10 percent were previously qualified as WMs, 60 percent were qualified as FLs, and 30 percent were qualified as IPs. These proportions are adjustable parameters in the model and were estimated based on data contained in the 20th FW crew composition sheets. Lastly, all API-6 pilots arriving at the squadron have completed at least one previous tour. Of those, 40 percent were previously qualified as FLs, and 60 percent were qualified as IPs.²⁰ The significance of n th-tour pilots’ previous qualifications is that they determine whether those pilots must complete abridged or full upgrade training programs upon arriving at the squadron, as detailed later.

¹⁸ These proportions are based on the assumption of 30 FAIPs per year in an annual distribution of approximately 250 B-Course graduates to the active component.

¹⁹ AFI 11-2F-16, 2015, paragraph 1.5.5. As a reminder, this definition of experience has recently changed.

²⁰ These proportions are model parameters that were estimated to yield the number of pilots by flight authorization duty code and qualification reported in the 20th FW spreadsheets.

Table 2.2. Pilot Inflow

API-1						
First tour		Nth tour			API-6 (Nth tour)	
UPT (90%)	FAIP (10%)	WM (10%)	FL (60%)	IP (30%)	FL (40%)	IP (60%)

In the model, first-tour pilots entered the squadron on a monthly basis, with the number of arrivals uniformly distributed across the year (estimates of the number and timing of first-tour arrivals could be refined using FTU distribution plans). *N*th-tour pilots entered the squadron at the start of four-month cycles spread three times across the year. To simplify matters, we assumed a constant tour length of two years and eight months (i.e., 32 months) for all pilots, regardless of tour number. Each pilot left the squadron upon reaching a TOS of 32 months.

3. Select Pilots for TDYs/AOR Deployments

Table 2.3 summarizes TDY and deployment parameters, which were based on recent experiences of squadrons from the 20th FW.²¹ Each squadron participates in about three exercises annually (e.g., Red Flag) during non-AOR deployment years. TDYs last for one month. In addition, each squadron completes a deployment once every three years. Deployments last for six months. Allowing time for travel, this equates to about one squadron in garrison, one squadron on TDY, and one squadron deployed per month.

Table 2.3. TDY and Deployment Parameters

Variable	TDY	AOR Deployment
Duration	1 month	6 months
Frequency	3x annually	1x every 3 years
% squadron	100% API-1	75% CMR/BMC
Average sortie duration (ASD)	1.5 hours	3.7 hours
UTE rate	13.0	15.4

All API-1 pilots attend TDYs, but pilots who have not yet completed MQT do not fly. These pilots attend exercises to gain experience in mission planning, mission briefing, and mission debriefing. Three-quarters of CMR and BMC pilots participate in deployments. Pilots who have not yet completed MQT do not deploy and, as shown in Figure 2.2, are temporarily attached to a sister squadron during deployments where they continue to train.

²¹ Data provided to RAND by the 20th OG.

Our analysis of FY 2017 UTE rate data revealed similar UTE rates during months when units were at home station and TDYs (13.0). ASD was slightly higher during TDYs than at home station (1.5 hours versus 1.4). The average UTE rate during deployments was higher (15.4), and the average ASD was longer (3.7 hours).

TDYs and deployments may disrupt upgrade and continuation training in four ways. First, pilots who have not completed MQT attend TDYs but do not fly, increasing the time to complete MQT. Second, pilots lack access to simulators during TDYs and deployments. Third, upgrade training only occurs while squadrons are in garrison. TDYs and deployments reduce the number of months available for upgrade training. This is exacerbated by the fact that squadrons must halt noncritical upgrade training prior to deployments. Fourth, although pilots accumulate many flying hours during deployments because of the longer ASD, they may only complete one or a small number of types of missions. The hours they accumulate may lack the diversity needed to develop them into truly “experienced” pilots.

The frequencies and durations of TDYs and deployments in our model, along with the corresponding flying activities, were based on the parameters reported in Table 2.3. During the month preceding a TDY or deployment, all noncritical upgrade training was completed (i.e., FLUG or IPUG), and no pilots began noncritical upgrades. During deployments, pilots who had not completed MQT were temporarily attached to sister squadrons where they continued to train.

4. Enroll Pilots in Upgrade Training

The 20th OG training syllabus outlines three formal training programs required to prepare and maintain pilots for combat operations and to meet all requirements for FLs and IPs that are described in RTMs. As described earlier, MQT must be completed as a prerequisite to training for CMR and BMC status. FLUG is designed for WMs who meet the minimum requirements in AFI 11-2F-16, Vol. 1, and who are nominated by their flight commander (FLT/CC). Upon completing FLUG, the pilot may act as a four-ship FL. Finally, IPUG is designed for FLs who meet the minimum requirements in AFI 11-2F-16, Vol.1, and who are nominated by their FLT/CC. Upon completing IPUG, the pilot may instruct all squadron missions. Table 2.4 contains the requirements to begin upgrades.

Table 2.4. AFI 11-2F-16, Vol. 1, Requirements for Upgrade Training

Program	Time to Complete	Minimum Requirements
MQT	90 days from arrival at squadron	B-Course completion
FLUG	90 days from initiation	WM and 300 hours F-16 ^a
IPUG	90 days from initiation	Four-ship FL and 500 hours F-16 ^b

^a Or 200 hours F-16 with 1,000 hours FAIP.

^b Or 400 hours F-16 with 1,000 hours FAIP.

With respect to initial qualification training, all pilots in the simulation began MQT upon arriving at the squadron. WMs reaching 300 hours were probabilistically enrolled in FLUG, and FLs reaching 500 hours were probabilistically enrolled in IPUG. The probability of a pilot beginning FLUG during each month after reaching 300, 350, 400, and 450 hours equaled 5 percent, 10 percent, 25 percent, and 50 percent, respectively. The probability of an FL beginning IPUG during each month after reaching 450 and 500 hours equaled 5 percent and 15 percent, respectively. These probabilities, which are adjustable parameters in the model, capture the fact that pilots must exceed hourly thresholds *and* be nominated by their FLT/CC to begin upgrades. Reports from the OG indicated that upgrades frequently began long after minimums were met.

In the model, enrollment into upgrade training was also influenced by the number of pilots currently completing upgrades and how far along each pilot was in his or her respective program. For example, the amount of upgrade training remaining for six pilots who had already completed half of their respective programs equaled the amount of upgrade training remaining for three pilots who had just begun upgrades. No more than six pilots with 100 percent upgrade training remaining were enrolled in FLUG or IPUG at once. Simulations showed that enrolling more pilots made it difficult to complete programs within the allocated three-month limits.

The 20th OG training syllabus states that pilots arriving from other operational F-16 assignments should regain FL status within 30 days and all other applicable qualifications within 60 days of arrival on station. Furthermore, the syllabus states that upgrade programs may be modified by squadron commanders to account for previous qualifications. Given that the modifications are not documented, and that they may vary by pilot, we treated the modified upgrade training programs as consisting of 50 percent of the full programs.

5. Compute Upgrade Sorties

The number of sorties required for upgrade training is determined in the model by the syllabus used by the 20th OG. Table 2.5 shows the 20th OG FLUG syllabus and the corresponding sortie and simulator resource requirements. Other syllabi exist for MQT and IPUG. All three upgrade programs include five or six simulator missions and 11 or 12 live missions. All missions include, at a minimum, the upgrade pilot and an IP. Most missions require many more pilots to provide direct support (for example, the IP in another aircraft), indirect support (for example, aircraft in another formation), and Red air support (i.e., adversary aircraft) to the upgrade pilot. The values in Table 2.5 are the numbers of pilots needed for each FLUG training mission. The upgrade flight lead (UFL) is included in the counts for MTC containers (simulator) and direct support (live). This means that only five of the 18 MTC missions correspond to the UFL, and only 12 of the 62 total sorties correspond to the UFL. The substantial number of additional pilots needed to support the UFL (about 4.7 additional pilots per FLUG mission) makes upgrades extremely resource intensive and may detract from a squadron's ability

to generate an adequate number of sorties to complete continuation training as well.²² Moreover, a considerable number of sorties are dedicated to Red air support—ten of 52 sorties for MQT and 12 of 62 for FLUG and IPUG. In other words, about 20 percent of upgrade sorties are dedicated to Red air.

Table 2.5. FLUG Syllabus Sortie and Simulator Resource Requirement

	Simulator Missions					Live Missions												Total
	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11	12	
FLUG																		
MTC containers	2	4	4	4	4													18
Direct support						2	2	2	2	4	4	4	8	4	4	4	2	42
Indirect support											2	2		2	2			8
Adversary									2	4		2		2	2			12
Sortie total																		62
MTC total																		18

The situation is complicated by the fact that pilots with the proper designations (IP, FL) must be available to support upgrade training. For instance, Live Mission 4 is a two-versus-two air combat maneuvering (ACM) sortie and requires two adversaries. The first two-ship consists of the UFL and an IP. The second two-ship consists of an FL (or IP) and a WM. All missions require an IP to fly on the wing of the UFL. Additionally, all missions with more than a two-ship require additional FLs (or IPs) and WMs.²³ MQT and IPUG generate similar requirements for IP, FL, and WM support.

We analyzed the aircraft required for all missions in MQT, FLUG, and IPUG to determine simulator and sortie requirements by aircrew designation. Table 2.6 shows the counts. This intermediate translation, from aircraft required to aircrew required, is necessary to determine whether there are enough qualified pilots in the squadron to support upgrade training and to schedule qualified pilots to the extent needed to support upgrade training.

²² The values are comparable for MQT (11 of the 52 sortie total and seven of the 14 MTC total correspond to the upgrade pilot) and IPUG (12 of the 62 sortie total and six of the 20 MTC total correspond to the upgrade pilot).

²³ The 20th OG syllabus states that MQT events may be flown in conjunction with IPUG events (but not FLUG events; 20th OG Commander, 2017). Our simulation includes a parameter to allow for MQT and IPUG events to occur concurrently, though the later results we report assume that the events occur separately.

Table 2.6. Sortie and Simulator Resource Requirement by Aircrew Designation

Upgrade	UP	IP	FL	WM	Total
MQT	11/7	11/7	15/2	15/2	52/18
FLUG	12/5	12/5	19/4	19/4	62/18
IPUG	12/6	12/6	19/4	19/4	62/20

NOTE: The numbers are presented as sortie requirement/simulator requirement. UP = upgrade pilot.

The values in Tables 2.5 and 2.6 are based on the minimum number of missions that upgrade pilots must complete. However, each syllabus event has standards of performance that the upgrade pilot must meet. As a result, some missions may need to be repeated because the standards of performance were not met. Additionally, some missions may need to be repeated due to unforeseen circumstances (e.g., weather) that make it impossible to complete the mission. In the model, we assumed a uniform 7 percent refly rate.²⁴

6. Compute RAP Sorties

The F-16CM Blk 50/52 RTM sets the numbers of live and simulator missions that pilots must complete on a monthly, quarterly, and annual basis as part of continuation training. Requirements depend on a pilot's mission status: CMR pilots must complete more training than BMC pilots. Requirements are also determined by pilot experience level: Inexperienced pilots must complete more continuation training than experienced pilots. Table 2.7 contains RAP counts by training status and experience level.

Table 2.7. Monthly F-16 Block 50-52 RAP Requirements

Status	Experience	Sortie	Simulator
BMC	Experienced	5	2
BMC	Inexperienced	6	2
CMR	Experienced	8	3
CMR	Inexperienced	9	3

As with upgrade training, continuation training can stress the squadrons' resources in two ways. First, the squadron must be able to generate enough monthly sorties to complete continuation training. Second, all pilots in the squadron who have not yet completed FLUG must

²⁴ A 7 percent refly rate is what was used in the 2015 syllabus for F-16 initial qualification training. See Air Education and Training Command, *AETC Syllabus F16C0B00PL (56 FW), F16C0TX0PL (56 FW), F16C0SOCPL (56 FW) F-16C/D Initial Qualification (56 FW), F-16C/D Requalification (56 FW), F-16C/D Specialized Qualification (56 FW)*, September 2015.

fly on the wing of an FL. In the simulation and in practice, this means that inexperienced pilots are typically paired with an experienced pilot for continuation training.

Many RAP sorties are dedicated to Red air support. The RTM allows RAP credit for 14 Red air sorties for CMR pilots and 12 for BMC pilots. These sorties arise, in part, from continuation training. The desired threat ratio for key mission types (e.g., offensive counterair, defensive counterair, suppression of enemy air defense) and basic skills (tactical intercepts and ACM) equals 1:1. This drives the requirement for many Red air sorties from within the squadron.

In the model, all live and simulator missions completed during upgrade training, with the exception of MQT missions completed by the upgrade pilot, count toward RAP.²⁵ Annual RAP requirements for a pilot arriving after the start of the year are prorated according to the time when MQT is complete.

7. Schedule Sorties

During months when a squadron is at home station, it must carefully allocate resources to accomplish upgrade and continuation training. As alluded to in the previous sections, there are two types of constraints that may prevent a squadron from accomplishing its required training.

The first type of constraint is materiel. Squadrons can only generate a finite number of sorties in a month. Given a PMAI of 24 airframes and a home station UTE rate of 13 sorties per airframe per month, squadrons could generate a maximum of 312 sorties per month. Squadrons also have a limited number of simulator periods available. The MTC used by 20th FW supports five simulator periods per day, with up to four pilots simultaneously participating in joint or separate missions. This amounts to about 400 simulator periods per month.

The second type of constraint is personnel. The number of IPs and FLs, combined with the maximum number of sorties per crew member per month (SCM), limit the number of upgrade missions that a squadron can complete. Relatedly, the number of FLs (and IPs) limits the number of RAP sorties that WMs can complete.

We included both types of constraints in the model. The number of live missions and simulator missions conducted during a single month at home station did not exceed the upper limits set by UTE rates and aircraft availability and by available simulator periods. The maximum SCM was controlled by an adjustable parameter in the model set to 14.²⁶

Resources were allocated first for upgrade training. When insufficient resources were available, (1) IPUG was scheduled before (2) MQT, which was scheduled before (3) FLUG. We

²⁵ 20th OG Commander, 2017.

²⁶ The F-16 RTM specifies a minimum one-month lookback of nine live sorties per month for inexperienced pilots in CMR status. That is, to maintain CMR status, an inexperienced pilot must have flown nine live sorties in the previous month. Given that this is the minimum, an experienced pilot completing 14 sorties per month in order to adequately support other pilots' upgrade and continuation training would constitute a suboptimal allocation of sorties.

settled on this order because of the necessary role of IPs in directing all other upgrades. The remaining resources were allocated for continuation training. Priority was given to pilots in CMR status over pilots in BMC status.²⁷ Within each status, priority was given to inexperienced pilots over experienced pilots.

The scheduling algorithm in the model distributed sorties equitably among pilots. For example, if two or more pilots were available to act as WMs to support an upgrade training mission, the pilot who had flown fewer sorties that month was given priority. If the pilots had flown the same number of sorties that month, the less experienced pilot was selected.

If, after all continuation and upgrade training for the current month is complete, and all continuation training not completed during earlier months in the year is complete, the scheduling algorithm will stop assigning sorties and simulator missions to pilots. This means that during some months (i.e., months when squadrons are undermanned), the squadron may accomplish fewer than the maximum number of sorties that it can generate.

²⁷ AFI 11-2F-16, 2015, paragraph 1.6.5.

3. Simulation Studies

We used the flow model to conduct three simulation studies to examine

- the ability of squadrons to complete upgrade and continuation training given current unit manning levels and accessions from the UPT pipeline
- the ability of squadrons to complete upgrade and continuation training given increased accessions from the UPT pipeline and varied UTE rates
- the impact of a new experience definition on absorption dynamics.

The flow model is stochastic. Each run produces slightly varying results. The averages we present are based on 100 or more runs of the model, with each run encompassing three squadrons and 72 months. All model parameters were set to values described in the earlier sections on model implementation except where otherwise noted.

Simulation 1: Baseline Case

Can squadrons complete upgrade and continuation training, and how will TDYs and deployments affect their ability to do so? To address these questions, we simulated a baseline scenario, based on actual information, where squadrons were slightly overmanned with the following pilots:

- 31 API-1s (versus 30 authorized)
- two CMR API-6s (as authorized).

Squadrons additionally supported

- one CMR API-6
- six BMC API-6 attached pilots.

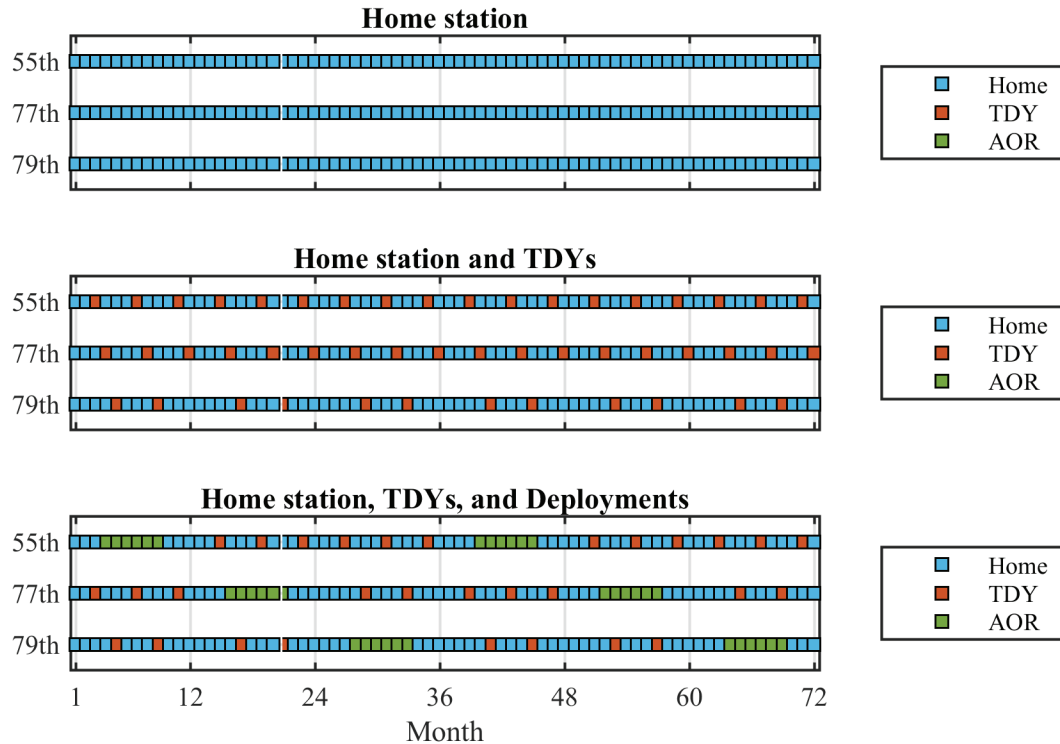
Standard UTE was set to 13, and six first-tour pilots arrived per squadron annually.¹

We considered three scenarios of increasing complexity, as shown in Figure 3.1:

- home station training alone
- home station training and TDYs
- home station training, TDYs, and deployments.

¹ To maintain manning of 40 pilots who serve 32-month tours, 15 new pilots must enter the squadron each year. Thus, in addition to the six first-tour pilots, nine n th-tour pilots enter each year. The model brings in 5.625 n th-tour API-1 pilots and 3.375 API-6 pilots annually, on average.

Figure 3.1. Squadron Schedules in Baseline Simulation



NOTE: Blue squares = months at home station; red squares = months on TDY; green squares = months on deployment.

Upgrade Training

Table 3.1 shows mean number of months to complete upgrade training in the three baseline cases. It also contains information about TTE for first-tour pilots and the percentage of pilots absorbed by the end of their first tour.²

Table 3.1. Time in Months to Complete Each Upgrade Training Level and to Become Experienced

	Home	TDY	TDY and Deploy
MQT	2.1	2.5	2.6
FLUG	2.1	2.1	2.5
IPUG	2.4	2.5	2.6
TTE	27.1	26.5	21.7
Absorbed by end of tour	96%	98%	99%

² TTE results exclude FAIPs, who become experienced more quickly than UPTs. Average TTE for FAIPs across the three baseline cases equaled 14.3 months, 14.6 months, and 13.2 months. However, FAIPs are included in the percentage of pilots absorbed by end of tour.

For the three scenarios examined, time to complete MQT, FLUG, and IPUG fell between two and three months. This meets the 20th OG training syllabus's requirement to complete upgrades within 90 days of beginning training. Time to complete MQT increased when TDYs were introduced (from 2.1 months to 2.5 months). This occurred because pilots who had not completed MQT attended TDYs, delaying MQT progress. Time to complete MQT increased slightly more when deployments were added. This was not a direct effect of deployments; pilots who were not yet mission qualified remained at home station during deployments and trained with sister squadrons, and so they were not prevented from completing MQT by the deployment. Deployments decreased the number of months at home station, however, concentrating more upgrades in the remaining months at home station. This reduced the number of sorties and qualified pilots available for each upgrade pilot and slowed the pace of all upgrades, including MQT. Time to complete FLUG increased when deployments were introduced. This occurred for two reasons. First, as was the case for MQT, deployments decreased the number of months at home station, concentrating more upgrades into the remaining months. This reduced the resources available to each upgrade pilot and slowed the pace of all upgrades. Second, ASD was more than twice as long during deployments than at home station (3.7 versus 1.5 hours). Given the substantial number of flying hours accumulated during deployments, many WMs had exceeded the minimum requirements to begin FLUG by the time they returned. Enrolling the backlog of eligible WM in FLUG further reduced the number of sorties and qualified pilots available for each upgrade pilot.

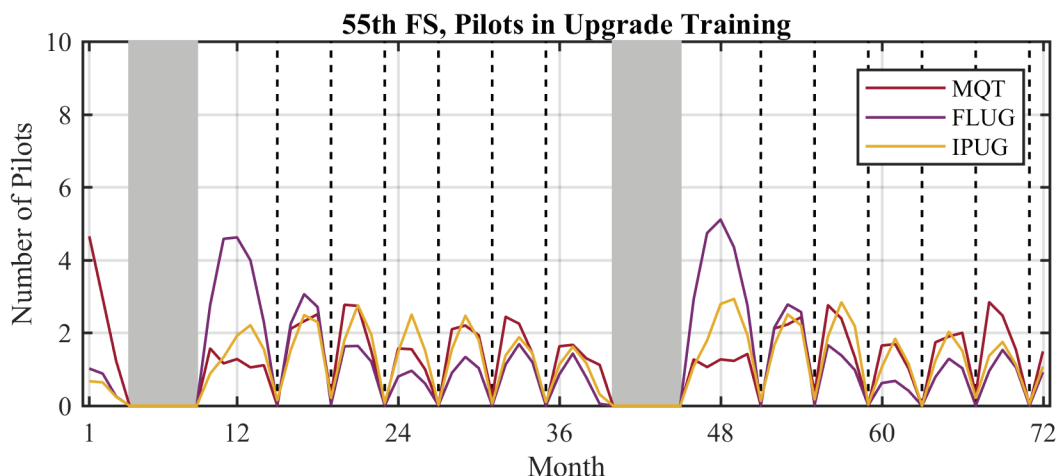
The accumulation of WMs who became eligible for FLUG while deployed and the subsequent bow wave of upgrade training after deployments can be seen in the number of upgrade pilots during each month. Figure 3.2 shows the number of UPs in one squadron, with deployments marked by gray windows. The purple curve, which corresponds to FLUGs, peaked immediately following deployments and dropped as UPs completed training. In addition, the number of pilots in upgrade training dropped to near zero every four months. These dips coincided with periods when the unit was on TDY and reflects the fact that the scheduler in the simulation prioritizes completing upgrades prior to TDYs.

TTE and the percentage of pilots absorbed by the end of the first tour was only slightly reduced by the addition of TDYs to home station training (Table 3.1) because of the slightly higher SCM and ASD during TDYs versus home station. TTE decreased and the percentage of pilots absorbed increased dramatically when deployments were added to the simulation. This was caused by the twofold increase in ASD during deployments. In terms of flying hours, each month deployed was worth more than two months at home station.

As a result of the reduced TTE in the deployment case, the percentage of experienced API-1 pilots in the squadron sustained and even increased (Figure 3.3). The cyclical nature of experience level arose from the deployment schedule (Figure 3.2), with the percentage of experienced pilots peaking after each deployment. The slight increases in percentage of

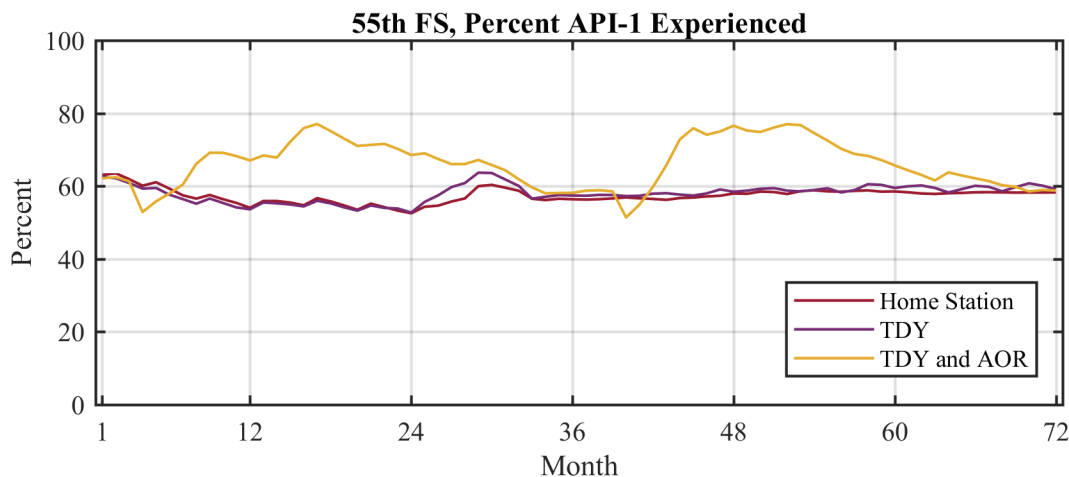
experienced pilots every four months reflects the arrival of experienced n th-tour pilots to the squadron.

Figure 3.2. Number of Pilots in MQT, FLUG, and IPUG in the 55th Fighter Squadron by Month



NOTE: Line colors correspond to simulations with home station training, TDYs, and TDYs and AOR deployments. Gray bars mark months when the unit is deployed, and dashed vertical lines mark months when the unit is on TDY.

Figure 3.3. Percentage of Experienced API-1 Pilots in the 55th Fighter Squadron by Month



NOTE: Line colors correspond to simulations with home station training, TDYs, and TDYs and AOR deployments.

Continuation Training

The previous set of results pertain to upgrade training. We also examined continuation training, calculating RAP completion across pilots, squadrons, and months. RAP credit was given for live and simulator training completed at home station, and for live sorties during TDYs and deployments. Table 3.2 contains the mean number of live and simulator missions completed on a monthly basis by pilot training status and experience level. In simulations without

deployments, CMR pilots failed to meet the RAP one-month lookbacks for live training. Given the PMAI and home station UTE rates used in the model, squadrons could not, on average, generate and fly enough sorties to meet RAP minimums.³ The number of sorties completed increased when TDYs and deployments were introduced because of the slightly higher UTE rates during TDYs and deployments. However, the number of simulator missions completed decreased because squadrons did not have access to the MTC during TDYs and deployments. In addition, although pilots logged increased sorties during deployments, the mixture of sorties were suboptimal from a training perspective because they lacked the variety called for in the RTM. Although deployments may have allowed pilots to meet RAP volume requirements, they could prohibit them from meeting the mixture of RAP mission requirements.

Table 3.2. Monthly RAP Completion Sorties

Status	Experience	Home (live/simulator)	TDY (live/simulator)	TDY and Deploy (live/simulator)	RAP 1-Month Lookback (live/simulator)
BMC	Experienced	5.2/2.0	5.3/2.0	6.5/1.8	5/2
BMC	Inexperienced	—	—	—	—
CMR	Experienced	7.5/2.9	7.9/2.7	8.3/2.5	8/3
CMR	Inexperienced	8.5/3.0	8.7/2.7	9.2/2.5	9/3

We calculated the volume of training dedicated to upgrades and to RAP when squadrons were in garrison. Upgrade training counts toward RAP, but for the purposes of this analysis, we treated the two types of activities separately. Doing so allowed us to calculate the amount of “pure” continuation training. Table 3.3 shows the cumulative number of live and simulator missions completed on a monthly basis when squadrons were at home station. The maximum number of sorties possible each month given the squadrons’ PMAI and UTE rate was 312.⁴ In the simulation that only included home station training (Home), about 50 percent of sorties were allocated solely to continuation training. Adding TDYs decreased the number of home station sorties allocated to continuation training to about 45 percent, and adding deployments further

³ This is problematic given that the UTE rates were based on actual data from maintainers in the 20th FW.

⁴ A simplifying assumption in the simulation is that units seek to complete the pro-rata share of RAP sorties on a monthly basis; if all upgrade training is complete, along with the pro-rata share of RAP sorties up to and including that month of the year, the simulation stops scheduling sorties. As a result, the simulation occasionally scheduled fewer sorties than the maximum number possible given the squadrons’ primary aircraft assigned and UTE rate. This had no discernible effect on the simulation results, since, in nearly every month, units logged the maximum number of sorties possible given their primary aircraft assigned and UTE rate and their experience ratio.

reduced the number of sorties allocated to continuation training to 34 percent.⁵ Reducing the number of months at home station forced squadrons to prioritize upgrades during those months, leaving fewer sorties for “pure” continuation training. Exacerbating matters, the desired 1:1 threat ratio for key mission types means that many RAP sorties are dedicated to Red air, reducing the value of continuation training for pilots assigned adversary roles.

Table 3.3. Monthly Total Home Station Sorties Dedicated to Upgrade and Continuation Training

Medium	Type	Home	TDY	TDY and Deployment
Live	Upgrade	147	167	199
	RAP	161	140	107
	Total	308	307	306
Simulator	Upgrade	44	48	54
	RAP	74	87	96
	Total	121	135	150

In addition to shifting the balance from continuation to upgrade training, TDYs and deployments increased the number of simulator missions completed during months at home station. To meet RAP minimums, pilots needed to compensate for lack of access to simulators during TDYs and deployments by increasing simulator usage during months at home station. However, as seen in Table 3.2, they were still unable to complete the RAP simulator requirement minimums.

Base Case Summary

The base case simulations show that under an optimistic assumption about aircraft UTE rate, squadrons can complete upgrade and continuation training, and pilots in their first tour can complete the sorties required to become experienced. Pilots become experienced more quickly with deployments because of the longer sortie durations they entail. This comes at the expense of an increased emphasis on upgrade training during months at home station and a corresponding decrease in “pure” continuation training during those months.

⁵ Some upgrade training events may be flown together. For example, the 20th OG training syllabus states that MQT sorties may be flown in conjunction with IPUG events, but not with FLUG events (20th OG Commander, 2017). We re-ran the simulation allowing for 50 percent of MQT and IPUG events in the same month to be flown concurrently, reducing the total number of direct and indirect sorties needed for upgrade training. This slightly reduced time to complete MQT, FLUG, or IPUG (2.5 months, 2.3 months, and 2.4 months), but did not affect TTE (21.8 months). Completing MQT and IPUG events concurrently also slightly reduced the total number of sorties allocated to upgrade training from 199 to 187.

Simulation 2: Increased B-Course Production

If the capacity of the UPT pipeline and B-Course increase, squadrons' ability to absorb pilots may begin to limit production of experienced pilots. An excessive inflow of newly assigned pilots can overwhelm a squadron's ability to train them. Once the squadron's absorption capacity is exceeded, TTE increases, fewer pilots become experienced in their first tour, and the unit's experience level drops.⁶ To avoid these outcomes, it is necessary to explore the implications of changing UPT output and to identify ways to increase a squadron's capacity to absorb new pilots.

We used the flow model to simulate the impact of two factors on absorption, each of which was set at three different levels:

- annual B-Course arrivals per squadron at six, eight, and ten
- home station UTE rates of 11, 13, and 15.

In these simulations, the numbers of *n*th-tour API-1 pilots and API-6 pilots entering the squadron annually remained constant, to try to maintain an adequate supply of experienced pilots.⁷ The arrival of increasing numbers of B-Course graduates produced a corresponding increase in unit manning levels. The increase in B-Course graduates was entirely produced by pilots arriving from the UPT, with no corresponding increase in FAIPs. We fully crossed annual B-Course arrivals and home station UTE rate to simulate nine possible cases. This allowed us to test whether increasing the UTE rate would allow squadrons to handle increased UPT production. To simplify matters, we did not include TDYs and deployments in the simulation. With the exception of varying annual B-Course arrivals and home station UTE, all other simulation parameters were identical to the baseline case.

Table 3.4 contains measures of squadron composition in the nine different cases (the baseline simulation used a UTE rate of 13 and six annual B-Course arrivals). The first measure (Inexperienced-to-Experienced) denotes the number of pilots per squadron absorbed annually. The number of B-Course arrivals and UTE had interactive effects on the number of pilots absorbed annually. Increasing B-Course arrivals *decreased* the number of pilots absorbed when the UTE rate was low (i.e., UTE = 11 or 13). When the UTE rate was high (i.e., UTE = 15), squadrons could accommodate a slight increase in the number of B-Course arrivals (i.e., they could absorb seven pilots annually given eight B-Course arrivals), but not a large increase (i.e., they could only absorb *four* pilots annually given ten B-Course arrivals). As the number of B-Course arrivals increases, more sorties are needed to support the greater number of pilots. If the UTE rate does not increase sufficiently, each pilot will receive a smaller proportion of the unit's

⁶ Taylor, Moore, and Roll, 2000; Taylor et al., 2002; Taylor, Bigelow, and Ausink, 2009.

⁷ This could easily become an optimistic assumption if the current shortage of fighter pilots continues to worsen. The supply of *n*th tour pilots could diminish to the point that they are not available in adequate numbers to meet the corresponding requirements for experienced API-1s and API-6s in operational units.

monthly sorties, TTE will increase, and fewer pilots will be absorbed. To maximize absorption, and to ensure that an adequate number of FLs and IPs are generated, the UTE rate must increase proportionally with the number of new arrivals.

Table 3.4. Squadron Absorption and Composition Given Different UTE Rates and Number of B-Course Arrivals

Factor		Measure			Crew Position			Sorties	
UTE	B-Course	Inexperienced-to-Experienced (#)	API-1 Experienced (%)	Manning (%)	WM	FL	IP	Upgrade	Continuation
11	6	3	51	102	15	7	17	136	128
11	8	2	44	113	19	7	17	140	124
11	10	1	40	123	23	7	17	145	118
13	6	6	55	102	14	8	17	146	161
13	8	4	46	113	18	7	17	150	161
13	10	2	40	123	23	7	16	153	159
15	6	6	58	102	14	8	17	151	171
15	8	7	51	113	18	8	17	161	189
15	10	4	42	123	22	8	17	163	193

NOTE: Green = healthy squadron; yellow = stressed squadron; pink = broken squadron.

In seven of nine cases shown in Table 3.4, the number of pilots absorbed annually was less than the number of B-Course arrivals. This produced a gradual net gain of inexperienced pilots. As the number of inexperienced pilots increased, the percentage of experienced API-1 pilots decreased. This was true when the number of B-Course arrivals exceeded six or when the UTE rate was less than 13.

We use the following terms to describe the health of fighter units:

- **healthy:** manning level of 100 percent with about 60 percent of API-1 pilots experienced
- **stressed:** manning level of 105 to 110 percent with about 45 percent of API-1 pilots experienced
- **broken:** manning level exceeding 120 percent with less than 40 percent of API-1 pilots experienced.⁸

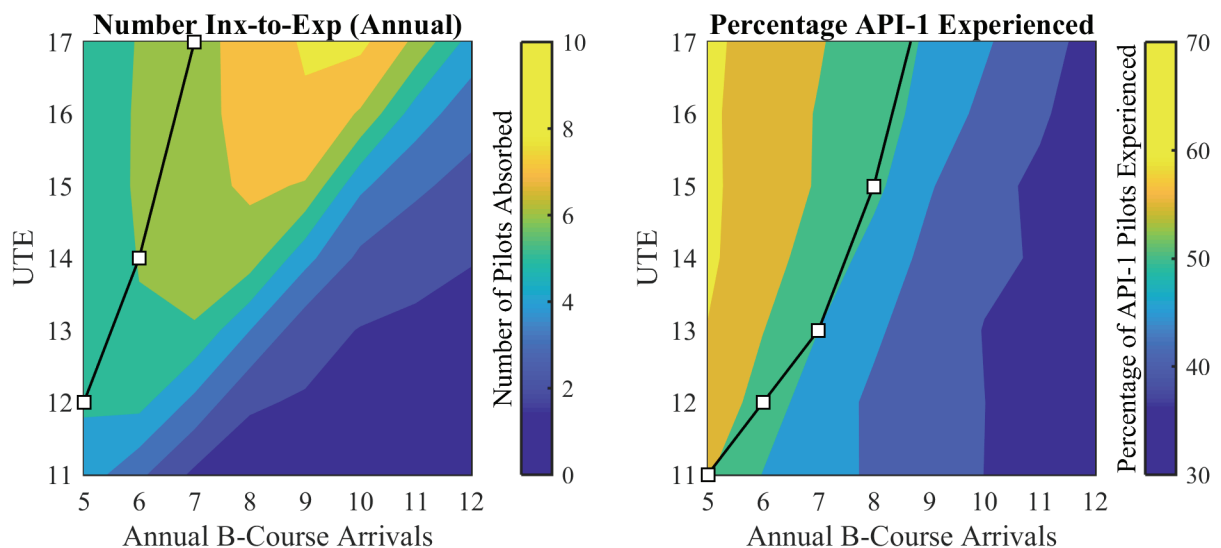
We found that increasing B-Course arrivals stressed and broke units, even if the UTE rate was increased, which indicates that increasing UTE only partially addresses the challenges associated with increasing new arrivals.

Figure 3.4 shows interpolated values for two key measures from these simulations—number of inexperienced pilots absorbed annually and percentage of experienced API-1 pilots. For the percentage of experienced API-1 pilots to remain constant, the number of pilots absorbed

⁸ These terms were first defined in Taylor, Bigelow, and Ausink, 2009.

annually must equal the number of B-Course arrivals (assuming squadron manning remains constant). Otherwise, the percentage of inexperienced pilots will gradually increase. Figure 3.4 (left panel) shows that for a given number of B-Course arrivals, the number of pilots absorbed annually increases with UTE. For example, in the left panel, when annual B-Course arrivals are nine, as the UTE rate increases along the vertical axis the color changes in the figure indicate that the number of pilots absorbed increases from close to zero (deep purple at the bottom) to between eight and ten (yellow at the top of the figure). For a given UTE, if the number of B-Course arrivals becomes too great, the number of pilots absorbed annually decreases. For example, at the top of the left panel of Figure 3.4 when the UTE is 17, annual absorption increases from around five (aqua) to ten (yellow) as annual arrivals increase from five to ten, but then decreases to around four (blue) as annual arrivals increase further to 12. The black line demarcates the boundary along which the number of pilots absorbed annually equals the number of B-Course arrivals. The UTE needed to absorb enough pilots annually increases steeply with the number of B-Course arrivals; a UTE of 14 is needed given six B-Course arrivals, and a UTE of 17 is needed given seven arrivals. Figure 3.4 (right panel) reveals the impact of these absorption dynamics on the percentage of experienced pilots. The black line demarcates when the percentage of experienced pilots equals 50 percent. The UTE rate needed to maintain this experience percentage increases sharply with number of B-Course arrivals.

Figure 3.4. Number of Inexperienced Pilots Absorbed Annually (left) and Percentage of Experienced API-1 Pilots (right)



NOTE: The black line in the left panel shows when the number of pilots absorbed annually equals the number of B-Course arrivals. The line in the right panel shows when the percentage of experienced pilots equals 50 percent.

We divided sorties by combat qualification (CMR/BMC) and experience level to examine how changes in B-Course arrivals and UTE rate affect home station training (Table 3.5). As the

number of B-Course arrivals increased, inexperienced SCM decreased. This occurred for two reasons: (1) There were too few sorties available for pilots, and (2) there were too few experienced pilots available to accompany inexperienced pilots.⁹ As a result, experienced pilots needed to fly more often, further reducing the number of sorties available to inexperienced pilots. This is reflected in the fact that experienced SCM often increased with the number of B-Course arrivals.

These simulations reveal that absorption results from the baseline case depend on assumptions about aircraft UTE rates and number of B-Course arrivals. A modest decrease in the UTE rate or a modest increase in number of B-Course arrivals is enough to stress and even break squadrons. To prevent this, the total number of B-Course arrivals must be carefully managed, and a unit's UTE rate must increase as it receives increasing numbers of B-Course graduates.¹⁰ Relatedly, UTE must be increased to allow inexperienced and experienced pilots to meet RAP one-month lookbacks. As the number of B-Course arrivals increases, RAP shortfalls will become even more pronounced for inexperienced pilots.

Table 3.5. Training Completed by Squadron Given Different UTE Rates and Number of B-Course Arrivals

Factor		Measure		
UTE	B-Course	Inexperienced SCM	Experienced SCM (CMR)	Experienced SCM (BMC)
11	6	7.1	6.5	4.8
11	8	5.8	6.1	5.2
11	10	4.8	6.0	5.4
13	6	8.6	7.5	5.2
13	8	7.2	7.0	5.7
13	10	6.0	7.0	6.1
15	6	9.0	7.9	5.3
15	8	8.6	7.8	5.7
15	10	7.2	7.7	6.6

⁹ More precisely, there were too few IPs and FLs to support pilots completing MQT and inexperienced pilots completing continuation training.

¹⁰ A key notion here is that total B-Course production increases must be accompanied with increasing total absorption capacities throughout the operational fighter fleet. For individual units, this reduces to increasing unit UTE rates, but other options are also available. For example, further developing and exploiting the Active Associate program would allow additional Air Force pilots to be absorbed in operational Guard and Reserve units. Another alternative is to increase fighter force structure so that more units become available to absorb new pilots as B-Course capacity increases. These options, however, are not addressed in our training model, which examines potential problems for existing units as the flow of B-Course arrivals increases.

Simulation 3: Alternate Experience Definition

Forthcoming editions of the AFI 11-2 Mission Design Series, Vol. 1, publications for fourth-generation fighters will incorporate a new definition for experienced pilots. According to the new definition, designation as an experienced pilot will require the following for FTU B-Course graduates: four-ship FL certification and 250 F-16 flying sorties. This differs from the old definition in several key ways:

- The new definition is based on number of sorties completed rather than number of hours accumulated. Given an average home station ASD of 1.5, 250 sorties equal 375 hours. This is fewer hours than the number previously required. However, as the baseline simulation showed, the longer ASD during deployments allows pilots to reach the minimum number of hours in far fewer sorties. Adopting a sortie-count-based system will eliminate the benefits of the greater ASD during deployments.
- The new definition does not include simulator usage. Simulator time accounted for 60 to 100 hours in the previous definition.
- The new definition does not distinguish between FAIPs and UPTs. As the baseline simulation showed, FAIPs reached the minimum number of hours about one year before UPTs.
- The new definition requires four-ship FL certification. In the baseline simulation, a small number of pilots may have become experienced without completing FLUG.

To examine whether the new definition increased or decreased average time to become experienced, we ran the flow model using the new experience definition. To make the differences between the old and new definitions most salient, we included TDYs and deployments in the simulations. All other simulation parameters were identical to the baseline case.

Table 3.6 shows time to complete upgrade training, time to become experienced, and percentage of first-tour pilots becoming experienced under the old and new definitions.¹¹ Initially, we held the criteria for enrollment into FLUG constant when comparing the definitions (“Current FLUG Entry”). Given an average of 9.2 sorties per inexperienced pilot per month (Table 3.2), it would take about 21 months to accumulate 250 sorties (including 56 completed during the FTU B-Course). The actual value shown in Table 3.6 is longer because pilots must also complete FLUG prior to becoming experienced.¹² This suggests that absorption will be slowed by the new experience definition. Furthermore, these values do not include FAIPs. As

¹¹ As in Table 3.1, TTE excludes FAIPs who, given the old experience definition, became experienced more quickly. Percentage of pilots absorbed by end of tour includes FAIPs.

¹² To separate the effects of the two factors, number of sorties and FLUG completion, we conducted a simulation that excluded the FLUG requirement from the experience definition. This reduced TTE from 25.6 to 23.0 months, and this increased the percentage of pilots experienced by the end of first tour from 81 percent to 99 percent. Although FLUG completion may be logical step toward becoming experienced, it may seriously extend the absorption process.

seen in the baseline simulation, FAIPs became experienced about a year sooner than UPTs, after 13.2 months. Given the new definition, TTE would be the same for FAIPs and UPTs.

Given the new definition, nearly 20 percent of the pilots did not become experienced during their first tour. This was because of the new requirement to be a four-ship FL. We examined whether accelerating entry into FLUG could rectify this problem (“Accelerated FLUG Entry”). Specifically, we doubled the probability that WMs with more than 300 hours would begin FLUG each month. This had two effects. First, it increased the percentage of pilots who became experienced during their first tour by about 10 percent. This was still lower than the percentage of pilots absorbed given the old definition. Second, it increased time to complete all upgrade training programs. This was caused by the increased number of pilots completing FLUG and competing for IP resources needed for the other upgrade programs.

These simulations show that the new experience definition may reduce absorption. Although the time to complete 250 sorties may be less than the time to accumulate 500 hours, the additional requirement to complete FLUG presents a new bottleneck. Currently, pilots must complete 300 hours before beginning FLUG, and FLUG may take up to three months to complete. To maintain absorption capacity given the new experience definition, pilots must begin FLUG earlier and/or complete FLUG more quickly.

Table 3.6. Time in Months to Complete Upgrade Training and Become Experienced

	Old Definition	New Definition	
	Current FLUG Entry	Current FLUG Entry	Accelerated FLUG Entry
MQT	2.6	2.5	2.8
FLUG	2.5	2.4	2.8
IPUG	2.6	2.6	2.9
TTE	21.7	25.6	25.3
Absorbed by end of tour	99%	81%	89%

4. Discussion

Aircrew management is a complex enterprise. In addition to continuation training, flying squadrons must accomplish other types of training: New pilots must be trained to perform a unit's assigned mission, inexperienced pilots must fly enough to become experienced, and pilots must undergo upgrade training to become FLs, IPs, and mission commanders. In other words, units must train to maintain proficiency for the present while also training to develop proficiency and sustain the unit's operations for the future—all while completing frequent TDYs and deployments.

To ensure that pilots maintain proficiency and improve their ability to perform a unit's assigned mission, the Air Force needs to understand the potential impact of numerous factors on the unit's ability to accomplish its training. The computational model described in this report shows the impact of policy changes on squadron manning, squadron experience levels, the time required for a pilot to become experienced, and the sorties available to accomplish continuation training. In turn, understanding this impact provides insight into the effect of policy changes related to pilot training.

We used the model to simulate squadron absorption dynamics, upgrade training completion, and continuation training completion under varying assumptions. The results of the simulation studies are informative about both the expected quantity of training completed by squadrons and the distribution of sorties between upgrade and continuation training.

Simulation 1 showed that, given realistic UTE rates and FTU production, units may absorb the majority of first-tour pilots and complete upgrade training within the allocated time. However, squadrons only met annual RAP sortie requirements by completing frequent TDYs and deployments, without which CMR pilots fell short of RAP minimums by about 0.5 sorties per month. The elevated UTE rate during deployments allowed squadrons to complete enough sorties to meet RAP minimums, but at the cost of falling short of simulator requirements by about 0.5 missions per month. Given the squadrons' starting compositions in the simulation, the number of sorties needed to meet RAP one-month lookbacks in an average month equals 313, which corresponds to a UTE rate of 13. However, sortie demand is not uniform across the year (demand may increase if the squadron is briefly overmanned, or if the experience ratio briefly decreases), and a UTE rate of 13 does not allow a squadron to accommodate any spike in demand. Additionally, MQT sorties completed by upgrade pilots do not count toward RAP. To effectively handle increases in training demand, and to deal with the real-world constraints that impact flight crew training, UTE must exceed the minimum value dictated by squadron composition by about 5 to 10 percent.

Simulation 2 showed that squadrons are in a precarious position: Given even a modest increase in B-Course arrivals or a modest decrease in UTE, time to experience increases,

triggering a cascade of negative outcomes. The number of pilots absorbed annually decreases, reducing the squadron's experience level. The resulting imbalance forces a disproportionate number of sorties to be expended on experienced pilots because they primarily make up the pool of IPs and FLs required to fly with inexperienced pilots. SCM for experienced pilots increases relative to inexperienced pilots, which is problematic because inexperienced pilots need more sorties to maintain skills and become experienced.

There are several alternatives for increasing pilot production and absorption.¹ One alternative was to increase UTE along with FTU production. Simulation 2 showed that increasing UTE from 13 to 15 nearly allowed squadrons to accommodate an increase in FTU production from six to eight pilots. However, manning level increased with FTU production in our simulations. If manning level was held constant, for example by shortening TOS for first-tour pilots, an even higher UTE would be needed to create experience pilots before they left the squadron. Additionally, the squadron would need enough experienced pilots to support the greater number of sorties required per month for first-tour pilots. In order to absorb pilots, squadrons must be able to generate enough sorties, and they must have enough IPs and FLs.

The Air Force recently changed the definition of "experience" for fighter pilots from one that depended only on the number of hours flown to one that includes the number of sorties flown and other qualifications, partly to prevent pilots from being designated as experienced after deployments during which they flew a limited number of very long sorties. Simulation 3 showed that this new experience definition actually increased TTE primarily because of the added requirement that pilots become a four-ship FL before being considered experienced. Additionally, if the definition causes an increase in the number of WMs relative to FLs, FLs may need to complete a disproportionate number of sorties to support WMs.

One capability of this model that differs from earlier RAND models is that it accounts for types of flying activities (i.e., continuation training, upgrade training, deployed sorties). For example, the results of our simulations showed that when a squadron is at home station, about 47 percent of sorties are flown by pilots who are either in upgrade training or pilots who are supporting an upgrade syllabus mission (e.g., the IP flying on the wing of an MQT pilot).² This leaves about half of the squadron's monthly sorties available for "pure" continuation training. TDYs and deployments further affect the composition of home station training: With less time at home to accomplish upgrade training, more home station sorties must be devoted to accomplishing upgrades (54 percent and 65 percent in the cases of TDYs and deployments, respectively). The reduced number of monthly sorties available for "pure" continuation training

¹ See Taylor, Bigelow, and Ausink, 2009, and A. A. Robbert, A. D. Rosello, C. R. Anderegg, J. A., Ausink, J. H. Bigelow, W. W. Taylor, and J. Pita, *Reducing Air Force Fighter Pilot Shortages*, Santa Monica, Calif.: RAND Corporation, RR-1113-AF, 2015, for lists of alternatives.

² Roughly 4.5 supporting pilots are needed for every upgrade syllabus mission. Therefore, about 80 percent of the sorties involved in upgrade training are supporting sorties.

is especially problematic in the case of deployments, because pilots may fly one or a small number of missions repeatedly when deployed. Thus, even when squadrons complete the quantity of training required, the quality may be suboptimal from the perspective of developing and maintaining proficiency.³

The model's capability to represent and track different types of training means that it can be used to help aircrew schedulers determine how many sorties are available for "pure" continuation training and to plan that training accordingly. The model also represents and tracks pilots' experience levels, their aircrew qualification codes, and whether they are FLs. These variables are needed to determine the amount of upgrade training that can occur in a given month. Therefore, the model can be extended to predict the optimal blend of experienced and inexperienced pilots in a squadron, as well as the optimal blend of IPs, FLs, and WMs. Finally, the model can be used to assess the efficiency and effectiveness of aircrew scheduling by comparing actual absorption and upgrade completion rates with those predicted by the model. If actual rates fall below rates predicted by the model, there may be ways to improve scheduling (or to increase the fidelity of the model to account for additional operational constraints).

Modest changes to the flow of incoming pilots, to squadron absorption capacity, and to experience definitions can have substantial consequences that are hard to anticipate and hard to correct. Modeling and simulation tools, such as the flow model described here, can provide advanced insight into the outcomes of proposed changes in order to support policy decisions and implementation.

³ By quality, we mean the ability to complete the distribution of mission types required by the RAP, which is meant to allow pilots to maintain proficiency.

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