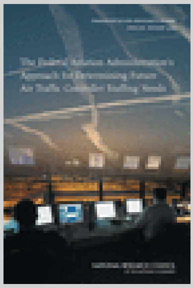

Transportation Research Board Special Report 314: Federal Aviation Administration's Approach for Determining Future Air Traffic Controller Staffing Needs

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Committee for Study of Federal Aviation Administration Air Traffic Controller Staffing; Transportation Research Board; Board on Human-Systems Integration; Division of Behavioral and Social Sciences and Education

TRANSPORTATION RESEARCH BOARD
SPECIAL REPORT 314

The Federal Aviation Administration's Approach for Determining Future Air Traffic Controller Staffing Needs

Committee for a Study of Federal Aviation Administration
Air Traffic Controller Staffing,
Transportation Research Board

Board on Human-Systems Integration,
Division of Behavioral and Social Sciences and Education

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Summary: "TRB Special Report 314, The Federal Aviation Administration's Approach for Determining Future Air Traffic Controller Staffing Needs, examines the methods used by the Federal Aviation Administration (FAA) to estimate how many controllers are needed to staff its air traffic control facilities and FAA's processes for using these estimates to properly distribute controllers across facilities. According to the report, FAA's models for determining air traffic controller staffing needs are suitable for developing initial estimates of the number of controllers required at terminal areas and airport towers, but the models used for the centers controlling aircraft en route between airports can be improved. In addition, as a matter of priority, the FAA should collaborate with the National Air Traffic Controllers Association to develop and implement an enhanced tool for all facilities that is capable of creating efficient controller work schedules that incorporate fatigue mitigation strategies. The report recommends that the FAA analyze a wide range of data, such as accident and incident reports and voluntary reports by controllers, to identify relationships between staffing and safety. In addition, the controller workforce should be involved in staffing decisions, particularly as knowledge emerges about relevant safety issues. The report also says that FAA should ensure that staffing continue to be appropriate as FAA implements the new air traffic operations environment associated with the Next Generation Transportation System, a modernization initiative to shift air traffic management from ground-based radar to a satellite system" —Provided by publisher.

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Preface

Section 608 of the Federal Aviation Administration (FAA) Modernization and Reform Act of 2012 (P.L. 112-95) required the National Academy of Sciences to study "the air traffic controller standards used by the [FAA] to estimate staffing needs for FAA air traffic controllers to ensure the safe operation of the national airspace system [NAS] in the most cost effective manner." The project "shall consult with the exclusive bargaining representative of employees of the FAA certified under section 7111 of title 5, United States Code, and other interested parties, including Government and industry representatives." The complete study charge is provided in more detail in Chapter 1.

In addition to the present study, the act tasked the National Research Council (NRC) with conducting two further studies related to the NAS:

1. An examination of the assumptions and methods that FAA uses in estimating the number of airway transportation system specialists needed to maintain and certify the equipment in the NAS, and
2. An examination of the Next Generation Air Transportation System's enterprise software development approach and safety and human factor design.

A report on the first item (NRC 2013) and a preliminary report on the second item (NRC 2014) have been issued.

The request for the present study originates in the National Air Traffic Controllers Association's (NATCA's) interest in having a robust, science-based method for determining the appropriate staffing at individual air traffic control (ATC) facilities. FAA's estimates show many facilities staffed at levels at or above the high end of their estimated staffing range, even though some such facilities require mandatory overtime to manage traffic adequately. NATCA had urged Congress to adopt a requirement for a third-party assessment of appropriate staffing at individual facilities. However, after consultation with congressional staff, the request that emerged from the House–Senate conference focused on the appropriateness of FAA's overall staffing forecast and the most cost-effective approach to staffing that does not compromise safety.

This study examines the methods used by FAA to estimate how many controllers are needed to staff its ATC facilities and the processes used to staff facilities consistent with these estimates. The committee's investigation of FAA's staffing process was complicated by the lack of adequate documentation of much of this process. The committee was heavily dependent on FAA to provide details of its staffing process through in-person briefings, teleconferences, and e-mail correspondence. In a number of instances, FAA staff members were asked to check the accuracy of the committee's factual summaries of what it learned. Thus, the report includes a large number of personal communications (teleconferences with FAA staff, small group meetings at FAA, and questions answered through e-mail) rather than references to published papers, conference proceedings, and the like.

As used throughout the report, the term "staffing standards" is defined narrowly by FAA to mean mathematical models used to relate controller workload and air traffic activity. Hence, these staffing standards, sometimes referred to as staffing models, constitute only one part of the larger process whereby FAA determines air traffic controller staffing levels. Consistent with clarification and guidance from congressional staff, the committee took a broader approach and considered the processes that FAA uses to model the number of controllers it needs and to adjust the modeled output on the basis of the judgment of facility managers and others, as well as the numbers of controllers actually added to the workforce and transferred among facilities.

Appointed by NRC, the study committee consists of 12 academicians, consultants, and current and retired air traffic controllers. Members have expertise in ATC and management, human factors, aviation safety, fatigue and sleep research, workforce planning, staffing models, aviation demand and management, public policy, economics, and budgeting. Biographical information concerning the committee members appears at the end of the report.

The full committee met five times between January 2013 and January 2014; at these meetings, it received briefings from FAA and other organizations, including Airlines for America (A4A), Airservices Australia, and the United Kingdom's National Air Traffic Services (NATS). Over the same period, small groups of committee members also met (in person or by teleconference) with FAA staff on more than 20 occasions to discuss details of the agency's controller staffing process. Despite these efforts to gather information from FAA, the committee had difficulty in obtaining clear and consistent descriptions of the staffing process and in establishing that the process steps are applied consistently.

As part of the committee's information-gathering activities, members visited several of FAA's ATC facilities (the Atlanta, Potomac, and Seattle Terminal Radar Approach Control facilities and the Atlanta Center), as well as the Delta Air Lines Operations Center in Atlanta. A committee subgroup met with representatives of the National Transportation Safety Board to discuss controller fatigue issues. To help inform comparisons between controller staffing processes used by FAA and by organizations in other countries, the committee obtained white papers from air navigation service providers (ANSPs) in Australia, Canada, Germany, and the United Kingdom describing their approaches to controller workforce planning. As part of this benchmarking effort, a subgroup of the committee held a conference call with Ralph Riedle, former Managing Director of Operations at Deutsche Flugsicherung (DFS) in Germany.

ACKNOWLEDGMENTS

The committee thanks the many organizations and individuals that contributed to the study through formal presentations, correspondence, telephone calls, and informal discussions. The participation of the following individuals in the committee's information-gathering activities is gratefully acknowledged: Rich McCormick, Tim Arel, Heather Biblow, Steve Bradford, Glen Buchanan, Gene Burdick, David Burkholder, Carl Burrus, Arthur Furnia, Todd Hoot, Rick Huss, Gretchen Koch-Noble, Stephen Lloyd, Darendia McCauley, Mike McCormick, Elliott McLaughlin, Finlay Mungall, Lynn Ray, Roger Schaufele, Nan Shellabarger, Joseph Teixeira, Dan Williams, and Mike Williams, FAA; Eugene Freedman, Dean Iacopelli, and Jeff Richards, NATCA; Greg Tennille, MITRE Corporation; Frank Danielski and Matthew Hampton, U.S. Department of Transportation Office of

Inspector General; Dan Allen, FedEx (member, A4A ATC Council); Kevin Brathwaite and Richard McCormack, Grant Thornton; Jessica Clevenger, Georgia Institute of Technology; Kate Bleckley, Dana Broach, Cristina Byrne, Jerry Crutchfield, Linda Pierce, and Kevin Williams, Civil Aerospace Medical Institute; Kelly Krokos, American Institutes for Research; Ralph Riedle, DFS (retired); and Dan Bartlett, National Transportation Safety Board.

The committee thanks all those who organized and hosted its visits to FAA's ATC facilities and to the Delta Air Lines Operations Center. Thanks go also to the authors of the ANSP white papers—Jason Harfield and Rodd Sciortino of Airservices Australia, Sid Koslow of Nav Canada, Nanda Hoefel of DFS, and Jonathan Astill and colleagues of NATS. The committee is particularly grateful to Jason Harfield, Rodd Sciortino, and Jonathan Astill, who gave generously of their time in traveling to and participating in the third committee meeting in July 2013 and responding to follow-up questions.

This study was performed under the overall supervision of Stephen R. Godwin, Director, Studies and Special Programs, Transportation Research Board. The committee gratefully acknowledges the work and support of Jill Wilson, study director, and Mark S. Hutchins in facilitating information-gathering activities and assisting the committee in the preparation of its report. The committee also acknowledges Karen Febey, who managed the review process; Norman Solomon, who edited the report; Janet M. McNaughton, who handled the editorial production; Juanita Green, who managed the production; Jennifer J. Weeks, who prepared the manuscript for prepublication web posting; and Javy Awan, Director of Publications, under whose supervision the report was prepared for publication. Thanks go to Amelia Mathis for arranging meetings and providing administrative support to the committee.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The

review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The committee thanks the following individuals for their review of this report: Colin Drury, State University of New York (emeritus), Buffalo; Antonio Elias, Orbital Sciences Corporation, Dulles, Virginia; John Fischer, Congressional Research Service (retired), and consultant, Annapolis, Maryland; Mark Hansen, University of California, Berkeley; Mark Harrison, University of California, Los Angeles; Paul Hogan, Lewin Group, Fairfax, Virginia; Melissa Mallis, M3Alertness Management, LLC, Courtdale, Pennsylvania; Michael Powderly, Airspace Solutions, Marietta, Georgia; and John Strong, College of William and Mary, Williamsburg, Virginia. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the committee's findings or recommendations, nor did they see the final draft of the report before its release. The review was overseen by National Academy of Sciences members Charles Manski, Northwestern University, and Susan Hanson, Clark University (emerita). Appointed by NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

—Amy R. Pritchett, *Chair*
Committee for a Study of
Federal Aviation Administration
Air Traffic Controller Staffing

REFERENCES

Abbreviation

NRC National Research Council

NRC. 2013. *Assessment of Staffing Needs of Systems Specialists in Aviation.* National Academies Press, Washington, D.C.

NRC. 2014. *Interim Report of a Review of the Next Generation Air Transportation System Enterprise Architecture, Software, Safety, and Human Factors.* National Academies Press, Washington, D.C.

Acronyms and Abbreviations

Acronyms and abbreviations used in the report are listed below.

A4A	Airlines for America
AATF	Airport and Airway Trust Fund
AIP	Airport Improvement Program
AIR21	Aviation Investment and Reform Act for the 21st Century
ALA	Office of Labor Analysis
ANSP	air navigation service provider
ARTCC	air route traffic control center
ASA	Airservices Australia
ASIAS	Aviation Safety Information Analysis and Sharing System
ASRS	Aviation Safety Reporting System
ATADS	Air Traffic Activity Data System
ATC	air traffic control
ATCT	airport traffic control tower
ATO	Air Traffic Organization
ATSAP	Air Traffic Safety Action Program
BTS	Bureau of Transportation Statistics
CAMI	Civil Aerospace Medical Institute
CANSO	Civil Air Navigation Services Organization
CBO	Congressional Budget Office
CEW	controller equivalent workforce
CFR	Code of Federal Regulations
CPC	certified professional controller
CPC-IT	certified professional controller in training
CWP	controller workforce plan

DFS	Deutsche Flugsicherung
DSFM	daily staffing forecast model
DSR	daily staffing requirements
ERAM	En Route Automation Modernization
ERR	employee request for reassignment
EVT	En Route Validation Tool
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FCT	Federal Contract Tower
FFT	field focus team
FRMS	Fatigue Risk Management System
FTE	full-time equivalent
FY	fiscal year
GA	general aviation
GAO	Government Accountability Office
GOMS	goals, operators, methods, and selection rules
HSI	human–systems integration
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NATS	National Air Traffic Services
NextGen	Next Generation Air Transportation System
NRC	National Research Council
NTSB	National Transportation Safety Board
OIG	Office of the Inspector General
OJT	on-the-job training
OMB	Office of Management and Budget
OPAS	Operational Planning and Scheduling
OPC	on-position controllers
OPD	optimized profile descent
PATCO	Professional Air Traffic Controllers Organization
PQC	position-qualified controller
PTT	positions to traffic
REDAC	Research, Engineering, and Development Advisory Committee

SCM	shift coverage model
SMS	safety management system
SUI	service unit input
TAF	Terminal Area Forecasts
TAF-M	Terminal Area Forecast Modernization
TARP	Traffic Analysis and Review Program
TRACON	terminal radar approach control
TRB	Transportation Research Board
TVT	Terminal Validation Tool
UAS	unmanned aircraft systems
USDOD	United States Department of Defense
USDOT	United States Department of Transportation
VFR	visual flight rules

Contents

Summary

The Federal Aviation Administration (FAA) faces four challenges in identifying the level of air traffic controller staffing needed to provide safe and cost-effective services for the diverse range of aviation operations supported in American airspace. First, there are no definitive methods available to FAA or to air traffic control (ATC) providers in other countries for relating staffing to safety or airspace performance beyond historical trends. Second, FAA is working with uncertain traffic forecasts, which have often overestimated future levels of air traffic. Third, controller training requires significant lead time. Most FAA trainees require between 1½ and 3 years of on-the-job training to qualify fully for all facility positions, and even certified controllers require at least a year to recertify when they are transferred to a new facility. Fourth, the controller workforce available within the next year can be uncertain. In 2014, for example, roughly 9.8 percent of the controller workforce is predicted to be lost because of trainees failing to qualify, promotions out of controller positions, and retirements. Indeed, 3,224 controllers (21 percent of the workforce) were eligible for retirement at the end of FY 2012. Thus, FAA recently increased the number of trainees, temporarily expanding the size of the workforce relative to traffic demand in anticipation of pending retirements.

FAA must address all the challenges identified above to ensure safe and cost-effective staffing, not only at the national level but also at each of its 315 facilities. Furthermore, it must ensure that staffing continues to be appropriate as it implements the new air traffic operations environment associated with its modernization initiative, the Next Generation Air Transportation System (NextGen).

In response to long-standing debates about appropriate controller staffing, Section 608 of the FAA Modernization and Reform Act of 2012

tasked the National Academy of Sciences with studying "the air traffic controller standards used by the [FAA] to estimate staffing needs for FAA air traffic controllers to ensure the safe operation of the national airspace system in the most cost effective manner." The term "staffing standards" is defined narrowly by FAA to mean mathematical models relating controller workload to air traffic activity (FAA 2013). These staffing standards, sometimes referred to as staffing models, are only one part of the larger process used by FAA in determining controller staffing levels. Consistent with clarification from congressional staff, the committee took a broader approach and considered the full range of processes that FAA uses in estimating the number of controllers it needs, including the input of facility managers as well as mathematical models, and the processes by which FAA ensures that controllers are properly distributed across facilities.

Overall, the committee found FAA's staffing standards for terminal ATC facilities to be reasonable for use in developing initial estimates of the number of controllers needed for managing traffic at each facility. However, it had concerns about the validity of the mathematical model used for en route facilities and the resulting estimates of controller staffing needs. The steps taken by FAA to create a controller staffing plan from the staffing standards and then execute this staffing plan are obscure. As a result, the committee was unable to determine the extent to which staffing imbalances are being corrected over time to help ensure cost-effective staffing.

SAFETY IN STAFFING

ATC is considered vital to the safety of aviation operations. However, the relationship between controller staffing levels and aviation safety is not well understood. Various FAA organizations gather data related to safety; examples include data on incidents violating various safety criteria without causing accidents, records of actual operations, and voluntary controller reports from the Air Traffic Safety Action Program. However, the committee found no systematic and proactive mechanisms within FAA for (*a*) analyzing these data for concerns relative to staffing levels or (*b*) involving the controller workforce in discussions about staffing concerns as knowledge about relevant safety issues emerges. Thus, FAA does not have the data to anticipate with any certainty the safety effects of changes in current controller staffing levels or changes in air traffic operations with NextGen.

Recommendation 1

FAA should explore the relationships between controller staffing and safety by

- **Analyzing the wide range of data that can identify relationships between staffing and safety, including accident and incident reports, voluntary reports by controllers from the Air Traffic Safety Action Program, and other databases that, if properly integrated, can relate safety to staffing concerns (e.g., records of actual shifts worked); and**
- **Involving the controller workforce in staffing decisions, particularly as knowledge concerning relevant safety issues emerges.**

FAA should use insights gained from these activities to inform decisions about controller staffing levels associated with the transition to NextGen and any other policies likely to result in changes in historically safe staffing levels. {2-5, 5-5}[1]

DETERMINATION OF WORKFORCE SIZE

The size of the controller workforce is based on three general steps: (*a*) point estimates derived from models, including forecasts of air traffic demand; (*b*) expansion of point estimates into ranges that incorporate input from facility managers; and (*c*) a hiring plan and transfer process that result in net changes to the total workforce and its distribution across FAA's 315 facilities.

The first step, point estimates for each of the facilities, is the output of the on-position staffing models. The models predict the number of controllers needed on position to perform traffic-related tasks, most notably, separating aircraft from one another. However, the models do

[1] The numbers in braces following the summary recommendations refer to related recommendations in the report chapters.

not explicitly account for a number of important off-position controller tasks, such as ongoing training to maintain certification, provision of training for new controllers, participation in safety initiatives, and support of new technology development and implementation.

In the committee's judgment, the models used to estimate controller staffing requirements for airport control towers and terminal radar approach control facilities are mostly reasonable for their purpose, with the exception of the current scheduling algorithm. However, in the case of the task load model for en route facilities, the committee shares the concerns of a predecessor committee, which focused exclusively on this model (TRB 2010). The 2010 report recommended actions to improve the model, but FAA[2] has taken only limited steps toward implementing these recommendations. Thus, the current committee cannot assess with confidence whether FAA's staffing model for en route facilities is on track to meet the recommendations of the 2010 report. The current committee had a broader charter than the authors of the 2010 report: to examine the entire staffing process as opposed to only the en route staffing model. In this context, the current committee questions whether the detailed task load model is appropriate for staff planning. The model's level of detail adds considerably to the cost and difficulty both of validating all of its parameters and of updating the model to describe the new types of operations envisioned under NextGen.

Because FAA "staffs to traffic," its staffing estimates are scaled by forecast changes in aviation traffic. FAA's traffic forecasts, at least since 2000, have consistently overestimated future levels of air traffic. The models applied by FAA are not sufficiently documented to explain or justify the overestimates. In practice, a high estimate one year can be followed by lower hiring the next year from a national perspective, but overstaffing can be created at individual facilities that do not experience enough attrition to correct any imbalance. Thus, overly optimistic traffic forecasts can have a lasting impact.

In the second step, the model-based staffing standards are combined with productivity data, where available, and with assessments of staffing

[2] The task load model for en route facilities was developed by MITRE Corporation under contract to FAA.

needs from operational managers to generate a desired staffing range for each facility. These ranges are reported to Congress annually in FAA's controller workforce plan. The input from operational managers, known as service unit input (SUI), is intended to reflect each facility's unique operational requirements. FAA's ongoing efforts to establish consistent methods for capturing SUI appear to address issues raised in an earlier report (TRB 1997). However, these methods have not been clearly documented and can appear arbitrary.

For the third step, the hiring of new controllers and the transfer of current controllers from one facility to another are FAA's primary mechanisms for adjusting staffing levels. The annual hiring plan for each facility is developed by FAA's Office of Labor Analysis and its Air Traffic Organization on the basis of staffing targets (derived from the staffing ranges) and operational and training constraints. As in the case of other elements of staff planning, this negotiation is not fully documented and can appear subjective. Requests for transfer are initiated by controllers themselves, and FAA management makes no attempt to encourage controllers to move from facilities staffed above their target to facilities staffed below their target. Not surprisingly, therefore, the committee finds that transfers appear to be poorly coordinated and do not achieve their potential of redistributing the workforce to meet facility targets.

Taken in its entirety, the staffing process by which FAA determines the total number of controllers can sometimes appear arbitrary, both to this committee and to the organizations and workforce that need to implement the staffing plan within FAA. This concern arises because staff planning is not consistently documented and because it can be modified by various organizations within FAA in uncoordinated ways. The model-based staffing standards themselves are clearly documented, but this is not the case for other parts of the process. In the committee's judgment, justification and consistent documentation and application of the methods used to determine the size of the controller workforce are critical for informed, data-driven decision making about staffing needs and hiring. Furthermore, the overall cost-effectiveness of FAA's controller staffing process depends not only on developing a robust staffing plan but also on FAA's ability to train and position these controllers appropriately at specific facilities. The body of the report offers several suggestions for enhancing the effectiveness of the training, hiring, and transfer processes.

Recommendation 2

FAA should reassess its approach to developing an improved staffing model for en route facilities and make any necessary changes, potentially including the adaptation or formulation of a new model likely to be developed and validated in a timely manner and at reasonable cost. Any new model should be constructed in such a way that it can be updated as NextGen operations are implemented. {3-2}

Recommendation 3

FAA should take steps to ensure that the planning and execution of its air traffic controller staffing process are clear, consistent, and transparent to a range of stakeholders. Stakeholders include but are not limited to the following:

- **The controller workforce, which needs to engage with FAA in the collaborative development of improved staffing plans and their execution to ensure overall cost-effectiveness; and**
- **Congress, which needs to make informed decisions about future budgets for controller staffing.** {3-3, 4-2, 4-3}

COST-EFFECTIVE AND SAFE SCHEDULING

Work schedules determine how many controllers report to a facility at any given time, when they take breaks, and how long a recuperative period they have between work shifts. Schedules can affect whether controller staff are used in a cost-effective manner, particularly at larger facilities, which can benefit from economies of scale. In addition, scheduling can affect safety. Extensive evidence shows fatigue to be a risk factor in 24/7 operations such as ATC facilities. Rare but widely publicized incidents of FAA controllers falling asleep on the job have highlighted the issue. FAA has begun establishing a Fatigue Risk Management System, including a working group involving controllers, management, and experts in fatigue. However, under recent budget cuts, FAA has effectively eliminated the Fatigue Risk Management System program's capability of monitoring for fatigue concerns proactively and of investigating whether recent initiatives to reduce fatigue risks are providing the intended benefits.

Air navigation service providers in other nations, including Canada, Germany, and Australia, have implemented new scheduling software. FAA uses only a simple scheduling algorithm at a national level in generating staffing standards. A major limitation of this algorithm is its inability to schedule shifts that start one day and end the next (i.e., that cross midnight). Given concerns about controller fatigue on midnight shifts, this limitation is particularly problematic, and the algorithm may generate staffing levels insufficient for adequate fatigue mitigation. In addition, FAA headquarters provides no consistent guidance or tools to local facilities to help them develop their operational schedules. As a result, each facility develops its own schedule independently of FAA's staff planning process. The actual controller schedules may not reflect key assumptions in the staff planning, may not be the most cost-effective, and may not incorporate best practices in fatigue risk management.

FAA is contracting with the same vendor used by air navigation service providers in other countries to implement a new scheduling tool, but the timeline of its implementation at all facilities is not fixed.[3] The following are among the potential benefits of sophisticated scheduling software:

- It would provide a consistent basis for establishing work schedules that minimize or mitigate the safety risks associated with controller fatigue.
- It would ensure that diverse facilities are all capable of generating efficient schedules, particularly at larger facilities where economies of scale may be possible.
- It would provide a consistent basis for informing the development of staffing standards at FAA headquarters and the creation of work schedules at the facility level.

Schedule changes significantly affect the controller workforce. FAA will, therefore, need to collaborate closely with the National Air Traffic

[3] FAA's target date for implementing the new scheduling tool at 15 facilities (the end of FY 2013) appears to have slipped.

Controllers Association in implementing an improved scheduling capability and in adopting revised schedules that address fatigue.

Recommendation 4

FAA should, as a matter of priority, continue its efforts to develop an improved scheduling tool capable of creating efficient controller work schedules that incorporate fatigue mitigation strategies. The agency should collaborate closely with the National Air Traffic Controllers Association in implementing this improved scheduling capability, notably in adopting schedules that reflect science-based strategies for managing the risks associated with controller fatigue. {2-3, 3-1, 4-9}

BUDGETS AND COST-EFFECTIVENESS

The cost of FAA's workforce of about 14,900 controllers in FY 2014 is estimated at $2.8 billion—about 18 percent of the total FAA budget and 29 percent of the Operations budget. FAA's capital expenses and some of its operating expenses are covered by the Airport and Airway Trust Fund. Over the past decade or more, the FAA Operations budget has required a substantial and growing amount of support from the General Fund—$4.4 billion in 2013, including $1.3 billion that helped to pay for the ATC workforce.

Congressional concerns about the cost-effectiveness of FAA's staffing models are driven, in part, by the growing cost of the ATC staff and the growing reliance of the FAA Operations budget on general revenues over the past decade. In a time of fiscal austerity and stalemate in Congress with regard to deficit budgets and taxes, continuing to depend on the General Fund makes FAA Operations vulnerable to budget cuts. Revised forecasts of rebounding aviation trust fund receipts by the Congressional Budget Office (CBO) in 2013 and the administration in 2014 imply that growing trust fund revenues will be able to reverse the demand for General Fund revenues. In contrast to the $4.4 billion of General Fund revenues received in FY 2013, the administration is requesting only $700 million for FY 2015. Whether the administration's and CBO's revised forecasts will hold is open to question. Both forecasts imply faster growth in aviation demand than in gross domestic product or in FAA's projected rate of increase in revenue passenger miles.

In case revised forecasts of aviation trust fund receipts prove optimistic and to help put concerns with regard to the cost of the ATC workforce in perspective, an illustrative example of a cut in ATC staffing of 8 percent is described in Chapter 6. Such a cut would reduce the cost of the ATC workforce by about $223 million, which represents about 1.4 percent of FAA's annual budget and 7 percent of the General Fund revenues used for FAA Operations in 2014. Such a cut in staffing would have unknown effects on aviation safety and service and should not, therefore, be taken as a suggestion.

Air traffic has declined significantly since its peak in 2000 and is not expected to return to that level in the near term (FAA 2013). Meanwhile, controller staffing levels are similar to those in 2000. However, the systemwide data do not indicate that all ATC facilities are overstaffed or that controller productivity has dropped dramatically in all facilities over the past 13 years. Indeed, detailed recommendations within the report address some important facilities that appear to be chronically understaffed. Comparisons of controller staffing over time are complicated by changes in the composition of the workforce—for example, the high percentage of controllers eligible to retire and the large number of trainees being brought in to replace them.

Furthermore, the volume and nature of traffic vary significantly among ATC facility types. For example, while almost all types of operations have been reduced since 2000, the decline in ATC operations has been particularly pronounced at smaller towers. Thus, broad generalizations about controller productivity mask important variations at the level of individual facilities. At some larger facilities, changes in staffing levels may affect the throughput of busy airspace and could result in direct costs or benefits to aircraft operators. In contrast, at smaller facilities, staffing levels may depend on minimum staffing requirements that are not driven by traffic levels but instead by the hours when the facility is required to provide service.

Defining the most cost-effective staffing model, as requested in the committee's charge, requires safety and performance metrics that FAA has not defined or assessed. Thus, the committee's recommendations presented in this summary and in the report aim to enable controller staffing decisions that are consistent; that are driven by proper science and data analysis; and that will address relationships between ensuring safety, meeting the operational needs of the aviation community, and demonstrating cost-effectiveness.

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Abbreviations

FAA	Federal Aviation Administration
TRB	Transportation Research Board

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1

Introduction

The National Airspace System (NAS) of the United States is dedicated to ensuring the safe, orderly, and expeditious flow of air traffic through the largest, most complex air navigation system in the world. The system encompasses a vast array of air navigation facilities, equipment, and services; airports or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures; technical information; and manpower and materials (FAA 2013a). Air traffic controllers are frontline operators in this system. They provide separation between aircraft operating under instrument flight rules (IFR) and a range of other safety functions to all types of aircraft and operations. This report examines the methods used by the Federal Aviation Administration (FAA) in estimating how many controllers are needed to staff its air traffic control (ATC) facilities and the processes used by FAA in staffing facilities consistent with these estimates. For context, as of the end of FY 2013 the FAA controller workforce totaled about 15,000, with a cost of approximately $2.8 billion (i.e., on the order of 20 percent of the total FAA budget).[1]

This chapter describes the job of an air traffic controller and notes how the demands on a controller vary across types of ATC facility and types of traffic. The challenges facing FAA as it seeks to establish safe and cost-effective staffing levels are discussed, and a high-level overview of the current staffing process is provided. The chapter concludes with discussion of the committee's task and an overview of the report's organization.

[1] Air traffic services for the NAS are also provided by 1,375 civilian contract controllers at contract towers and by more than 9,500 military controllers (FAA 2013b).

AIR TRAFFIC CONTROLLER FUNCTIONS AND FACILITIES

Air Traffic Controller Functions

Air traffic controllers are tasked with ensuring the safe and efficient flow of air traffic through the NAS at all times and under all conditions. The primary functions of air traffic controllers who are "on position" are to separate aircraft safely and issue safety alerts (FAA Order 7110.65). In addition, particularly at busy facilities, controllers' activities support not only safety through other support functions to pilots but also the efficient handling of traffic within the airspace to increase throughput, reduce delays, and increase operational efficiency (e.g., by allowing flight profiles that reduce fuel consumption). Controllers are required to perform a variety of ancillary functions outside their on-position activities, such as participating in mandatory training and Air Traffic Safety Action Program activities and supporting the development, evaluation, and implementation of new technologies and procedures. Fully qualified controllers [certified professional controllers (CPCs)] may provide on-the-job training for partially qualified controllers [developmental controllers (developmentals) and CPCs in training (CPC-ITs)]. Thus, controllers not only spend time on position working traffic but also time off position fulfilling a range of ancillary duties (see Table 1-1).

ATC Facilities

Air traffic controller positions and tasks vary significantly among ATC facility types. Figure 1-1 provides an overview of the various facility types: terminal facilities [airport traffic control tower (ATCT) and terminal radar approach control (TRACON)] and en route facilities [air route traffic control centers (ARTCCs)]. The following paragraphs provide an overview of FAA's air traffic facilities in en route and terminal environments and of facilities operated by private-sector organizations under FAA's Federal Contract Tower (FCT) program.

En Route Environment

En route facilities—also referred to as ARTCCs—provide for control and separation of aircraft that operate within a large section of airspace and are not assigned to towers or other terminal facilities. At the end

TABLE 1-1 Air Traffic Controller Functions

Priority	Function
First priority (on position)	Separate aircraft safely from one another and the terrain. Monitor safety and issue safety alerts.
Workload permitting	Facilitate more efficient flight routes and traffic flow management (on position). Support pilots with functions such as traffic advisories and basic radar services to aircraft operating under visual flight rules (on position). Provide OJT (on position). Provide posttraining OJT debriefing of trainees (off position).
Other (off position; may include activities outside facility)	Receive mandatory refresher and recurrent training. Receive additional training, such as introduction to new equipment. Participate in Air Traffic Safety Action Program, Partnership for Safety councils, and quality assurance and quality control activities. Support broader safety management functions of FAA. Provide expert input to FAA enterprise programs, such as support of the Next Generation Air Transportation System, and details on safety initiatives.

NOTE: OJT = on-the-job training.

of FY 2012, FAA reported to the committee that, of the 15,063 total air traffic controllers in 315 FAA facilities, 6,278 (i.e., just over 40 percent) worked in the ARTCCs. Twenty of these facilities are located within the contiguous United States (see Figure 1-2), and three additional facilities are located in Anchorage, Alaska (ZAN); Guam (ZUA); and San Juan, Puerto Rico (ZSU).

Each center is divided into four to eight areas of specialization, each of which is then partitioned into five to nine smaller sectors of low, high, or ultrahigh altitude. More than 750 sectors of airspace exist over the continental United States, and each sector can vary in size from several hundred to more than 30,000 cubic miles. While areas of specialization are well defined and rarely change, sectors within an area can be opened and closed or combined and uncombined in response to air traffic demand.

Each sector is staffed with one, two, or three controllers, depending on traffic demand. All open sectors are staffed with one lead radar, or R-side,

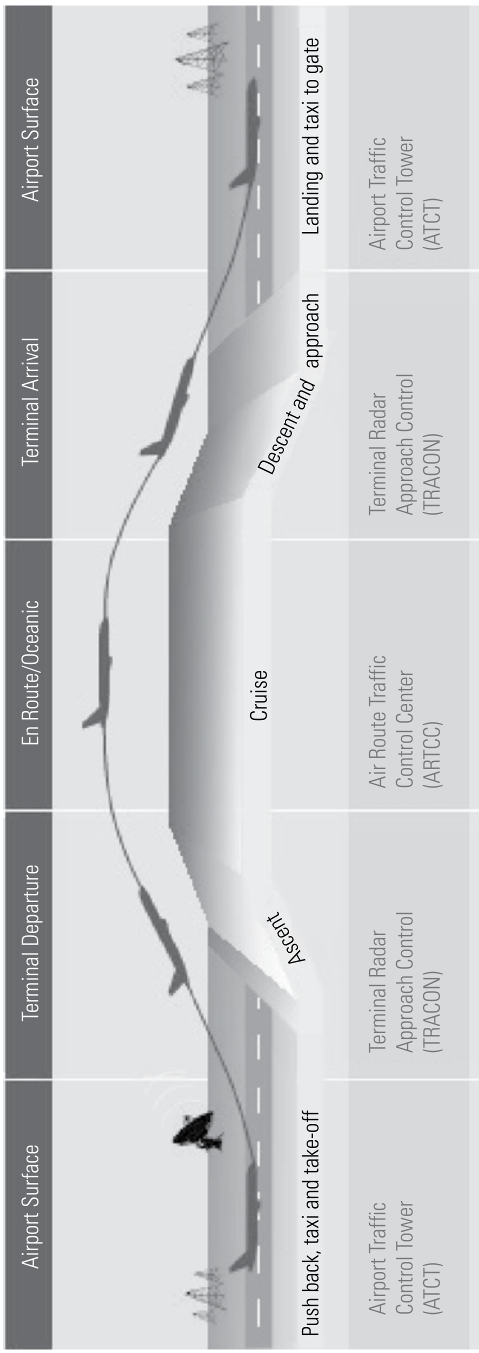

FIGURE 1-1 ATC facility overview. (SOURCE: FAA 2013b.)

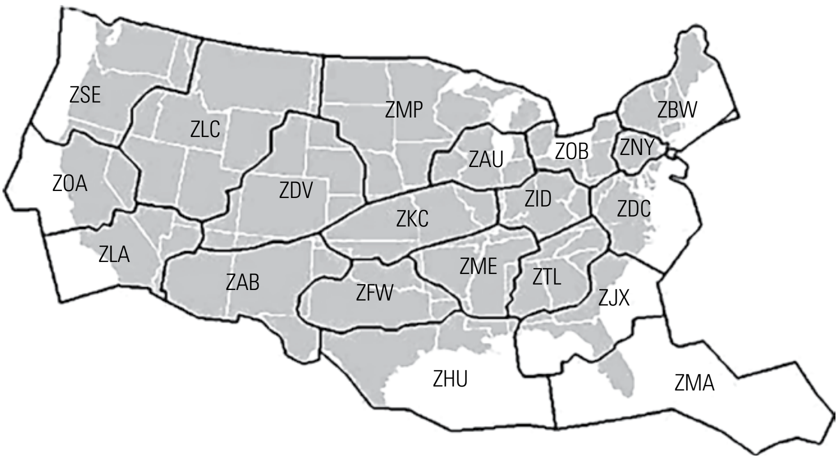

FIGURE 1-2 Boundaries of ARTCCs in the contiguous United States. (SOURCE: FAA, Presentation to the Committee for a Review of the En Route Air Traffic Control Complexity and Workload Model, 2010.)

controller. The R-side controller is responsible for communicating with and maintaining safe separation of aircraft and for coordinating other air traffic controllers. As traffic increases in a sector, a second, or associate, controller (known as a data, or D-side, controller) is added. The D-side controller typically receives flight plan information and assists in planning and organizing the flow of traffic within the sector. Infrequently a third (or T-side) controller is added during busy periods to support the lead R-side controller.

En route centers handle a variety of traffic. Some sectors may have more pass-through or overflights, or international flights, while other sectors may have more nonradar traffic. Different traffic situations require different controller tasks, each with its specific demands. Thus, a simple count of the number of flights within a sector does not indicate a controller's workload.

Terminal Environment

The terminal environment includes ATCT and TRACON facilities that manage air traffic in the immediate vicinity of an airport, particularly during ground operations and taxi, takeoff and departure, arrival, approach, and landing.[2] FAA data show that, at the end of FY 2012, 8,785 controllers (i.e., just under 60 percent of the controller workforce) worked in the more than 290 terminal facilities.

Towers Controllers at towers typically manage air traffic within a range of a few miles of the airport (see Figure 1-1). Tower controllers manage takeoffs and landings, ensure minimum separation between aircraft both in the air and on the ground, transfer control of departing aircraft to TRACON controllers, and receive control of aircraft entering their airspace. The number and types of controllers on duty in a tower depend on the size of the tower and the layout of the airport. As air traffic, workload, and complexity increase and decrease, towers open additional or different positions and close or combine positions accordingly.

TRACON Airspace for TRACONs typically covers a 40-mile radius surrounding a primary airport, although this area can vary by facility. In general, TRACONs also deliver services to several smaller airports in the vicinity. Consolidated (or large) TRACONs in major metropolitan areas service multiple airports and are divided into areas of specialization, with each specialization containing groups of sectors.

Depending on the amount of traffic each day, the number of sectors in a TRACON and the number of controllers required to staff them are adjusted (up or down) to respond to air traffic demand. As air traffic, workload, and complexity increase, controllers can be added within a sector or sectors can be partitioned and more controller positions opened. Likewise, as air traffic and workload decrease, controller positions can close and sectors can be recombined. For busy airports, TRACON controllers play a vital role in establishing efficient traffic flows that position aircraft for maximized landing rates and allow for efficient flight profiles during arrival and departure.

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[2] A number of terminal facilities combine tower and TRACON components and are categorized by FAA as "up–down" facilities. Controllers at these facilities can typically work in either component.

Contract Towers

ATC services for the NAS are provided not only by FAA facilities of the types described above but also by facilities operated by private-sector organizations under contract to FAA. The FCT program allows FAA to contract out ATC services at low-activity towers operating under visual flight rules. As of January 2014, there were 252 towers[3] in the FCT program, of which 230 were fully funded by FAA, 16 were funded on a cost-sharing basis with airports that would not otherwise receive ATC at their towers, and six were used by the Air National Guard (see OIG 2012) under a special agreement with the Department of Defense. These towers are distributed throughout the United States; about one-fourth are located in three states (California, Florida, and Texas). Contract towers have attracted interest in the context of ATC staffing discussions because they cost significantly less to operate than low-activity FAA towers (see, for example, OIG 2012). Later chapters of this report provide comparisons between low-activity FAA towers and contract towers in terms of safety (Chapter 2) and cost (Chapter 6).

Evolving Demands of Industry Sectors

Different industry sectors require different services within the NAS. Air carriers operating under Federal Aviation Regulations (FAR) Part 121 and air taxis and commuters operating under FAR Part 135 dominate operations at large airports and their TRACONs and through en route centers. In contrast, small general aviation (GA) aircraft subject to FAR Part 91 often operate out of smaller towers, and many of their flights do not interact substantially with the TRACON and en route center facilities. However, many GA operations involve aircraft without ground-based corporate dispatch services or onboard weather detection systems and thus depend heavily on the various support functions a controller can provide, workload and resources permitting. There may also be differences in the levels of ATC support needed within the air

[3] See p. 10 of the following document for a complete list: http://www.contracttower.org/ctaannual/13CTAannual.pdf.

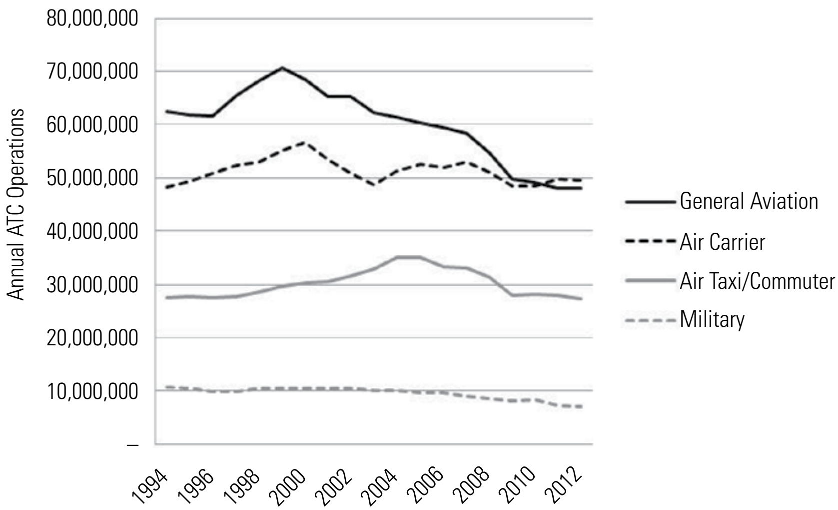

FIGURE 1-3 Total ATC operations by industry segment, 1994–2012.
[SOURCE: FAA Air Traffic Activity Data System (http://aspm.faa.gov/opsnet/sys/Main.asp?force=atads).]

carrier and the air taxi and commuter categories. Under normal circumstances, for example, an experienced air transport pilot is likely to require less support than an inexperienced pilot of a smaller aircraft.

The demand for air traffic services is evolving. The total number of ATC operations[4] declined by 21 percent from its high in 2000 to 2012 in response to a number of events. However, this aggregate number masks differences between industry segments (see Figure 1-3). The decline in

[4] ATC operations consist of tower operations, TRACON operations, and center aircraft handled. A tower operation is a takeoff, landing, or overflight. The term includes so-called touch-and-go's, in which a plane touches down and immediately becomes airborne again. TRACON operations consist of itinerant flights (to or from an airport under the TRACON airspace) and overflights (aircraft passing through the TRACON airspace but not landing at any airport in the TRACON's coverage area). Center aircraft handled is the number of ARTCC en route IFR departures multiplied by two, plus the number of en route IFR overflights. An IFR departure is an en route IFR flight that originates in an ARTCC's area and enters the center's airspace. An IFR overflight is an en route IFR flight that originates outside the ARTCC's area and passes through the area without landing (personal communication, Arthur Furnia, FAA, August 27, 2013).

general aviation operations has been particularly marked, while air carrier and air taxi and commuter operations have experienced more modest declines.

The decline in ATC operations has not been the same across all facility types. Figure 1-4 shows total ATC operations by facility type from 1994 to 2012. From 2000 to 2012, tower operations declined by 15.1 million (22 percent) and TRACON operations declined by 13.8 million (27 percent), whereas ARTCC operations declined by 5.4 million (12 percent). During the early part of this period, there were more operations at TRACONs than at ARTCCs; from 2005 on, there have been more operations at ARTCCs. The committee's analysis of the change in operations at each type of facility by industry segment shows that the drop in total ATC operations has been largely the result of a drop in GA operations. This drop has been especially pronounced at towers and significant at TRACON facilities but has not been a major factor at ARTCC facilities.

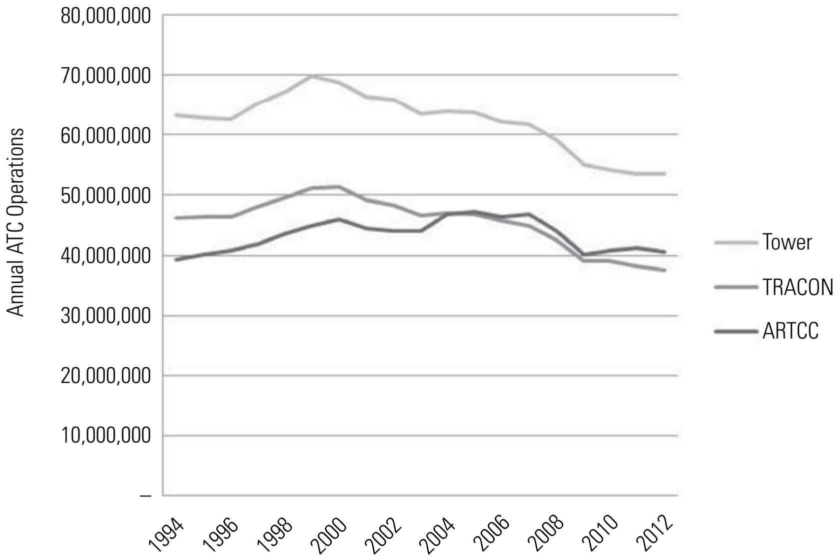

FIGURE 1-4 Total ATC operations by facility type, 1994–2012.
[SOURCE: FAA Air Traffic Activity Data System (http://aspm.faa.gov/opsnet/sys/Main.asp?force=atads).]

(ARTCCs have also experienced a drop in operations requested by military flights.)

STAFFING CHALLENGE

Establishing levels of controller staffing is not an exact science. There are no explicit quantitative methods for calculating the number of controllers needed to provide safe air traffic services other than information from historical trends, and there is no developed or agreed-on measure of the true staffing requirement in the United States or in other countries. Australian Civil Aviation Safety Regulations, for example, do not provide explicit guidance on how to determine the number of operational staff needed to provide air traffic services (Harfield 2013). Likewise, National Air Traffic Controllers Association (NATCA) representatives who attended the committee's first meeting noted the absence of an objective, science-based method for establishing controller staffing standards independent of political and other influences.

Safety is the overarching requirement for ATC. Data from the National Transportation Safety Board show that ATC errors, including omissions, have not been a major cause of aviation accidents in the past, which indicates that current controller staffing levels are safe, at least in the aggregate. (Chapter 2 notes potential areas for safety improvements, particularly for general aviation.) However, the relationship between safety levels and controller staffing is not understood; key metrics have not been defined and appropriate data have not been collected or analyzed to identify whether staffing levels are near the limit required to maintain this safety level.

The impact of controller staffing on both safety and performance is further complicated by FAA's ability to limit the number of operations it allows within the airspace. For example, a perceived shortfall in staffing may lead the agency to decide against opening a sector to accommodate more traffic during busy periods. Such action ensures the continued safe operation of the NAS, but at the expense of a degradation of performance in the form of flight delays and possible cancellations. As the example illustrates, the impact of controller staffing on safety is carefully managed during day-to-day operations. This operational response to staffing can affect performance of the NAS, but it is not the only driver of NAS performance. Flight delays, for example, may be attributed to inadequate controller staffing levels, but they arise regardless of staffing levels when the layout of sectors, routes, and runways prevents the airspace from handling more traffic. As discussed in the preceding section, a further complication in assessing performance is the diversity of air traffic services FAA must provide that would require both measures of airspace throughput in the broad sense and measures of benefit to each aircraft—for example, the ability to provide more fuel-efficient routings.

Thus, there are no broadly applicable criteria for the NAS that can relate staffing to safety, to performance measures of the airspace throughput, and to measures of benefit to the aviation community simultaneously. Development of such criteria would require weighting between measures of safety (or some “safety margin”) and performance and between performance measures of importance to different users of the airspace. As indicated by the committee’s discussions with various parties—FAA, NATCA, aviation industry representatives, and so forth—there is no clear consensus on what these values should be. All agree, however, that safety has priority over other goals.

All of these concerns are compounded by uncertainty with regard to the size of the controller workforce itself: while a controller may retire on short notice, a new hire can take up to 3 years to qualify into a facility. Thus, staffing levels often reflect not only the controllers required to staff positions now but also the trainees who are brought into the system in advance of expected retirements. The degree of flux in controller staffing is illustrated by the following: at the end of FY 2012 the FAA controller total workforce of 15,063[5] comprised 11,753 CPCs (78 percent of the workforce, of whom just over one-fourth are eligible to retire), 1,143 CPC-ITs (8 percent of the workforce), and 2,167 developmentals in training (14 percent of the workforce). The 1981 Professional Air Traffic Controller Organization strike and subsequent firings created a situation in which retirement eligibility peaked as a large proportion

[5] The 148 trainee controllers at the FAA Academy are not included in this head count.

of the controller workforce reached retirement age within the span of a few years. FAA data indicate that the latest retirement wave has now passed its high-water mark, and under current hiring plans the intent is to "spread out the retirement eligibility of the current wave of new hires and reduce the magnitude of the retirement eligibility peak in future years" (FAA 2013b, 30).

Like all air navigation service providers (ANSPs), FAA faces several challenges in determining the appropriate controller staffing needs to ensure the safe operation of the NAS in a cost-effective manner. A report from the Civil Air Navigation Services Organization (CANSO) summarizes the issues as follows:

> One of the unique limitations of air navigation service provision, as compared to other industries, revolves around the difficulty in staffing to demand. ANSPs cannot quickly respond to changes in traffic as the development of new [controllers] requires somewhere between two to three years of training often with high failure rates. . . . [W]hile traffic may suddenly dip (or drop) due to external factors—economic downturns, extreme weather conditions, a terror event—the [controller] workforce cannot be right-sized accordingly. ANSPs cannot quickly or easily reduce that workforce . . . [controllers] are not particularly mobile as a move requires learning new sectors or areas, another lengthy training process. (CANSO 2012, 10)

FAA's STAFFING PROCESS

FAA's staffing process involves several steps spanning various organizations within the agency. The first step seeks to model, as far as possible, the number of controllers required on position at each facility to handle current and forecast traffic demand and then to convert the outcome to the number of controllers needed on staff at each facility, with scheduling and other constraints being taken into account. The resulting model-based "staffing standard" is then an input into a broader process in which input from the field[6] and productivity data are considered in identifying a "staffing range" for each facility. Staff planning examines transfers and hiring, and these plans are executed.

[6] As used in this report, "the field" designates any facilities outside of FAA headquarters.

For more than 50 years, FAA has developed and applied staffing standards (models) to help establish staffing requirements for its ATC facilities. Over this period, independent groups, including the Transportation Research Board (TRB), have scrutinized the data sources and methods used by FAA. A 1997 report, for example, recommended an approach that combines formal modeled predictions with less formal methods based on expert judgment concerning staffing requirements at individual facilities (TRB 1997). That report noted that controller workforce planning is not a one-size-fits-all problem and observed that national planning needs to recognize features specific to individual ATC facilities. A more recent report reviewed the task load "complexity model" used in generating staffing standards for en route facilities and offered advice on "ways to improve the modeling process going forward" (TRB 2010, 6).

In the committee's judgment, the efficacy of the entire process needs to be judged by the extent to which the plans result in the right staffing at all of FAA's air traffic facilities. Thus, subsequent staffing plans governing the hiring, training, and transfer of controllers and the extent to which they are properly executed must be considered, not merely the specific model used in generating the staffing standards or the correctness of the staffing ranges.

CHARGE TO THE COMMITTEE

As stipulated in Section 608 of the FAA Modernization and Reform Act of 2012, this project will study "the air traffic controller standards used by the [FAA] to estimate staffing needs for FAA air traffic controllers to ensure the safe operation of the national airspace system in the most cost effective manner." The project "shall consult with the exclusive bargaining representative of employees of the FAA certified under section 7111 of title 5, United States Code, and other interested parties, including Government and industry representatives." The study shall include

(1) An examination of representative information on productivity, human factors, traffic activity, and improved technology and equipment used in air traffic control;
(2) An examination of recent [National Research Council] reviews of the complexity model performed by MITRE Corporation that support

the staffing standards models for the en route air traffic control environment; and

(3) Consideration of the Administration's current and estimated budgets and the most cost-effective staffing model to best leverage available funding.

Conversations involving TRB staff and congressional staff provided the committee with further guidance on its task. In particular, Congress's main interests are whether the forecasts from FAA's staffing model (*a*) are reliable at the national level for the purpose of future budgeting and (*b*) incorporate cost-effective strategies for staffing that align future labor costs with anticipated appropriations. Consistent with this focus on budgetary concerns, congressional staff also asked the committee to investigate FAA's controller staffing process from planning through execution, rather than focus exclusively on the staffing standards (models).[7]

As discussed earlier, controller staffing affects not only safety but also the performance of the air traffic services provided in the NAS. This report focuses primarily on safety for four reasons: (*a*) the charge explicitly mentions safety; (*b*) confounding factors such as airspace structure and operational procedures complicate efforts to isolate the impacts of controller staffing on performance beyond the current state of the art in modeling airspace; (*c*) these confounding factors are themselves expected to change with ongoing initiatives, such as the Next Generation Air Transportation System (NextGen); and (*d*) widely accepted performance metrics relevant to all industry segments and all types of ATC facility remain to be defined. Thus, relating performance to staffing is left as a subject for further study that will require both policy decisions to define performance metrics and clarification of how air traffic will be operated in NextGen.

Congressional staff also expressed particular interest in comparisons between the approaches to controller staffing taken by FAA and by ANSPs in other countries. As noted in the Preface, four ANSPs (Airservices Australia, Nav Canada, Deutsche Flugsicherung in Germany,

[7] As noted in the Preface, FAA's definition of staffing standards is limited to the models relating controller workload and air traffic activity and does not include adjustments to the modeled output or implementation of the resulting staffing plan.

and National Air Traffic Services in the United Kingdom) provided the committee with white papers on their staffing processes. The papers, together with discussions with representatives of these ANSPs, provided valuable insights into specific aspects of controller workforce planning and execution, such as the implementation of fatigue risk management systems and of new, more sophisticated scheduling software. The lessons learned from the interactions with ANSPs are referenced in relevant sections of this report. In identifying these lessons, the committee was mindful of differences in labor laws and in the type and volume of air traffic services provided that raise questions about the transferability of ATC staffing practices from one nation to another.

Different ANSPs operate in different settings and serve diverse constituencies, which complicates efforts to compare performance indicators, such as controller productivity (CANSO 2012). Factors affecting performance include, but are not limited to, type of ownership (government agency, state-owned agency, or private company), regulatory environment, traffic levels and complexity, and range of services provided. The committee also noted that metrics such as number of ATC operations may be counted differently in different countries, further complicating efforts to establish robust comparisons.

The committee found that highly aggregate systemwide data do not provide an accurate picture of trends in controller productivity, as discussed in Chapter 7. Thus, the comparisons of controller productivity at different ANSPs presented in a recent report from CANSO should be interpreted with caution. FAA's controller productivity for IFR flight hours in continental operations was found to be among the highest reported by CANSO members, but the report notes that this productivity indicator can be influenced by volume of traffic and by size and complexity of airspace (CANSO 2012). It also warns of the need to "avoid taking specific metrics in isolation without considering the broader context of the environment in which an ANSP operates" (p. 9). A recent comparison of U.S. and European air navigation systems illustrates this point. It notes that, while the two systems are of similar size, "the European system handles fewer flights . . . and is more labor intensive than the American system" (Button and Neiva 2013, 2). The differences are attributed to a number of technical reasons but also, in particular, to the lack of coordination among European systems, with the small size of many of these systems preventing economies of scale. Thus, the differences in productivity reflect institutional constraints and airspace design issues rather than controller productivity per se.

The committee explored the possibility of comparing staffing levels at other countries' ATC facilities similar in size and function to selected U.S. ATC facilities but was unable to obtain the necessary data from ANSPs.

In the aggregate, FAA's staffing process spans all operational facilities and several offices creating national plans. Such a process must be complex and have the ability to account for myriad concerns. However, in the committee's view, the inherent complexity does not relieve FAA of the responsibility of making staffing decisions that are transparent and as consistent as possible with established data, science, and documented practices. Throughout its activities, the committee recognized the value of consistent and transparent staffing decisions in FAA's ability to engage the controller workforce effectively and to substantiate staffing decisions to the aviation industry and to taxpayers.

ORGANIZATION OF REPORT

Chapter 2 examines the role of ATC in aviation accidents and incidents and identifies opportunities for developing a better understanding of the relationships between ATC staffing and aviation safety. It compares the safety of low-activity FAA towers and contract towers and discusses concerns about the adverse impacts of fatigue on controller performance and possible fatigue mitigation strategies. The chapter concludes by examining the implications of a robust FAA safety culture for controller staffing. In particular, the need for improved data collection and analysis for better understanding of the relationship between staffing and safety and the value of further involvement of controllers in reporting and safety improvements are noted.

Chapter 3 reviews the formal staffing models and the overall process used by FAA in estimating the number of controllers needed to staff its ATC facilities. Key features of the models used for towers, TRACONs, and en route facilities are summarized, and their strengths and weaknesses are identified. The chapter provides an overview of FAA's traffic forecasting methods.

Chapter 4 examines staffing levels at FAA's ATC facilities relative to FAA's staffing ranges. It reviews the hiring and staffing plans developed to manage the staffing at each facility and how, and how well, FAA executes these plans. Several potential strategies targeting concerns with regard to getting the right staff to the right facility are suggested.

Chapter 5 considers the implications of FAA's NextGen for controller staffing and discusses the role of the controller in the development and fielding of system technologies.

Chapter 6 presents current and estimated future budgets for ATC staffing and discusses current and anticipated revenue streams. The chapter identifies the pros and cons of policy options that might allow FAA to cut costs without commensurate reductions in ATC services.

Each of Chapters 2 through 5 concludes with findings and recommendations addressing the chapter's content. Chapter 7 summarizes key insights from the preceding chapters and presents the committee's major recommendations.

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Abbreviations

CANSO	Civil Air Navigation Services Organization
FAA	Federal Aviation Administration
OIG	Office of Inspector General, U.S. Department of Transportation
TRB	Transportation Research Board

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2

Aviation Safety and Controller Staffing

Air traffic controller staffing affects safety. This chapter examines the aviation safety record in the United States, the role that accidents related to air traffic control (ATC) play in that record, and how aviation safety data might be analyzed to shed light on the relationships between air traffic controller staffing and aviation safety. A discussion of the Federal Aviation Administration's (FAA's) Federal Contract Tower (FCT) program follows, along with an evaluation of safety comparisons between low-activity FAA towers and contract towers. The chapter describes known best practices in scheduling to address concerns with regard to fatigue as identified in the United States and by other air navigation service providers (ANSPs) and the International Civil Aviation Organization (ICAO). Implementing such practices could require adjustments in how a controller staffing plan is executed and perhaps in staffing levels. Finally, the chapter addresses concerns in establishing and maintaining a "safety culture" in which staffing levels must be sufficient for managing traffic and for enabling proper reporting and controller involvement in safety management and in which the appropriate data are collected and used in the planning and implementation of controller staffing.

INDICATORS OF THE RELATIONSHIPS BETWEEN CONTROLLER STAFFING AND AVIATION SAFETY

This section places ATC-related accidents[1] in the context of all aviation accidents.[2] It then considers how accident and incident data might be

[1] The committee considered ATC-related accidents to be those in which accident investigation by the National Transportation Safety Board found that air traffic control was either a "cause" or a "factor" in the accident.

[2] For official definition of terms, see 49 CFR 830.2—Definitions (http://cfr.regstoday.com/49cfr830.aspx).

TABLE 2-1 U.S. Aviation Accidents by Industry Segment and Injury Level, 1990–2012

	All Aviation Accidents			ATC-Related Aviation Accidents		
	Injury Level			Injury Level		
Industry Segment	Total Fatal	Total Nonfatal[a]	Total Fatalities	Total Fatal	Total Nonfatal[a]	Total Fatalities
Air carrier	59	753	1,738	3	8	79
Air taxi and commuter	455	1,355	1,322	6	3	30
GA	7,772	30,940	14,148	57	25	140
Total	8,286	33,048	17,208	66	36	249

[a]The injury category "nonfatal" is the sum of serious injury accidents, minor injury accidents, and accidents in which there were no injuries.
SOURCE: NTSB Aviation Accident and Incident Data System accessed through FAA's Aviation Safety Information Analysis and Sharing System.

analyzed to help in understanding relationships between air traffic controller staffing and aviation safety.

Table 2-1 shows the total number of aviation accidents and the total number of ATC-related accidents from all causes in the United States between 1990 and 2012, by industry segment. Fatal accidents accounted for 20 percent of the more than 41,000 total accidents during the period. Air carriers accounted for less than 1 percent of fatal accidents, although these accidents corresponded to slightly more than 10 percent of aviation fatalities, which is likely due to the larger number of passengers per airplane associated with air carrier operations. Air taxis and commuters were responsible for approximately 5 percent of fatal accidents and for 8 percent of fatalities, and general aviation (GA) accounted for 94 percent of fatal accidents and for 82 percent of fatalities.

ATC was considered as either a cause or a factor by the National Transportation Safety Board (NTSB)[3] in 66 fatal accidents, which corresponded to 249 fatalities over the period from 1990 to 2012—about

[3] For purposes of the committee's analysis, no attempt was made to distinguish the degree of involvement of ATC errors, including omissions, in the fatal accidents. Thus, the two NTSB categories, causes and factors, were combined.

TABLE 2-2 ATC-Related Fatal Accident Rates and Accident Type by Industry Segment, 1990–2012

		ATC-Related Fatal Accidents			
Industry Segment	Total ATC Operations	Total ATC-Related Accidents	Fatal Accidents per 10 Million ATC Operations	Loss of Separation Accidents	Single Aircraft Accidents
Air carrier	1,832,471,000	3	0.05	2	1
Air taxi and commuter		6		3	3
GA	1,378,570,000	57	0.41	15	42
Total	3,211,041,000	66		20	46

SOURCE: Accident data are from NTSB's Aviation Accident and Incident Data System accessed through FAA's Aviation Safety Information Analysis and Sharing System. Total ATC operations are by calendar year and include all U.S. ATC operations as reported in the Operations Network Factbook Yearly Summary Report.

0.8 percent of all fatal accidents and 1.4 percent of all fatalities. ATC is considered vital to the safety of almost all aviation operations; thus, the small number of accidents in which ATC is considered a causal or contributing factor reflects the success of the ATC system in the aggregate.

The frequency of ATC-related accidents was not the same across all aviation industry segments. Table 2-2 shows the total number of ATC operations, the number of ATC-related fatal accidents, and ATC-related fatal accident rates, by industry segment. Clearly, GA has been responsible for more fatal ATC-related accidents than have air carriers and air taxis and commuters combined. In addition, the rate of fatal ATC-related accidents per 10 million ATC operations has been much higher for GA than for commercial aviation (air taxis and commuters and air carriers).[4] As with accidents from all causes, GA accounted for the majority of ATC-related accidents (86 percent of those accidents and 54 percent of fatalities).

[4] The committee was unable to determine whether the distinction between air carriers and air taxis and commuters in the Air Traffic Activity Data System was precisely the same as the distinction between the aircraft operating under Part 121 and the aircraft operating under Part 135; thus, the committee reported the combined air carrier and air taxi and commuter numbers as "commercial aviation."

Relatively simple analyses of accident data could offer useful insights into the nature of ATC-related accidents, as illustrated by the following discussion of loss of separation and single aircraft accidents. The committee's intent here is not to conduct a definitive piece of original analysis but rather to highlight opportunities for gaining safety insights related to controller staffing from an examination of accident and incident data.

Discussions of ATC safety typically focus on maintaining safe separation between aircraft, although controllers are required to give first priority both to separating aircraft and to issuing safety alerts.[5] For example, FAA's tracking of ATC incidents that threaten safety focuses almost entirely on loss of separation; similarly, FAA's risk analysis process within the Air Traffic Organization (ATO) deals exclusively with loss of separation events.[6] However, as the data in Table 2-2 show, an important fraction of ATC-related fatal accidents did not involve a loss of separation. In the two rightmost columns of Table 2-2, ATC-related fatal accidents are divided into two categories: those involving a loss of separation, either between two aircraft (in the air or on the ground) or between an aircraft and another ground vehicle, and those involving a single aircraft in which the controller failed to provide required safety information or provided other types of inaccurate or inadequate information. For the aviation industry as a whole, loss of separation has not been the dominant cause of fatal ATC-related accidents. Only about 30 percent of fatal ATC-related accidents involved a lack of separation. The remainder involved single aircraft and controllers' failure to provide weather information to pilots or failure to issue terrain alerts—such as minimum safe altitude warning alerts—or to issue other instructions, which put the aircraft in a hazardous situation.

[5] While the primary purpose of ATC is to prevent collisions between aircraft and to manage the flow of traffic, ATC is required to perform other controller safety functions, such as providing safety alerts and disseminating weather information. See FAA JO Order 7110.65, Section 2-1-2, Duty Priority, and Section 2-1-6, Safety Alert. https://www.faa.gov/air_traffic/publications/ATpubs/ATC/atc0201.html.

[6] "Standard Operating Procedures for the Quality Assurance Risk Analysis Process," FAA Document AJI-12-RAP-SOP05-F, provided by Rick Huss on January 17, 2014.

The data presented in Table 2-2 suggest that failure to provide timely and accurate safety information is a cause or a factor for a large proportion of fatal ATC-related accidents, particularly for GA. The data suggest that FAA might benefit from giving more attention to the provision of information to pilots in addition to focusing on loss of separation. Analyzing accident and incident data could also be an important step for guiding future data collection.

SAFETY OF FAA's CONTRACT TOWER PROGRAM

FAA's FCT program began more than 30 years ago and offers an alternative business model for the delivery of ATC services at low-activity towers operating under visual flight rules. As noted in Chapter 1, FAA contracts with private-sector organizations[7] for ATC services at its contract towers.[8]

Since 1998, the U.S. Department of Transportation Office of Inspector General (OIG) has released five reports evaluating numerous aspects of the FCT program (OIG 1998; 2000; 2001; 2003; 2012a). In general, the OIG reports have found that contract towers provide ATC services at a lower cost than similar FAA towers, with little difference in the quality of services between FAA and contract towers. The OIG also found that "contract towers had a significantly lower number and rate of safety incidents compared to similar FAA towers" (OIG 2012a, 2). The committee, however, has reservations about this finding for the reasons discussed below.

The 2012 OIG report compares contract towers and FAA-operated towers with similar average traffic densities. The OIG used the numbers of operations and the hours of service for FY 2009 and FY 2010 to calculate the average traffic density[9] for its population of 240 contract

[7] Contract towers are operated by one of three companies. See http://www.contracttower.org/fctcontractors.html.

[8] As of January 2014, 252 facilities are in the contract tower program; see p. 10 of the following document for a complete list: http://www.contracttower.org/ctaannual/13CTAannual.pdf.

[9] The OIG defines density as the average number of operations at a tower per hour the facility is open (OIG 2012a, 4).

TABLE 2-3 Levels of Selected FAA-Operated Towers with Similar Average Traffic Density

Tower ID	Tower Name, State	Average Traffic Density	Level
SJU	San Juan Tower, Puerto Rico	22.1	7
GCN	Grand Canyon Tower, Arizona	20.7	5
ADS	Addison Tower, Texas	20.2	5
PHF	Patrick Henry Tower, Virginia	19.8	6

NOTE: Density is defined as the average number of operations at a tower per hour the facility is open.
SOURCE: Adapted from OIG 2012a.

towers and 92 FAA towers and then matched a randomly selected sample of 30 contract towers to 30 FAA facilities with similar air traffic densities.[10]

Average traffic density is only one of several metrics characterizing the demands placed on controllers as they manage traffic. Other metrics that can influence controller workload include traffic complexity, types of users, and special geographical and meteorological features of an airport. In an effort to capture the various factors contributing to controller workload, FAA classifies its ATC facilities into nine levels, ranging from 4 to 12, with 12 being the most demanding. However, contract towers are not classified by level, which complicates efforts to establish pairs (or groups) of FAA-operated and contract towers with comparable air traffic demands.

The OIG's method of matching average traffic densities is one approach for comparing towers, but other factors should be considered. As shown in Table 2-3, towers with similar average traffic densities can be assigned different levels by FAA. Furthermore, as shown in Table 2-4, average traffic density can vary by a factor of two or more among facilities at the same level. These observations raise questions about the extent to which the OIG was able to establish

[10] For a more detailed description of its methodology, see OIG 2012a, p. 11, Exhibit A, Scope and Methodology.

TABLE 2-4 Average Traffic Density for Selected Level 7 FAA-Operated Towers

Tower ID	Tower Name, State	Average Traffic Density
TMB	Tamiami Tower, Florida	37.3
BED	Hanscom Tower, Massachusetts	32.4
SJU	San Juan Tower, Puerto Rico	22.1
TEB	Teterboro Tower, New Jersey	17.5

NOTE: Density is defined as the average number of operations at a tower per hour the facility is open.
SOURCE: Adapted from OIG 2012a.

analogous groups of FAA and contract towers for purposes of safety comparisons.

All five OIG reports cited above consider the safety of contract towers by comparing the number or rate of safety incidents. In all cases, however, identifying real differences in rates of these safety incidents is challenging. The Government Accountability Office (GAO) concluded that "comparisons of operational error rates alone are not sufficient to draw conclusions about the relative safety records of air traffic control facilities" (GAO 2003, 3) and that "comparisons . . . among types of air traffic control facilities, such as FAA-staffed facilities versus contractor-staffed facilities, cannot be used alone to provide valid conclusions about safety due to three factors" (GAO 2003, 2). First, any differences in reporting practices between types of towers can raise questions about the completeness and accuracy of incident data. Since some errors are self-reported, controllers may not report all incidents, leading to underreporting (GAO 2003). FAA controllers voluntarily self-report information about operational errors through the Air Traffic Safety Action Program (ATSAP) beginning October 2010, without fear of reprisal. Contract towers did not have such a voluntary reporting program, although they were expected to implement one by December 31, 2012 (OIG 2012a). Second, any analyses of data would need to control for other factors that could affect the rate of operational errors, including age and experience of controllers, weather conditions, and traffic complexity. Third, low rates of operational errors make detection of real differences in error rates among facilities difficult (see GAO 2003, 2–3).

FATIGUE AND ATC

Impact of Fatigue on Safety

Fatigue is a risk factor for errors and accidents, and it is frequently encountered in operations that need to be sustained 24/7, like ATC. Fatigue can be broadly defined as "a physiological state of reduced mental or physical performance capability." Numerous factors are known to induce or contribute to fatigue (ICAO 2011):

1. Acute sleep loss (i.e., being awake for a prolonged period of time),
2. Chronic sleep restriction (i.e., not getting enough sleep per 24 hours on a regular basis),
3. Circadian rhythm (e.g., working at night when the body is programmed to sleep or sleeping during the day when the body is programmed to be awake),
4. Low-quality sleep due to sleep fragmentation that is induced internally (e.g., by sleep disorders) or externally (e.g., by noise),
5. Sleep inertia (i.e., a period of reduced performance capability immediately after waking up),
6. Time on task (i.e., prolonged work periods without breaks),
7. High workload, and
8. Traitlike (i.e., likely genetic) interindividual differences in susceptibility to the above factors.

The safety of the National Airspace System (NAS) depends on continuously high levels of controller performance. At the same time, the tasks of controllers can be complex and demanding, and they require a high level of attention. The latter is affected profoundly by sleep loss, circadian misalignment, and other fatigue-inducing factors (Lim and Dinges 2008, 2010). Several studies demonstrate the impact of fatigue on air traffic controller performance (for example, Schroeder et al. 1998; Signal and Gander 2007; OIG 2009). For these reasons, fatigue deserves special attention as a risk factor for air traffic controllers.

Rare but highly publicized incidents of controllers falling asleep on the job have drawn attention to the risks associated with controller fatigue.[11]

[11] See NTSB Press Release (http://www.ntsb.gov/news/2011/110324.html); Scovel 2014, 10; OIG 2013a; and OIG 2009.

As a result of these incidents, night shifts with a single controller on duty are no longer permitted in most circumstances.[12] Other prescriptive limitations on controllers' work schedules and duty times, such as mandatory breaks and lunch periods and limits on the number of hours worked in a shift, aim to mitigate the risks associated with controller fatigue. Another result was the 9-hour rule, which requires controllers to have a minimum of 9 hours off duty preceding the start of a day shift. The intention of such actions is to improve safety by increasing controllers' opportunities for nighttime sleep.

Despite recent policy changes such as the 9-hour rule and efforts to educate controllers about fatigue issues through a series of fatigue risk management bulletins,[13] some controller schedules continue to raise concerns about fatigue. In particular, the counterclockwise rotating 2-2-1 schedule (shown in Figure 2-1) compresses the workweek and then allows controllers 80 hours off. Although the schedule, described in Box 2-1, is popular among controllers, it results in severely reduced cognitive performance during the midnight shift because of fatigue.

The extent to which fatigue has affected safety is impossible to address in view of the limited data collected in accident and incident reports. The treatment of potential fatigue concerns in such reports by FAA and NTSB has been variable, and important elements of information relative to fatigue are often not included. In view of the small number of safety incidents that can be attributed to ATC, data-driven evaluation of the effects of controller fatigue on safety would be difficult on the basis of incident data alone even if such elements are included in incident reports. Nonetheless, evidence from incidents in which fatigue played a role has triggered FAA scrutiny about controller staffing and scheduling and has generated follow-up action (e.g., the new 9-hour rule and the release of fatigue risk management bulletins, which were mentioned above). The relationship between safety and fatigue can be examined

[12] Under certain conditions, single controllers are permitted on the midnight shift. See FAA JO 7210.3Y, 2-6-12c, effective date April 3, 2014 (http://www.faa.gov/documentLibrary/media/Order/JO_7210.3Y.pdf).

[13] FAA provided the committee with nine bulletins published so far. Among them are Fatigue Risk Management Bulletins No. 1: The 9-Hour Rule, published March 13, 2013; No. 2: 7 and 9 Hour Shifts, published April 8, 2013; and No. 3: Self-Declaration of Fatigue, published April 22, 2013.

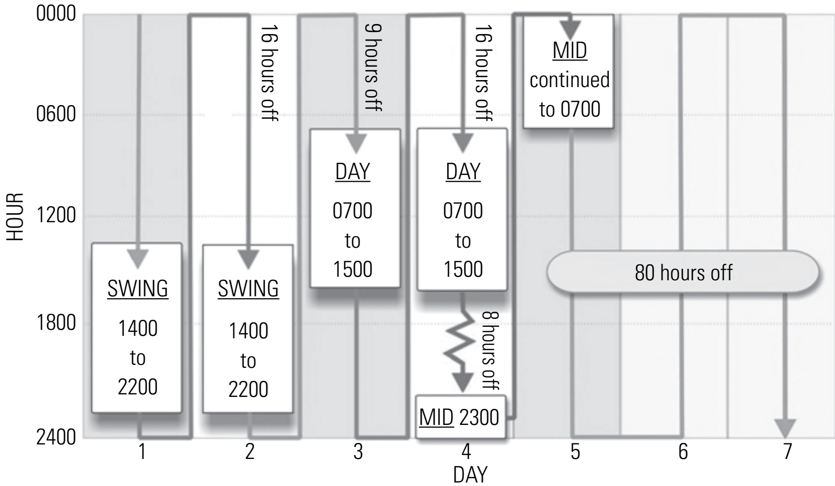

FIGURE 2-1 **Example of counterclockwise rotating 2-2-1 schedule.**

further through wider analysis of other data sets, including controller reports of situations that did not rise to the level of "incident" but that were believed to warrant investigation, as discussed in the next section of this chapter.

Best Practices Addressing Fatigue

Full implementation of a fatigue risk management system (FRMS) could go beyond duty time limitations and mitigate fatigue in a more comprehensive manner. ICAO defines an FRMS as "a data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness." An FRMS shares characteristics with safety management systems (SMSs), including effective safety reporting, senior management commitment, a process of continuous monitoring, a process for investigation of safety occurrences that aims to identify safety deficiencies rather than apportion blame, the sharing of information and best practices, integrated training for operational personnel, effective implementation of standard operating procedures, and a commitment to continuous improvement.

BOX 2-1

Counterclockwise Rotating 2-2-1 Schedule

The counterclockwise rotating 2-2-1 schedule compresses the workweek (five shifts during 4 days followed by 80 hours off) and is thus popular among controllers. From a fatigue and safety perspective, this scheduling practice is questionable, and the committee was astonished to find that it is still allowed under current regulations.

The schedule involves two swing shifts on Days 1 and 2, two day shifts on Days 3 and 4, and a midnight shift starting at the end of Day 4. The second day shift usually starts early in the morning, and controllers with long commute times will have to get up even earlier to arrive on time for their shift. As a consequence, controllers likely will not get enough sleep before the second day shift, and controllers with a late circadian preference (i.e., those who would usually go to bed and get up late) are especially likely to start the second day shift with a sleep deficit. After the second day shift, controllers have 8 hours to recuperate before they have to arrive for the final midnight shift.

The commute will cut down on their time for recuperation, and since controllers are asked to sleep during the afternoon or early evening when the circadian system is maximally promoting wakefulness, they are unlikely to log a substantial amount of sleep (if any) before the final midnight shift, where they are required to work through the circadian nadir. This combination of acute sleep loss and work during the biological night increases the risk for fatigue and for associated errors and accidents.

As a step toward implementing an FRMS, in 2009 FAA and the National Air Traffic Controllers Association (NATCA) established the Article 55 Fatigue Risk Management Work Group, which included members from FAA and NATCA. They published a memorandum of understanding in July 2011 stating that "the Agency will implement a Fatigue Risk Management System (FRMS) in the ATO for air traffic operations that includes the Union, to analyze, identify and recommend mitigation strategies for fatigue risks. The FRMS will be implemented no later than January 2012." To date, FAA's FRMS program remains incomplete.

The results of a 2009 study conducted jointly by FAA and the National Aeronautics and Space Administration (NASA) examining controller fatigue have been available to the nascent FRMS program. They have remained in a "for official use only" format and have not been released to the public (or to the committee). Nevertheless, the FRMS program has issued a series of fatigue-related recommendations aimed at increasing the safety of the NAS and improving the health and well-being of the controller workforce. FAA has addressed these recommendations through policy changes (such as the 9-hour rule noted earlier) and fatigue awareness training.[14]

With the budget sequestration in 2013, FAA has effectively eliminated the FRMS program's capability of monitoring for fatigue concerns proactively. Policy changes made since FAA received the results of the FAA–NASA study have not been scientifically monitored or evaluated to determine whether they are achieving the intended reductions in safety concerns with fatigue.[15] Thus, a recent OIG audit report noted the following: "We could not determine the extent to which these new policies impact fatigue because FAA does not have metrics to measure the effect of its scheduling practices" (OIG 2013a). Similarly, after meeting with the remaining FAA staff administering the FRMS program, the committee

[14] Fatigue interventions developed and implemented through the efforts of FAA's Fatigue Risk Management Office. Fatigue implementation and utilization reports for FY 2012 and FY 2013 for ATC and Technical Operations were provided by Darendia McCauley, FAA Civil Aerospace Medical Institute, February 12, 2014.

[15] For example, FAA's briefing to the Human Factors subcommittee of the Research, Engineering, and Development Advisory Committee (February 26, 2013) reported plans to eliminate all contractor spending on air traffic controller fatigue research in FY 2014 and FY 2015. Research would be limited to what could be performed by in-house personnel, and field studies would be canceled.

could not verify or determine the metrics that FAA intends to use to evaluate the implementation of these policies or whether FAA has collected or analyzed any data to which metrics would be applied. The committee did not see—or was not provided—with evidence that FAA has plans for such evaluations or the appropriate resources to complete them.

Additional recommendations concerning fatigue mitigation are likely to result from further implementation of an FRMS. The extent, if any, to which staffing requirements for sustaining the operation will be affected by such mitigations is not known. The committee tried to address this question by using a scheduling tool under development by FAA, Operational Planning and Scheduling (OPAS), to investigate the effects of the minimum duration off between a night and a day shift on required staffing levels. Three different demand curves[16] were compared for 8 hours, 9 hours, and 10 hours off between shifts at constant traffic levels. For two of the three demand curves, one additional employee was needed if the off-duty period was increased from 8 to 9 hours (in this hypothetical scenario, 22 controllers instead of 21 are required for "flat," and 24 controllers instead of 23 are required for "camel"). The number of controllers did not increase further if the off-duty period increased to 10 hours. However, with 10 hours off between shifts, schedules generated by the tool resulted in start and end times that were somewhat atypical, which could be considered a disruption by controllers in terms of rescheduling their work and commute times (Grant Thornton 2013).

Ultimately, a full FRMS implementation—similar to that of ANSPs in other countries[17]—will build not only on policy and training but also on tools at local facilities that plan controller duty schedules with consideration of fatigue risk and provide immediate decision support to managers in changing schedules at short notice in response to unexpected events. While FAA is headed in this direction with the OPAS tool, program implementation is still in its infancy, concerns about the software and its utilization remain unresolved, and the target date for

[16] The three demand curves include "flat," with no major demand peaks; "camel," with limited demand peaks; and "multipeak," with numerous demand peaks. The only variable that changed was the time between shifts.

[17] For example, Airservices Australia reported to the committee that its enhanced FRMS was implemented in 2012.

its implementation appears to have slipped.[18] Furthermore, the controller workforce may resist the implementation of any scheduling tool if it results in significant changes in common scheduling practices at the facility level. Changes in scheduling practices would be easier to justify to the workforce if they were substantiated by data and monitored for unintended side effects, as originally planned in the implementation of the FRMS program's activities. However, recent budget cuts to the FRMS program have hampered progress toward its goals.

MOVING FORWARD: MONITORING FOR STAFFING'S IMPACT ON SAFETY AND ON SAFETY CULTURE

As discussed earlier, ATC-related accidents since 1990 have been a small proportion of accidents from all causes. This safety level reflects the steady professionalism of controllers and FAA, yet evaluating this level of safety is problematic. Various FAA organizations gather data related to safety; examples include data on incidents violating various safety criteria without causing accidents, records of actual operations, and voluntary controller reports from ATSAP.[19] Many of these metrics are marked as proprietary or confidential and were not available to the committee, which limited its ability to assess data. Accordingly, the committee is uncertain whether current FAA practices monitor this safety record sufficiently to identify where further safety improvements can be made. The committee is even less certain whether these practices analyze the association between ATC-related accidents and incidents and staffing indicators,[20] such as overall staffing levels relative to staffing targets, the use of overtime, and fatigue risk factors. The examination of accident data has been useful in other

[18] "FAA plans to implement OPAS at 15 FAA facilities by the end of fiscal year 2013, and achieve nationwide implementation in the fiscal year 2016–2017 timeframe" (OIG 2013a, 16).

[19] The committee received indications from FAA that data are collected and that various metrics are generated, analyzed, and acted on. However, the committee did not receive examples of these data or how the data are analyzed. See http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/safety/media/NSF-Presentation-final-for-web.pdf, prepared by Joseph Teixeira, FAA, May 2013.

[20] As reported to the committee, FAA does not actively analyze relationships between safety and staffing levels (Joseph Teixeira, FAA, briefing to a subgroup of the committee at FAA headquarters, January 6, 2014).

areas of aviation safety analysis (Oster et al. 2013), and FAA is encouraged to examine ATC-related accidents and incidents more closely. For example, determination of how these accidents and incidents varied across industry segments and ATC facility types might be possible (see Pape et al. 2001). Such analyses could be helpful to FAA in reducing ATC-related accidents and incidents stemming from various causes and types of operations. Furthermore, changes in staffing practices or staffing levels might reduce the safety of ATC operations and lead to an increase in ATC-related accidents and incidents. An understanding of the possible link between staffing practices, staffing levels, and ATC-related accidents and incidents would require a better understanding of ATC-related accidents, their causes, and when and where they have occurred.

Investigation of the impact of controller staffing levels on safety is complicated by FAA's ability to limit the number of ATC operations it must manage. For example, faced with reduced controller staffing levels, the agency can decide against opening a sector to accommodate more traffic during busy periods and can order pilots to hold flights on the ground until FAA controllers can accept them, with resulting flight delays. Such built-in adjustments to air traffic management procedures complicate efforts to relate staffing to safety because the impacts of inadequate controller staffing levels are manifested as a degradation in the performance of the NAS (i.e., in flight delays) rather than as a reduction in safety.[21]

The level of safety reflects not only individuals' actions but also the broader organization's collective functioning in preventing and mitigating risks where they are possible to predict and in committing to monitor for and address unpredictable risks as they emerge. Some of these collective functions can be captured by a centrally organized SMS, but recent efforts in aviation and other disciplines have characterized how safety is reflected through the organization as a "safety

[21] In late April 2013, reductions in controller staffing due to furloughs associated with the sequester led to some flight delays, particularly in congested airspace in the New York City area (Elias et al. 2013). However, some of these delays were attributed to weather problems at key hub airports rather than to reduced controller staffing (Lowe 2013). Experience during the sequester does not provide robust, quantitative evidence about the impacts of reduced controller staffing levels on the performance of the NAS over a prolonged period.

culture." Such a culture may be defined as "the product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's safety programs. While there are many methods for promoting a safety culture, and no one metric by which it may be judged, organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measures" [U.K. Health and Safety Commission, as cited by Reason (1997, 194)]. The following paragraphs examine the extent to which FAA's staffing processes may support or hinder key components of safety culture.[22]

While safety culture covers a broad range of concerns, several aspects of safety culture are important to this committee's charter to examine FAA controller staffing. First, safety is promoted within an organization when it is "informed," that is, when "those who manage and operate the system have current knowledge about the human, technical, organizational and environmental factors that determine the safety of the system" (Reason 1997, 195). Safety data would ideally be linked with facility-specific staffing data to determine, for example, whether the frequency of various types of incidents or safety reports is associated with staffing levels relative to a benchmark or standard. These and other analyses could provide insight into the effects of changes in staffing levels or practices on safety. Such analyses (and supporting data) with regard to the NAS are scarce. Databases of potential value include but are not limited to FAA's ATSAP, which allows controllers (and others) to identify and report safety and operational concerns voluntarily; the Aviation Safety Reporting System, which collects voluntarily submitted aviation safety incident and situation reports from pilots, controllers, and others; and operational databases that record when each controller is on duty and could be examined for a controller's work history to determine whether fatigue, for example, may have contributed to an incident.

[22] For more recent research on safety culture and air traffic control, see Mearns et al. 2013, Ek et al. 2007, and Gill and Shergill 2004.

The committee was concerned with whether the requisite data are consistently collected and whether appropriate plans are in place to analyze the data to inform staffing decisions. For example, in reviewing the Traffic Analysis and Review Program (TARP), the OIG (2013b) pointed out shortcomings in the collection of program data and in integration with other data. GAO has pointed out shortcomings in FAA's collection and analysis of incident data (GAO 2011; GAO 2012). Furthermore, the implementation of FRMS has been effectively curtailed by eliminating proactive research into fatigue risks and potential fatigue mitigations in controller staffing and scheduling.

FAA has effectively limited the ability of outside researchers to provide the independent and in-depth analyses of safety that, historically, were provided by the academic and research community. While the collected information in FAA's Aviation Safety Information Analysis and Sharing (ASIAS) System[23] features both public and proprietary data, many of the collected incident data are not available to outside researchers. A recent OIG (2013c) report criticized the limited use of ASIAS data by FAA's own workforce, especially among its field inspectors, and recommended better dissemination of and guidance on the use of aggregated and de-identified ASIAS data to help in distinguishing safety trends. FAA's external Research, Engineering, and Development Advisory Committee recently wrote the FAA Administrator as follows: "Realizing the full potential of 'Big Data' will require development of data access policies allowing the most open possible access to researchers and other users while providing appropriate data protections . . . enabling a level of effort in this data analysis greater than can be conducted in-house by the FAA alone."[24]

A second aspect of a safety culture is the promotion of safety within an organization through the fostering of reporting by members of the workforce themselves about hazards that they experience. This reporting function is the intent of FAA's ATSAP. The committee received a general briefing on the program and a copy of the form that controllers fill out when they file a report, but it did not receive responses to detailed

[23] As the data steward and integrator for ASIAS data, the MITRE Corporation maintains all the data and prepares any aggregated results for the purposes of information sharing.

[24] Letter to the Hon. Michael Huerta, October 2, 2013.

requests for data or analyses performed by FAA on the data and thus could not assess the program directly.[25] Noting similar concerns with whether FAA is suitably informed by appropriate collection of accident data and by the collection and integration of TARP data, the OIG pointed out shortcomings in the collection and use of ATSAP reports provided by controllers in 2012 and 2013 (OIG 2012b; OIG 2013b). The committee's discussions with FAA officials indicated that efforts to perform such analyses are expanding and that there are difficulties with "stovepiped" data sets, where one organization within FAA may be unaware of or find difficulty in accessing and incorporating data sets held by other organizations.

A third important aspect of a safety culture is that it must foster learning from history and from current experiences and translate such learning into the appropriate reforms. At the facility level a positive step is the nascent Partnership for Safety program, which seeks to establish (by June 2014) local safety councils at each air traffic facility to identify and resolve safety concerns as they are reported. As of January 2014, 22 of 23 en route facilities and 84 of 292 terminal facilities had completed local safety council training.[26] Accounts suggest that at least some controllers may perceive that they do not have the time to contribute ATSAP reports and join in the local safety councils or that the reports are not worth providing because they do not lead to improvements, which may temper the impact of these collaborative efforts.[27] More objectively, the committee found that the time required by controllers to participate in these councils is not included in the processes for determining facilities' staffing levels, as described in Chapter 3. Thus, the formation of these councils has no impact on the assessment of required staffing levels. In the committee's view, this suggests that a reporting culture may not be fostered

[25] For example, in a briefing to the committee, FAA reported that approximately 10 percent of the 30,000 ATSAP reports submitted since May 2011 contained fatigue-related input (Rick Huss, FAA, November 22, 2013). The committee was unable to obtain additional details about this input or how FAA uses it.

[26] PowerPoint document titled "Officers Group Brief: Safety and Technical Training, January 2014" provided to the committee on February 19, 2014.

[27] Andrew LeBovidge, committee member and NATCA representative, personal communication to Safety subgroup of the committee, March 19, 2013. Also, Dean Iacopelli and Eugene Freedman, NATCA, presentation to the committee, January 2013.

in facilities where staffing concerns may warrant monitoring yet limit controller availability for providing reports and participating in collaborative safety teams.

Activities such as the Partnership for Safety program seek not only to gather and analyze data but also to translate the information into actionable responses that will prevent, reduce, or mitigate safety concerns. In the committee's view, this aspect of safety culture is obstructed by a perceived lack of transparency in determining staffing targets and in carrying out hiring and transfers to achieve those targets. As a consequence, staffing levels that support robust data collection, analysis, and subsequent corrective action may be compromised. Similarly, the benefits of FRMS will be achieved only when the appropriate tools are in place and when the reasons for changes in scheduling according to fatigue risk management best practices are substantiated and clearly communicated.

SUMMARY

This chapter reviews the safety record of aviation and the role that air traffic controllers play in that record. The chapter considers how best to analyze any possible relationship between aviation safety and ATC staffing. GA accounted for 94 percent of both total accidents and all fatal accidents and for 82 percent of all fatalities over the past 22 years—far more than commercial aviation, which included air carriers and air taxis and commuters.

According to NTSB accident investigations reviewed by the committee, ATC was considered either a cause or a factor in 66 fatal accidents during the same 22-year period, or about 0.8 percent of all fatal accidents, which indicates that ATC has not been a major cause of or factor in aviation accidents in the past. Of the 66 fatal accidents linked to ATC, GA accounted for 86 percent.

Discussions of ATC safety often focus on maintaining safe separation between aircraft and on incident data that concentrate on loss of separation. Even controller workload models tend to focus on tasks related to separation. Yet almost 70 percent of fatal ATC-related accidents involve single aircraft and controllers' failure to provide required safety information, and 91 percent of those fatal accidents involved GA. Staffing models of controller workload and analyses of safety data that include controller duties other than preventing loss of separation—such as providing safety information to pilots—would more accurately reflect controllers' impact on accidents and would result in a more refined baseline of staffing requirements.

Published OIG reports indicate that contract towers deliver ATC services at a comparable quality level, provide these services at a lower cost, and have a lower number and rate of safety incidents than similar FAA towers. The committee has reservations about OIG's findings relating to safety because of (*a*) the difficulty of establishing analogous groups of FAA and contract towers for comparison purposes and (*b*) the differences in safety reporting practices at the two types of tower. In addition, GAO reports that comparison of operational error rates alone is insufficient to draw conclusions about the relative safety records of different ATC facilities.

Fatigue is a risk factor for errors and accidents frequently encountered in ATC operations. The risks associated with controller fatigue are well known, and efforts to educate controllers about fatigue issues and to use best practices that address fatigue through more efficient scheduling are encouraged.

Because of the limited fatigue-related data that have been collected in accident and incident reports, the committee is unable to determine the extent to which fatigue has affected safety. The treatment of fatigue concerns in accident and incident reports by FAA and NTSB has been variable, and important elements of information relative to fatigue are often not included.

The full implementation of an FRMS could mitigate fatigue in a more comprehensive manner and could help support the requirement for better data collection and reporting. However, recent budget cuts threaten to limit FRMS's capability of monitoring for fatigue concerns and taking appropriate actions.

Any SMS needs a positive safety culture to reinforce an organization's safety goals. A positive safety culture does not just materialize; it develops over time and is characterized and maintained through vital components such as the sharing of information, reporting, and continuous monitoring and learning—functions that must be accounted for within staffing plans.

FINDINGS AND RECOMMENDATIONS

Finding 2-1. FAA's and NTSB's methods for collecting and categorizing safety data are insufficient for establishing the relationship between ATC-related accidents and incidents and staffing indicators such as overall staffing levels relative to staffing targets and overtime.

Finding 2-2. FRMS has a scientific basis in other domains and with other ANSPs. Full execution affects staff planning, generation of intended schedules during staffing implementation, and adjustments to schedules during day-to-day operations. However, there are still practices (like the popular 2-2-1 schedule) that appear questionable from a fatigue management perspective, and mitigation may require adjustments in staffing levels. Recent initiatives to address fatigue through policy and training have not had sufficient follow-up evaluation to verify that they provide the intended fatigue risk mitigation. Furthermore, full implementation of FRMS will require the proper tools for scheduling controllers' shifts and adjusting them on short notice in response to unexpected events and for relating these schedules to staffing levels during staff planning.

Finding 2-3. Safety results not just from the performance of individual controllers but also from the ability of the organization to foster a collective safety culture. The safety culture is affected by staffing, since staffing levels either foster or obstruct reporting, evaluation, and learning within the organization. Such reporting, evaluation, and learning are necessary for the implementation of an SMS (including safety management focusing on fatigue, i.e., FRMS).

Recommendation 2-1. To analyze the fatigue-related hazards associated with staffing levels and to assess the effectiveness of mitigation strategies, **FAA should ensure that factors increasing the likelihood of fatigue are clearly documented in incident and accident reports.** Such factors can include information on prior shift schedules, time on position, and traffic density and complexity.

Recommendation 2-2. The safety of the NAS has highest priority. **FAA should ensure full implementation of an FRMS, with sufficient resources**

for proactive analysis of potential fatigue concerns and mitigations and with follow-up evaluation of all changes in policy, training, and scheduling. Before claiming success for any recent (and future) initiatives addressing controller fatigue, FAA must ensure that these initiatives are assessed properly and are having their intended impact once they are implemented at local facilities.

Recommendation 2-3. FAA should accelerate the implementation of a scheduling tool that can be used to determine staffing standards and to generate schedules at the facility level (e.g., OPAS). Safe scheduling in terms of fatigue may require the incorporation of biomathematical models into a tool that can optimize schedules relative to staffing and to fatigue, or at least illuminate schedules that do not reflect best practices with regard to fatigue management.

Recommendation 2-4. FAA should ensure that staffing levels are sufficient to foster appropriate reporting by controllers and to enable controller involvement in organizational learning and responses to safety issues (such as safety councils). In support of recent collaborative initiatives between FAA and NATCA, FAA should monitor for situations or facilities where staffing and scheduling issues may be obstructing full controller participation in these safety functions.

Recommendation 2-5. To ensure that staffing decisions are properly informed and to help communicate the basis of these decisions throughout the organization, **FAA should promote data collection and analysis to improve identification of key relationships between controller staffing and safety.** Specifically, (*a*) the data should consistently include relevant staffing and fatigue concerns so that they can be considered in the analysis, considered in accident and incident investigations, and incorporated into the appropriate questions in the forms underlying safety reports; (*b*) the data should be compiled and stored in a way that allows integration of data sets (e.g., integration of staffing records with incident reports); (*c*) the appropriate data analyses should be conducted to examine where and how controllers have contributed to accidents and incidents to help inform the models of controller activity underlying staffing standards—including whether controllers have adequate time both to separate traffic and to issue safety alerts, as required by FAA Order 7110.65—and to identify relationships between staffing and safety; and (*d*) especially in view of the limitations on FAA resources, FAA should ensure that enough researchers have access to the data to provide the range of perspectives and expertise necessary for identifying how staffing concerns relate to safety.

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Abbreviations

GAO	Government Accountability Office
ICAO	International Civil Aviation Organization
OIG	Office of Inspector General, U.S. Department of Transportation

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3

Evaluation of Staffing Standards

The Federal Aviation Administration (FAA) describes staffing standards as mathematically derived assessments of required staffing that relate controller workload and air traffic activity on the basis of "staffing to traffic." This chapter describes how the standards are generated. FAA's staffing standards are not the sole determinant of staffing levels; they are one of several inputs into staffing ranges and FAA's hiring plan.

The chapter reviews the formal staffing models and the process underlying the staffing standards. It examines the process by which the standard is estimated for each facility. The two uses of the standards—as input for the staffing range and for determination of the staffing target for the hiring plan—are described. The chapter ends with a discussion of how the standards (and resulting staffing ranges) are communicated to the field, how feedback from the field is provided to headquarters for the central generation of staffing standards, and how the standards and their implementation may be improved by the coordination of scheduling at facilities with central planning.

MODEL-BASED GENERATION OF STAFFING STANDARDS

The staffing process up to the generation of the staffing standards is summarized in Figure 3-1. The standards are inputs to the staffing ranges published in the controller work plan and the hiring plan. The following subsections describe each of the processes in the order shown in Figure 3-1.

On-Position Staffing Models

The staffing standards process starts by applying models of controller activity and workload that identify the number of on-position controllers

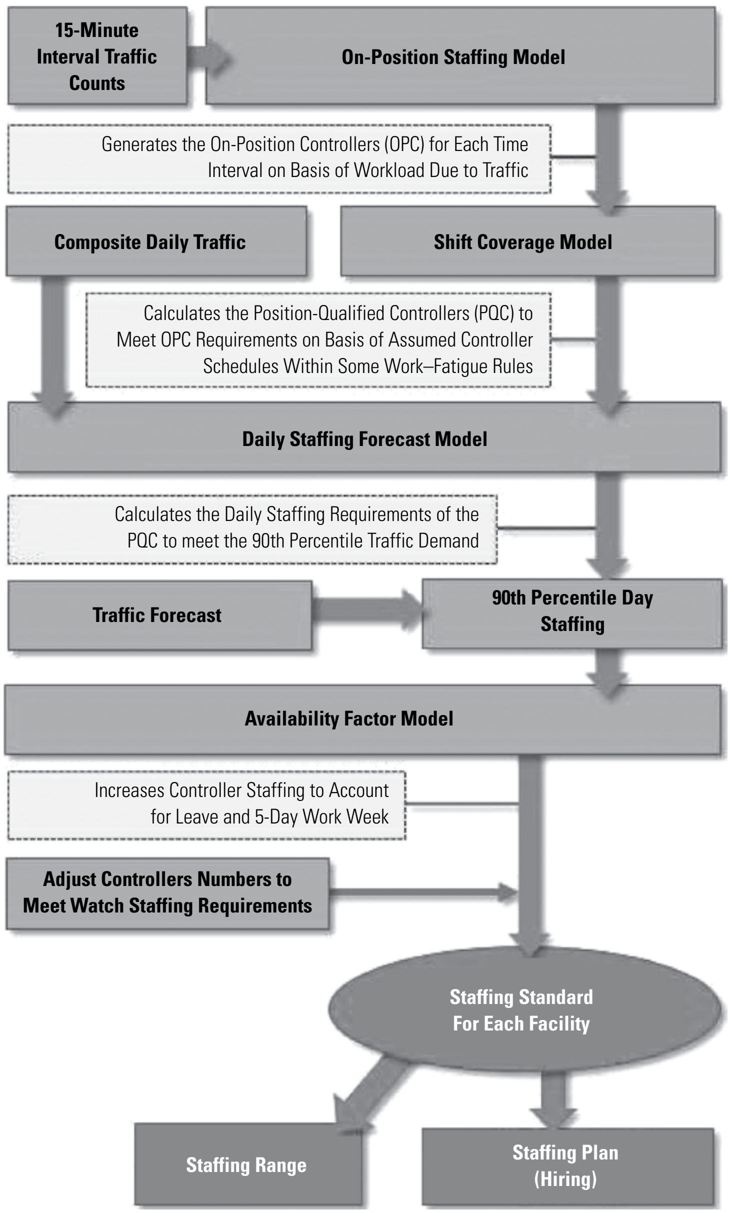

FIGURE 3-1 Planning process leading to generation of staffing standards as inputs to the staffing range and hiring plan. (NOTE: As of FY 2014, the hiring plan is calculated on the basis of the staffing range rather than the staffing standard. SOURCE: Generated by the committee.)

(OPCs) required to control traffic within 15-minute intervals. Because controllers in different facilities have significantly different tasks, separate models exist for en route centers, towers, and terminal radar approach control (TRACON) facilities. The en route model has been reviewed previously, but part of the committee's charter is to examine that model in particular. The next section reviews the en route center on-position staffing model and discusses its status in the context of the prior reviews. The on-position staffing models for tower and TRACON facilities are then examined.

En Route Centers

As described in Chapter 1, an en route sector is staffed by one, two, or (rarely) three controllers, depending on the amount of traffic. Multiple sectors may be combined into one large sector or a large sector split into smaller sectors to create the correct balance between the amount of traffic within each sector and the number of OPCs.

A Transportation Research Board (TRB) committee (see TRB 1997) reviewed FAA's staffing models for terminal facilities and en route centers and questioned the parameter then used: simple counts of the number of flights within a specific area of airspace. Although FAA's staffing models were adequate for estimating national workforce needs, the committee observed that the models were too general to predict facility-level needs and often produced higher values than those from managers at the facility level. Put another way, the models did not account for how the complexity of an air traffic situation affects "controlling capacity."

Thus, the 1997 study committee recommended that FAA develop quantitative staffing models that considered air traffic complexity. Specifically, the committee recommended modeling the time controllers spend in executing the observable tasks associated with air traffic control (ATC) to estimate a controller's "task load," which could then be analyzed to identify the number of sectors and the number of controllers within each sector required in each 15-minute traffic interval.

On the basis of the report's recommendations, in the decade that followed MITRE Corporation's Center for Advanced Aviation Systems Development converted a "task-based" model (developed for other purposes) to serve as an on-position staffing model. Figure 3-2 presents its

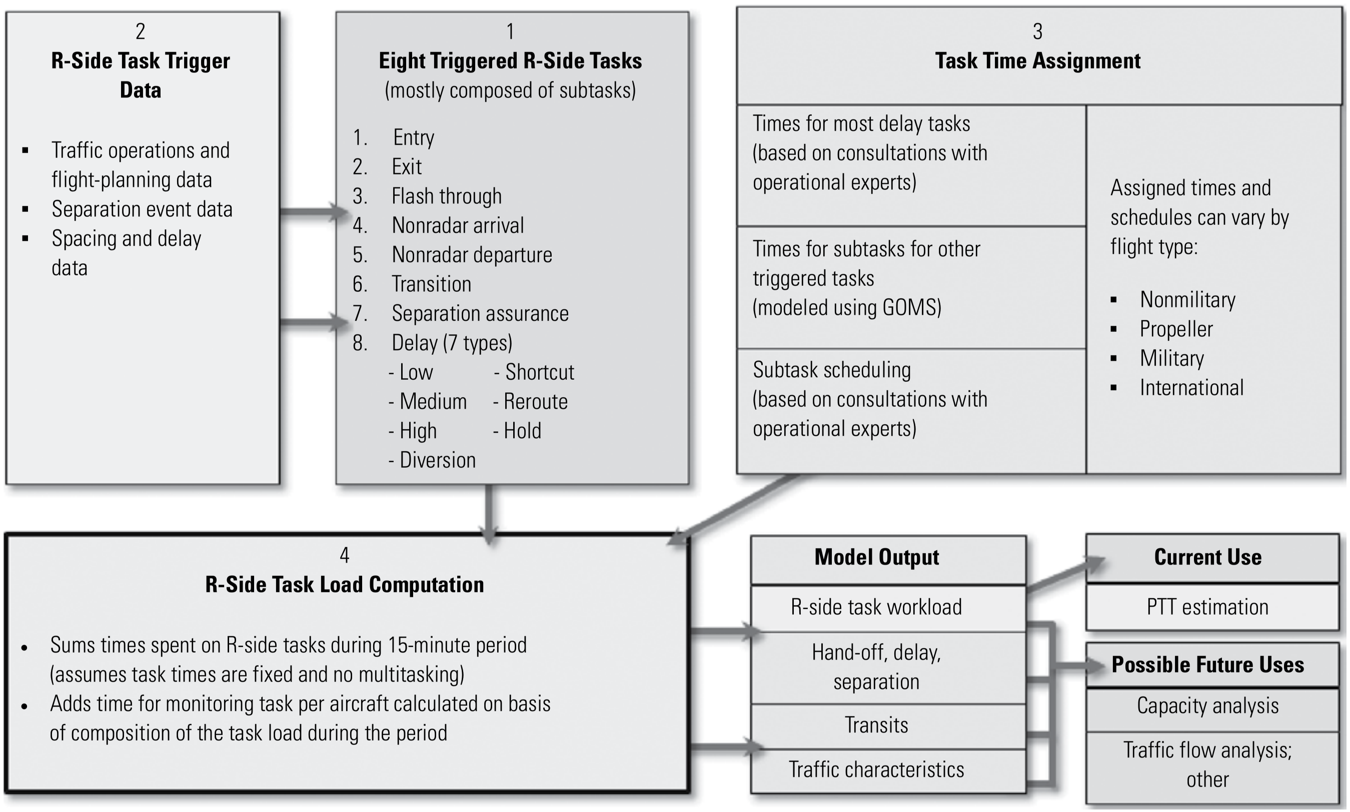

FIGURE 3-2 General structure of task load model. (NOTE: GOMS = goals, operators, methods, and selection rules; PTT = positions to traffic. SOURCE: Generated by the committee.)

basic structure. Box 1 in the figure shows eight of the model's nine major radar (R-side) tasks. Tasks of the lead R-side controller trigger associated subtasks, some of which comprise detailed cognitive tasks represented by the goals, operators, methods, and selection rules (GOMS) construct. These tasks are triggered by traffic events for which historical data for that sector are available (Box 2). All identified tasks and associated detailed subtasks (Box 3) are divided into basic operators, and an execution time is assigned for each operator. The operator execution times are summed to calculate the total time required for performing each subtask, and ultimately each task, for each 15-minute period of the day. Thus, the time for each task is the sum of estimates of the times required for multiple cognitive subtasks and is not based on direct observations of controllers performing the tasks. Additional time for monitoring each aircraft—the MITRE model's ninth R-side task—is assigned at this point (see Box 4). The MITRE model assumes that tasks are completed in sequence and that the times required for each task are independent of one another.

To date, the MITRE task load model only includes the tasks associated with the R-side controller to assess traffic capacity and does not include related data (D-side) tasks. However, determining the "positions to traffic" (PTT)—the estimated number of controllers (one, two, or three) required for handling a sector's air traffic during a 15-minute period—requires knowledge of the total R-side and D-side task load. The MITRE model used "fuzzy logic modeling" to account for additional traffic complexity and total task load from the modeled R-side tasks. The fuzzy logic method weights an R-side task according to the task's perceived D-side complexity. The weightings were based on input from operational experts and regarded as valid depictions of D-side task loads, even though D-side task were not explicitly identified and quantified.

MITRE has been applying this model for FAA since 2007 to support the generation of staffing standards.[1] In 2009 FAA requested that TRB conduct a follow-up study of the model. The request called for an expert review of the MITRE model's methodologies and its capabilities for estimating en route sector PTT. The committee that performed the study noted that a task-based approach is an improvement over earlier models

[1] See http://www.faa.gov/air_traffic/publications/controller_staffing/ for the most recent air traffic controller workforce plan.

in that it accounts for traffic complexity, and the committee noted that the model uses available traffic data. That committee made three recommendations (see TRB 2010, 63–64), which shaped this committee's questions to FAA and MITRE.

The first recommendation, summarized as "observe and measure controller task performance," addressed questions concerning how tasks are modeled. The report noted that task times for seven of the nine modeled tasks are derived by summing subtask times that are not based on data from the field, while task times for the remaining tasks are based on input from subject matter experts—that is, task times are not derived from observing or analyzing controllers performing the tasks in the field or in experiments. The assumption that tasks are performed sequentially and separately does not consider the possibility that certain tasks are performed concurrently and does not account for variability in task completion times due to fluctuating levels of traffic activity and number of controllers working the sector.

MITRE has since reported to this committee that field observations were made in July 2013, with ongoing analysis and comparison with human-in-the-loop simulation data through 2014. The committee was not provided with sufficient detail to ascertain the extent of the completed and planned observations needed to develop and validate the model.

The second recommendation of the 2010 TRB committee, summarized as "model all controller tasks," noted that the model's inclusion of nine R-side tasks appears representative of the work performed by the lead controller and "may be sufficient" for analyzing traffic capacity. However, omitting all D-side tasks—those performed by the associate controller—makes the model's task load output "inadequate for estimating PTT." The model compensates for the lack of the D-side task load only by using techniques "that infer total task load" to estimate PTT. The techniques for converting the model's total task load to PTT, such as fuzzy logic modeling, are similarly flawed—the methods rely on operational experts for an understanding of total task load instead of identifying and measuring the time required for a controller to perform the D-side tasks.

MITRE has since reported to this committee that its field and laboratory human-in-the-loop evaluations are designed to collect data on both the R- and D-side controller tasks and task times. MITRE further reported as follows: "The need to explicitly model D-controller tasks and add such a capability to the model will be determined by the cost vs. the potential amount of benefit to be gained, as the capability to directly model D-side tasks may or may not be feasible based on the availability of and/or accessibility to D-side task trigger data" (MITRE 2013, 2).

The third recommendation of the 2010 TRB committee, summarized as "validate model elements," noted that key assumptions within the model—including the summation of subtasks to find total task time and conversion of R-side task time to PTT—had not been validated. The conversion of the model from its original purpose of estimating sector traffic capacity relied on estimates from subject matter and operational experts; the model was not based on tasks for which measurable performance data existed or could be gained. The 2010 study committee did not find strong documentation that explained the model's logic and structure or that established and validated the model's parameters, assumptions, and outputs.

The recommendation emphasized that validation should examine the underlying model itself, particularly assumptions that concern task performance by the controllers when they work alone and in teams, whether tasks are performed sequentially or concurrently, and how total task load affects the pace of task performance. This approach would justify the model's role as an independent assessment of controller staffing. That role would be negated if the model itself is adjusted to match the current controller staffing level.

MITRE subsequently reported to this committee several model development and validation activities. As noted earlier, MITRE plans a cost–benefit analysis for incorporating the D-side controller, and it plans an evaluation of the accuracy of the task times estimated by GOMS. The results of this evaluation might enable replacement of the fuzzy logic modeling of monitoring with data gathered during human-in-the-loop simulations in a laboratory, and they might verify or contradict inferences and assumptions inherent in the current model of how the R- and D-side controllers interact. With this information, MITRE plans to identify tasks that the model needs to but does not yet account for. The intended validation of the thresholds to move from one to two controllers is to apply postscenario verbal protocol analysis during laboratory human-in-the-loop simulations in which controllers will be asked to identify the time at which they believe the D-side controller should have been added to support the R-side for each scenario, and their opinions will be contrasted with the thresholds of the model.

The discussions indicated that MITRE's plan for observations and for validating the model may lead to large structural changes, which may require further validation. Such validation would almost certainly extend the overall timeline well beyond the currently estimated September 2014 completion date (MITRE 2013); in the interim, staffing standards would continue to be based on unvalidated model output. MITRE reported the following (MITRE 2013, 3):

> One of the goals is to use the results of the evaluation effort to determine if any layers of complexity can be removed from the model while retaining its ability to accurately reflect the historical task workload and estimate the number of controllers needed to service the traffic. A fundamental question that MITRE's evaluation is intended to answer is: "Do improved task times and task coverage from empirical observation and measurement of controller task performance along with enhanced information on task workload thresholds allow for the removal of data-fitting elements like Fuzzy logic modeling from the model?"

The charter of this committee was broader than that of the 2010 TRB committee. In this broader context, the committee noted that the MITRE model has an extreme level of detail and includes some subtasks that are difficult to model quantitatively and for which there are no observable data. Such detail will require significant time and expense to develop and validate and will be difficult to extend to new controller tasks such as those anticipated with the Next Generation Air Transportation System (NextGen, as discussed in Chapter 5).[2] Indeed, MITRE's response above questions its own model's complexity. In addition, as noted in Chapter 2, the model is intended to reflect the tasks believed to drive controller workload, which are largely focused on traffic separation. The control-

[2] As noted in a recent report on FAA's airway transportation systems specialists, a "robust and accessible staffing model should be capable of incorporating . . . additional inputs as they become available, not only with respect to NextGen but also with respect to inevitable technological advances" (NRC 2013, 4).

lers' advisory functions are for the most part not included in the model and will not "roll up" in its summation of task time.

Tower Facilities On-Position Staffing Model

FAA updated the on-position staffing model for tower facilities in 2008.[3] The model applies to 260 FAA-controlled facilities—130 stand-alone tower with radar (Type 7) sites and the tower portion of 130 combined TRACON–tower (Type 3) sites. It is documented in a report by an FAA–Grant Thornton study team.

The model's underlying assumptions are that the predominant driver of workforce size is traffic volume and that controller workload (consisting of communication with pilots, airport staff, and other controllers) changes with volume. Accordingly, traffic volume is the input. For each tower facility, traffic data include all departures, arrivals, and local flight operations recorded in hourly intervals, 24 hours a day, 365 days a year. (Hourly counts are divided by four to get 15-minute counts for the on-position staffing model.) All categories of traffic are included—air carrier, air taxi, general aviation (GA), and military.[4] The study team visited 20 percent of the towers (representative of various types and levels) to observe and collect data relating traffic operations and controller workload. Its internal "communication model" is constructed as a regression analysis with traffic volume as input. The dimensions of the traffic input for towers are as follows:

- GA arrivals and departures,
- Non–GA arrivals and departures,
- Touch-and-go landings[5] (not included in the previous two dimensions), and
- Overflights [for the Type 7 (tower with radar) facilities].

The output of the regression, controller workload, is communication measured in minutes, with a regression equation for each facility level.

[3] Rich McCormick, PowerPoint briefing to the committee, February 4, 2013.
[4] The data are collected and maintained by the Air Traffic Organization in the Operations Network.
[5] A touch-and-go landing involves landing on a runway and taking off again without coming to a complete stop.

For each 15-minute interval, the model converts traffic operations to controller workload (in communication minutes) for a given crew size. A capacity factor analysis makes an assessment to predict the number of OPCs required to accomplish the workload. This number includes both certified professional controllers (CPCs) and non-CPCs—CPCs in training and developmentals—who are qualified to perform some of the necessary functions of each facility. As a result, the model's output is not exclusively in terms of CPCs (FAA 2013a, 6; FAA 2013b, 7). The capacity factor analysis is performed with different parameters for each "level" of tower facilities reflecting the nature of the tower operations and positions that may need to be staffed.

As noted in Chapter 2, the model is intended to reflect the tasks believed to drive controller workload, which are largely focused on traffic separation and nominal communications. The controllers' other functions are not explicitly included in the model. Because the workload model is regressed to observed workload, the impact of these additional functions is implicitly covered to some degree in the rating of acceptable workload levels (on the modeled tasks) to OPC requirements for the traffic situation.

TRACON Facilities On-Position Staffing Model

FAA updated the on-position staffing model for TRACON facilities in 2009.[6] The model applies to 157 FAA-controlled facilities: three consolidated TRACON (Type 9) sites, 24 stand-alone TRACON (Type 2) sites, and the TRACON portion of 130 combined TRACON–tower (Type 3) sites. A study team (with many of the same members as the team for tower facilities) documented the TRACON model (FAA 2013b).

From a big-picture point of view, the model for TRACONs performs the same function as the on-position staffing model for towers, namely, the conversion of traffic input for a 15-minute interval to the number of OPCs required for that interval. However, the key factors underlying the model are sector type and workload type. A sector is

[6] Rich McCormick, PowerPoint briefing to the committee, February 4, 2013.

dynamically designated as one of the following types: departure, feeder, final approach, or mixed (FAA 2013b, 21).

Estimated controller workload is the aggregate of three component workloads, which are uniquely specified for the sector type. The component workloads are as follows:

- Fixed workload, that is, "time spent on tasks . . . not directly dependent on the number of aircraft in the system" (FAA 2013b, 25);
- Variable workload, that is, "time spent on activities that are dependent on operational activity in the airspace and incorporates the complexity metrics" (FAA 2013b, 26–27); and
- Active scope workload, that is, "time the controller must monitor the scope due to the complexity of airspace" (FAA 2013b, 29).

Although no "communication model" is explicitly described in the TRACON model report, the sector type and workload type equations perform the comparable function in that they estimate workload (controller activity measured in minutes) on the basis of traffic and other inputs. A capacity factor representing the maximum sustainable workload in a 15-minute period is applied to the aggregated fixed, variable, and active scope workloads. Again, the output of the model is the number of OPCs for each time interval.

As in the case of the tower model, the TRACON model is intended to reflect tasks believed to drive controller workload, which are largely focused on traffic separation and nominal communications. The controllers' other functions are not explicitly included in this model. Because the workload model is regressed to observed workload, the impact of these additional functions is implicitly covered to some degree in the rating of acceptable workload levels (on the modeled tasks) to OPC requirements for the traffic situation.

Shift Coverage Model

Once the on-position staffing models provide an estimate of OPCs for each 15-minute time interval, the shift coverage model (SCM) determines the optimal number of controllers for meeting the on-position staffing requirements for a 24-hour day. This number is called the position-qualified controller (PQC) staffing level. It accounts for some general scheduling constraints, including the following:

- A 30-minute break for a meal within a specified window in the shift;
- Two nonconsecutive rest periods, each at least 15 minutes;
- No more than 2 consecutive hours on position; and
- The capability of allowing 8, 9, or 10 operational hours in a shift (the default maximum is set to 8 hours).

These constraints represent important concerns, but they do not reflect all of the requirements associated with FAA policy and practices or with the collective bargaining agreement. In particular, the SCM does not take into account constraints that can cross a 24-hour (midnight to midnight) period. Examples are minimum breaks between shifts (an 8-hour break before the start of evening and night shifts, a 9-hour break before the start of a day shift, and a 12-hour break after a night shift) and a maximum of 6 consecutive days without a day off.

During one demonstration to the committee, the SCM generated outputs that were not consistent with the scheduling constraints above. Furthermore, as reported to the committee, the model's output is not always optimized to generate the minimum number of shifts to satisfy OPC requirements.

Daily Staffing Forecast Model

The daily staffing forecast model (DSFM) is a regression analysis designed to estimate the daily staffing requirements (DSRs). The DSRs can be thought of as the number of controllers present for duty at a facility each day to meet the on-position staffing requirements for each 15-minute interval. The regression maps historical total operations data[7] to the output of the SCM to find the PQC associated with the 90th percentile day of operational traffic data.[8]

[7] For FY 2014, the Office of Labor Analysis reports that the Traffic Count Index Program has replaced the Terminal Track Analysis Program.

[8] For a future year, the 90th percentile operations count is modified by the traffic forecast factor.

TABLE 3-1 Percentage Change in DSRs Relative to Varying Percentile Days

	Percentile Day Chosen					
Facility	**100th**	**90th**	**80th**	**70th**	**60th**	**50th**
Terminal facility	10	0	–3	–5	–6	–8
En route center	7	0	–2	–4	–5	–7
Overall	9	0	–3	–4	–6	–8

SOURCE: Data provided by FAA; table generated by the committee.

At the committee's request, the Office of Labor Analysis (ALA) made multiple model runs in which only the percentile days chosen in the DSFM were varied, as shown in Table 3-1. The controller workforce could be 9 percent larger if it were sized to the heaviest traffic day. Conversely, it could be 8 percent smaller if it were sized to the median traffic day.

Therefore, the implications of choosing this percentile should be considered. The choice of the 90th percentile would result in acceptable staffing 90 percent of the time and in low staffing 10 percent of the time. From an operational perspective, low staffing is generally reflected in delays in providing services to pilots. This apparently conservative choice may compensate for unmodeled aspects of controller staffing. Thus, the impact of a change in this percentile threshold on safety and delay may be complex.

Traffic Forecasts and 90th Percentile Day Staffing

Air traffic forecasts are necessary inputs in the preparation of air traffic controller staffing plans because the DSR values provided by the DSFM are scaled to match the 90th percentile day *forecast* (see Figure 3-1). The amount of look-ahead time is matched to the time required to train new controllers for each facility. Thus, for some facilities a 1-year forecast is used, for others a 2-year forecast is used, and for the most complex facilities requiring the most training time a 3-year forecast is applied.

The forecasting process is independent of the staffing standards process. The forecasts of primary interest are those concerned with the number of aircraft operations at (*a*) airports with FAA-operated towers, (*b*) TRACONs, and (*c*) en route centers. FAA's Forecast and Performance Analysis Division of the Office of Aviation Policy and Plans generates the forecasts on an annual basis. Forecasts for towers and TRACONs, including national totals, are provided in the Terminal Area Forecasts (TAF)[9] and summarized in FAA's annual *Terminal Area Forecast Summary Report.*[10] Summaries of forecasts of en route [air route traffic control center (ARTCC)] operations are published in FAA's annual report *Forecasts of IFR Aircraft Handled by FAA Air Route Traffic Control Centers.* The appendix presents a brief description of the methodological approach used in preparing these forecasts. The description is, of necessity, based primarily on interviews with FAA personnel[11] and a review of a small number of technical papers. Detailed reports documenting FAA's forecasting models and methodology either do not exist or could not be provided in response to the committee's requests during its deliberations.

Forecasting air traffic operations is challenging. For example, in predicting commercial aircraft operations, passenger demand must be estimated and converted into aircraft operations through forecasts of the characteristics of the aircraft fleet that the airlines will use and the load factors they will aim for. GA activity forecasts are also difficult because of the sector's high volatility. The challenge is compounded by the need to produce forecasts for individual airports or specific origin–destination pairs (see Appendix).

The forecasting challenge is exacerbated by the difficulty in anticipating the change in air traffic operations between 2000 and present, which is partly attributable to such events as the September 11, 2001, attacks and the financial crisis of 2008–2009. These events could not have been predicted and have affected air travel negatively. Similarly, airline industry developments, such as mergers of major carriers and network consolidations, have reduced the availability of air travel options. For example, several major airports—such as those of Cincinnati, Ohio; Memphis,

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9 See http://aspm.faa.gov.

10 Aviation forecasts are found at http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts; FAA prepares a national forecast reported annually in the *FAA Aerospace Forecasts.* The aggregate national forecasts reported in FAA's *Terminal Area Forecast Summary Report* can differ from those in the *FAA Aerospace Forecasts.* For example, the TAF includes traffic activity at facilities not serviced by FAA, whereas the FAA national forecast does not. Since the focus of ATC staffing is on local requirements, the TAF and the ARTCC forecasts are more relevant than the national *FAA Aerospace Forecasts.* The remainder of this section focuses on the TAF and the ARTCC forecasts.

11 Roger Schaufele, FAA, briefing to the forecasting subgroup of the committee, December 12, 2013.

TABLE 3-2 U.S. Air Traffic Operations, FY 2000 Versus FY 2012

	Number of ATC Operations (millions)		
Operations	**FY 2000**	**FY 2012**	**Percent Change**
Tower operations			
Commercial, commuter, and taxi	24.3	20.7	–15
General aviation	27.8	16.3	–41
Total[a]	54.2	38.6	–29
TRACON total operations	51.9	37.8	–27
En route total operations	46.8	40.8	–13

[a]Includes military.
SOURCE: Generated by the committee; data from Air Traffic Activity Data System and TAF.

Tennessee; and Salt Lake City, Utah—and many secondary airports have experienced sharp reductions in the number of available flights. In addition, uncertainties may be present in some of the inputs that FAA uses in its econometric models, such as forecasts of economic growth generated by the Office of Management and Budget.

FAA's forecasts did not capture the striking reduction in air traffic activity, as measured by aggregate numbers of aircraft operations, that has occurred since 2000. The intensity of this trend varies by location and by industry sector (commercial aviation versus GA), but the cumulative effect is unprecedented in modern U.S. aviation history. Table 3-2 presents a summary comparison of FAA air traffic activity levels in FY 2000 and FY 2012.

Table 3-2 shows significant declines in all three types of facilities, ranging from 13 percent for en route operations to 29 percent for tower operations. GA operations at airports declined by 41 percent, while commercial operations declined by only 15 percent.

Figure 3-3 shows the declining trend of actual total airport operations and the corresponding forecasts issued by FAA over the period 2001–2013. For example, the 2002 forecast for 2012 projected in excess of 30 percent more operations than actually took place in that year. In addition, according to the 2012 forecast, the total number of U.S. airport operations in 2020 is projected to be more than 40 percent lower than the number of movements projected in 2002.

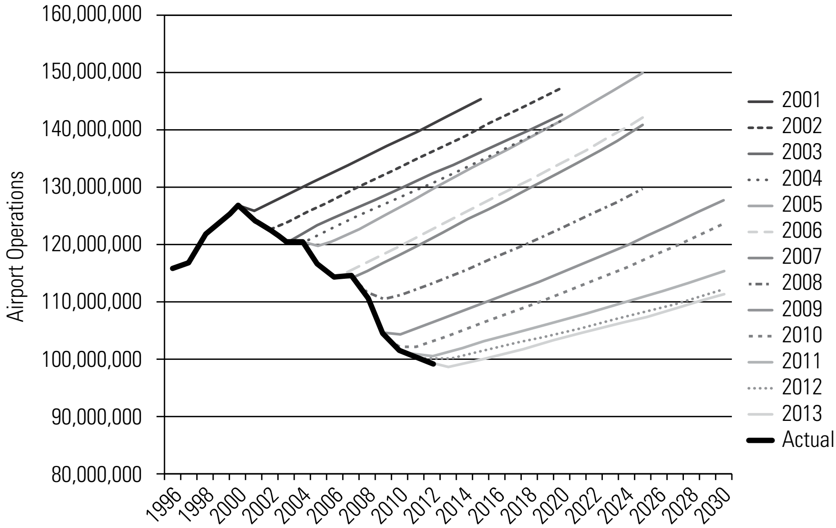

FIGURE 3-3 Terminal area forecast—total U.S. airport operations: actual traffic from 1997 to 2012 and FAA forecasts issued annually between 2001 and 2013. All U.S. airport operations are included, not just FAA towers; actual operations data are those reported at the time of the corresponding forecast. (SOURCE: TAF; figure prepared by MCR Federal, LLC.)

Decisions concerning new hires of air traffic controllers are essentially irreversible. For most facilities, 2 to 3 years of training are required for a controller to reach full certification (FAA 2013c). After they complete their training, air traffic controllers will typically serve until they become eligible for retirement and, most likely, for several years thereafter. The consistent optimism in traffic forecasts tends to result in the hiring of more controllers than required. That effect can only be partially corrected in subsequent years after forecasts have been recognized as optimistic.

Availability Factor and Adjustments

The workforce calculations to this point have focused on the number of controllers required to be available to perform duties on position. Like many other workers, the controller has a 5-day, 40-hour workweek. There are many hours when the controller is not on duty, either away from the facility or at the facility but not available for position-related duties. ALA reports[12] that annual off-position time (e.g., annual leave, sick leave, holiday leave usage) averages 422 hours per controller. With an annual base of 2,087 hours of work (i.e., a man-year), ALA reports "total available" time as an average of 1,665 hours—the difference between annual base and off-position time. Accordingly, the preliminary availability factor is the ratio of annual base hours to total available time, that is, 2,087/1,665 = 1.254; put another way, the total annual hours required of controllers will be this fraction multiplied by the required time on position. Accounting for the requirement for 7-day coverage in a week, during which each controller typically works five shifts, yields a factor of 7/5 = 1.4. The total availability factor is the product of these two factors (1.254 × 1.4), or 1.76.

The Organisation for Economic Co-operation and Development reports[13] that the average hours worked per worker in the United States was 1,790 in 2012. At first glance, this appears to be significantly larger than the 1,665 total available hours noted above. Although the bulk of off-position time is hours not worked (annual leave, sick leave, holiday leave, etc.), it does include some hours worked, such as training, meetings, work groups, and union activities. Augmenting the 1,665 hours by these other hours worked in off-position time makes the two figures more comparable.

In some instances, traffic volume may be so light that the process does not generate staffing requirements sufficient for maintaining a minimum number of controllers[14] on position (watch staffing) during all hours of operation. In such cases, typically at small facilities, the staffing standard is manually adjusted to ensure that FAA's watch staffing levels are satisfied. Similarly, facilities having unique physical configurations, such as multiple operational towers, require special attention and adjustment to the staffing standard (FAA 2013a, Section 2.4, 34–36).

The application of the availability factor to the DSR, with any watch staffing or site-specific adjustments, completes the staffing standards process.

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[12] Rich McCormick, FAA, presentation to the committee, March 2013.
[13] http://stats.oecd.org/Index.aspx?DatasetCode=ANHRS.
[14] At many sites the minimum is one controller per shift, increased to two controllers at some times of day. At combined TRACON–towers (Type 3), the minimum is two controllers on position during hours of operation.

STAFFING RANGE INPUTS AND CALCULATION

As shown in Figure 3-1, FAA's staffing standards have two main uses: as one input in calculating the staffing range and in determining the staffing target in the ALA-generated hiring plan. The development of the staffing ranges and staffing target is a multiple-step process and is described in the next section. The ALA hiring plan and the agreed-on staffing plan with the Air Traffic Organization (ATO) are discussed in Chapter 4.

According to the most recent controller workforce plan (FAA 2013c, 14), the four inputs to each facility's staffing range are as follows:

- The staffing standard—the activity-based, schedule-constrained controller staffing requirements described in the above standards process;
- Service unit input (SUI)—"the number of controllers required to staff the facility, typically based on past position utilization and other unique facility operational requirements";
- Past productivity—"the headcount required to match the historical best productivity," where "productivity is defined as operations per controller"; and
- Peer productivity—"the headcount required to match peer group productivity." Peer group productivity is a calculated productivity for facilities of the same type and level.

The staffing standard, past productivity, and peer productivity inputs to the staffing range are data driven. For the two productivity inputs, outliers are ignored. SUI is derived from a combination of past position utilization and field subject matter expertise.

According to the controller workforce plan, the midpoint of the staffing range is calculated as the unweighted average of the four (or possibly fewer) inputs rounded to the nearest integer. The upper and lower limits of the staffing range are the values 10 percent greater and 10 percent lower than the midpoint, respectively, again rounded to the nearest integer. ALA provided the committee with each facility's staffing range inputs and calculations for FY 2011 through FY 2013.

All facilities typically have staffing standard and SUI values. For the 3-year period for which data were provided, an average of 120 facilities (38 percent) had missing (or outlier) past productivity values, while an average of 159 facilities (50 percent) had missing (or outlier) peer productivity values. A facility or service area may raise a concern, but documentation suggesting that the majority of facilities have any direct or specific input into the staff planning process was not provided to the committee. According to FAA, the SUI incorporated into the planning process was primarily determined at the service area and headquarters levels and may not have adequately reflected operational needs expressed by the individual facilities. Thus, this process could create a dichotomy between the staffing requirements developed centrally and staffing levels deemed operationally necessary by the field. During FY 2013, FAA began to address this disconnect with the establishment of two field focus teams (FFTs)—one for en route facilities and one for terminal facilities—to facilitate workforce planning. Each FFT was made up of senior FAA managers who were tasked with developing plans that more strategically address staffing issues such as imbalances between facilities. For terminal facilities, the FFTs incorporated past position utilization data in the Terminal Validation Tool (TVT), an Excel-based application used to identify the field's estimate of staffing needs.[15] Historically, SUI for the en route centers tended to mirror ALA's staffing standard for most cases; however, in those cases where SUI differed from the staffing standard, FAA was unable to provide documentation on how the SUI estimates were developed. Therefore, ATO has indicated that it intends to use an En Route Validation Tool (EVT), similar to the TVT, to assist in generating an objective SUI. That program has yet to be vetted. Little documentation is available on the design and use of either the TVT or the EVT, so the committee could not explore their effect on staffing models.

SCHEDULE CREATION

Operational schedules are the responsibility of each facility. A default schedule template familiar to the facility's personnel is often used. Such schedules have evolved locally and reflect local conditions and actual schedules at each facility, but they may also reflect scheduling practices that are inconsistent with national policy or that do

[15] ATO, FAA, teleconference with the committee, November 19, 2013.

not incorporate best practices for managing the risk of fatigue, as described in Chapter 2.

As discussed in the staffing standards section earlier in this chapter, the SCM is a scheduling algorithm that calculates the number of PQCs needed for a facility. The algorithm is part of the centralized planning process at FAA headquarters that assumes some schedule for each facility generated from a basic set of work and fatigue rules. However, such a centralized schedule cannot work for all facilities—as reported to the committee, one size does not fit all.[16] Each facility may have specific local conditions, such as varying air traffic patterns throughout the day or heavy congestion on surrounding roads at certain times of the day. As a result of such congestion, controllers' local commutes will take longer, which may negate efforts to mitigate fatigue by extending intervals between scheduled duty times. Such variations in scheduling can result in staffing standards that are based on incorrect assumptions.

As described in Chapter 2, FAA is attempting to implement a more sophisticated scheduling tool (Operational Planning and Scheduling). Such a tool could be used at facilities, with each facility granted a level of flexibility appropriate to adapting its schedule to local conditions. The local adaptations in scheduling could be fed back to inform the centralized calculation of the staffing standards. Such a scheduling tool may allow for more efficient schedules at facilities, reduce the use of overtime, and (as noted in Chapter 2) help facility managers apply best practices in managing fatigue risk.

COMMUNICATION AND ENGAGEMENT

The generation of the staffing standards, and ultimately the staffing plan, is inherently a function of central planning units in ALA and ATO at FAA headquarters. How individual facilities interact with this centralized process with regard to specific needs is unclear and not fully documented. The operational reality of staffing at the facility level may not be reflected in the mathematical models underlying the staff planning process.

[16] Glen Buchanan, FAA, presentation to the committee, March 2013.

The process needs to be well defined and use the best available input. Both sides of the staffing process, facilities and headquarters, need a better understanding of how a facility's staffing level is assessed or counted, how staffing ranges are generated, whether the staffing level accounts for all duties and demands of the position or only for "core duties," and what is the target hiring or staffing number. ALA acknowledges that it needs better outreach to the service areas and facilities, although the staffing ranges are published. For example, ALA recognizes the need for more constructive engagement with facilities when the staffing standards vary significantly from the SUI (these two values for each facility differ from each other by 7 percent on average). Such engagement could involve facility management making a "bottom-up" business case when the two staffing range components disagree.[17]

The disconnect between the outputs of the modeling process and the operational perspective generated concerns that prompted ATO and the National Air Traffic Controllers Association (NATCA) to embark on a collaborative effort to review, revise, or improve data-based operational models for the distribution of ATC specialists throughout the field facilities. The effort seeks to uncover reasons why the modeling process has been generating staffing ranges that are perceived by some facilities as inconsistent with operational needs and to assist in rectifying the concerns.[18] The FFTs mentioned earlier may be subsumed into this collaborative endeavor to maintain a commonality of approach so that labor and management collectively can improve the theoretical and practical aspects of staffing the air traffic system.

SUMMARY

FAA operates 315 ATC facilities, which are staffed by approximately 15,000 controllers. FAA uses a series of mathematical models to estimate the staffing standard—the total number of PQCs needed at each facility to cover 90th percentile day traffic.

[17] Rich McCormick, FAA, presentation to the committee, March 2013.

[18] Andrew LeBovidge, committee member and NATCA representative, personal communication to Safety subgroup of the committee, March 19, 2013.

The committee had two concerns with the models common to the staffing standards for all types of facilities. The first relates to the SCM, a scheduling algorithm that has limited capabilities and may not reflect the scheduling complexities of an individual facility. The staffing standards could be improved if the central planning process and facilities used the same scheduling tool, if facilities were able to adapt their schedule to local conditions, and if central planning was aware of those adaptations.

Second, air traffic forecasts are necessary inputs for the ATC staffing standards process, yet over the past 12 years, the annual forecasts have been overly optimistic. The forecasting models and processes are not documented well enough for this committee to evaluate them in detail and to assess whether they provide a rigorous, consistent basis for generating staffing standards. However, the consistent optimism in traffic forecasts results in a tendency to hire more controllers than required. This effect can only be partially corrected in subsequent years after recognition that hiring has been based on inflated forecasts.

Different models are applied for different types of facilities at the first step in generating the staffing standards. While the committee found the models for tower and TRACON facilities to be based on well-documented, appropriate constructs, it had concerns with the MITRE task load model used to estimate the on-position staffing requirements for en route control centers. FAA and MITRE have presented a plan and proposed timeline for meeting the recommendations of the 2010 study committee, which also had concerns with regard to this model, but they had not completed the plan's proposed activities at the time of this committee's report. The current committee questions the appropriateness of continuing to use the MITRE model in determining the number of OPCs for en route facilities.

FINDINGS AND RECOMMENDATIONS

Finding 3-1. The overall process for generating staffing standards appears reasonable, except where noted below. Starting with models for estimating OPCs is logical. The models for tower and TRACON facilities, which are developed from observations of a representative sample of these facilities, relate traffic volume data for each facility to the prediction of controller activity and estimate on-position requirements on the basis of controller workload.

The analytical approach in the DSFM appears to be realistic. The "safety buffer" resulting from use of the 90th percentile day of operations permits controllers to have reasonable on-position times during a shift.[19] FAA's current availability factor calculation is consistent with generally accepted practices.

Finding 3-2. FAA's traffic forecasts are persistently high, with correspondingly high long-term hiring estimates. The projected number of ATC hires needed over a 10-year period, as reflected in the controller workforce plan, relies directly on traffic forecasts generated by a separate organization within FAA. The medium- and long-term projections of air traffic operations appear optimistic and unreliable and could provide inaccurate long-term hiring estimates. Persistent optimism in traffic forecasts brings about a tendency to hire more controllers than required, particularly for facilities requiring 3 years of training for new controllers to qualify. This effect can only be partially corrected in subsequent years.

Finding 3-3. The ability to estimate staffing standards centrally is limited by poor assumptions about scheduling. The SCM is used at the national level to make assumptions about controllers' schedules with regard to meeting traffic demand and constraints on allowable work shifts. The tool is limited in that it does not account for certain constraints on work shifts (e.g., rest requirements on off-duty time crossing midnight), does not account for significant considerations at local facilities requiring them to adapt their schedules, and was observed by committee members to produce results that were inconsistent with its own documentation.

Recommendation 3-1. FAA and NATCA should collaborate to implement an operational scheduling tool and appropriate procedures for its use at each facility. They should establish shift–schedule templates

[19] ALA reports that the average controller spent approximately 4 hours on position during a nominal 8-hour shift in FY 2013—slightly more at terminal facilities, slightly less at en route centers.

suitable for each facility's traffic patterns. More than one standard schedule should be available to each facility, and a "request for further consideration of unique circumstances" process should be available for facilities if their managers believe that local considerations require adjustments in schedule templates. The scheduling tool and associated procedures should allow each facility to design, revise, and publish its schedules on the basis of best practices in fatigue mitigation. The scheduling templates used at the facility should be transparent and available to others, including the staffing process. This may be fostered by the scheduling tool having the capability to archive the templates in a manner that allows various organizations, including central staffing processes, to access them as appropriate.

Finding 3-4. With regard to the task load model used for estimating the number of OPCs needed for en route centers, FAA and MITRE have yet to meet the 2010 study committee's recommendations. The current plan may address the modeling and validation recommendations in the 2010 study or identify the need for further observations and human-in-the-loop simulations to provide the necessary data. It may also indicate that extensive changes are required in the workload model.

The current committee discussed not only whether the model is (or can be made) accurate but also whether the model form is appropriate for its function in the generation of staffing standards for en route centers (which was not its original purpose). Given its extreme level of detail, the sheer number of elements needing to be modeled and validated would entail significant cost and delay. The modeling of tasks and subtasks in detail makes the output more sensitive to omitted tasks, such as the issuing of safety advisories and the provision of help for aircraft in abnormal situations, which are likely subsumed in the higher-level regression models used in the equivalent models applied to tower and TRACON facilities. The cost of adapting the model to predict NextGen staffing standards could be substantial, and the forecasts would need to be validated by monitoring the staffing they call for over the course of several years.

The detailed structure of the MITRE model—which drills down to individual cognitive subtasks and sums their task times—may itself be a concern. Such a large model may be costly to validate and may also require redefinition and revalidation. Given that the model's output requires validation by assessments of controllers and facility managers as to whether it correctly predicts OPCs, a simpler model based on data that can be observed easily and objectively, closer in form to the tower and TRACON models, may have greater construct validity at lower cost.

Recommendation 3-2. FAA should develop a new, simpler en route model built on data that can be observed easily and objectively, closer in form to the terminal and tower models described in this chapter. In developing the model, a cost–benefit analysis would need to be made that compares the value of the increased insight provided by greater model detail with the financial and time costs of developing and validating the model.

Finding 3-5. Most of the models underlying staffing standards generation appear to be well documented and consistently applied, but traffic forecasting and the process of calculating the staffing ranges were opaque and open to concerns that they were arbitrary or inconsistent. This is especially true of the determination of SUI. When differences occur between the staffing standard and SUI outputs (or facilities' considerations), proper engagement and communication between headquarters and the field are necessary to ensure that the process is transparent. Likewise, it was unclear which workforce quantity is used for comparing the staffing range with the "acceptable," "high," or "low" assessment of staffing for each facility presented in the current controller workforce plan.

Recommendation 3-3. FAA should ensure that the field understands the staffing process by providing greater clarity and transparency, and it should continue collaborative efforts ensuring that local facility considerations are properly addressed in—and continuously fed back to—its generation of the staffing standards.

REFERENCES

Abbreviations

FAA	Federal Aviation Administration
NRC	National Research Council
TRB	Transportation Research Board

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4

Development and Implementation of Staffing Plan

The model-based staffing standards and the staffing ranges described in Chapter 3 are developed by the Federal Aviation Administration's (FAA's) Office of Labor Analysis (ALA) to inform an annual hiring plan. The goal of the hiring plan is to move each facility to a level consistent with the staffing range. The Air Traffic Organization (ATO) and ALA then develop an annual staffing plan, including new hires and transfers among existing staff, that serves as the basis for decisions concerning each of FAA's 315 operational air traffic control (ATC) facilities. The execution of the staffing plans, which results in new hires and transfers and in the placement of personnel among facilities, is carried out by ATO.

This chapter focuses on the methods applied by FAA in its detailed staff planning and execution. In some cases the methods were unclear to the committee; they are analyzed on the basis of FAA data representing typical inputs to the methods and their outputs. The efficacy of staff planning and execution depends on the extent to which the result is consistent with the published controller workforce plan. That measure can change as FAA's methods change.

The chapter describes how FAA assesses current facility staffing status and explores how FAA develops its hiring and staffing plans. It describes the committee's understanding of the execution process and illustrates how the number and location of controllers in the workforce compare with the goals of the staffing plan. Potential strategies for improvements in staff planning are noted. The final section summarizes the chapter and gives the committee's recommendations.

FACILITY STAFFING STATUS

Assessment of Status

Staff planning requires a target and a clear path for reaching it. In concept, plans for individual facilities span at least 3 years to account for losses due to attrition (such as retirements, promotions, and deaths) and the period needed to train personnel to reach full certification, which typically ranges from 1 to 3 years. Achieving the target staffing level over time for a facility requires a good understanding of the current staffing status. ALA uses the head count of certified professional controllers (CPCs) and certified professional controllers in training (CPC-ITs) to assess each facility's staffing status relative to the staffing range described in Chapter 3. Status is assessed as follows:

- Above range: CPC + CPC-IT is more than 10 percent above the staffing range midpoint.
- Within range: CPC + CPC-IT is within ±10 percent of the staffing range midpoint.
- Below range: CPC + CPC-IT is more than 10 percent below the staffing range midpoint.

In FAA's terminology, the "above range" category is referred to as "high" staffing, the "within range" category as "acceptable" staffing, and the "below range" category as "low" staffing. Figure 4-1 is a modified version of a figure that appears in the 2013 controller workforce plan. It shows several implications and potential causes of above- and below-range staffing.

The committee reviewed data on FAA's 315 ATC facilities from the end of FY 2012. According to the committee's calculation,[1] 135 (representing 53 percent of the CPC + CPC-IT workforce) were classified as above range, 102 (representing 34 percent of the CPC + CPC-IT workforce) were classified as within range, and 78 (representing 13 percent of the CPC + CPC-IT workforce) were classified as below range (Table 4-1). According to FAA, the large proportion of facilities that are above range is explained in part by the gradual movement of the retirement bubble

[1] The committee's calculations in the following section are based on data provided by FAA and are not rounded.

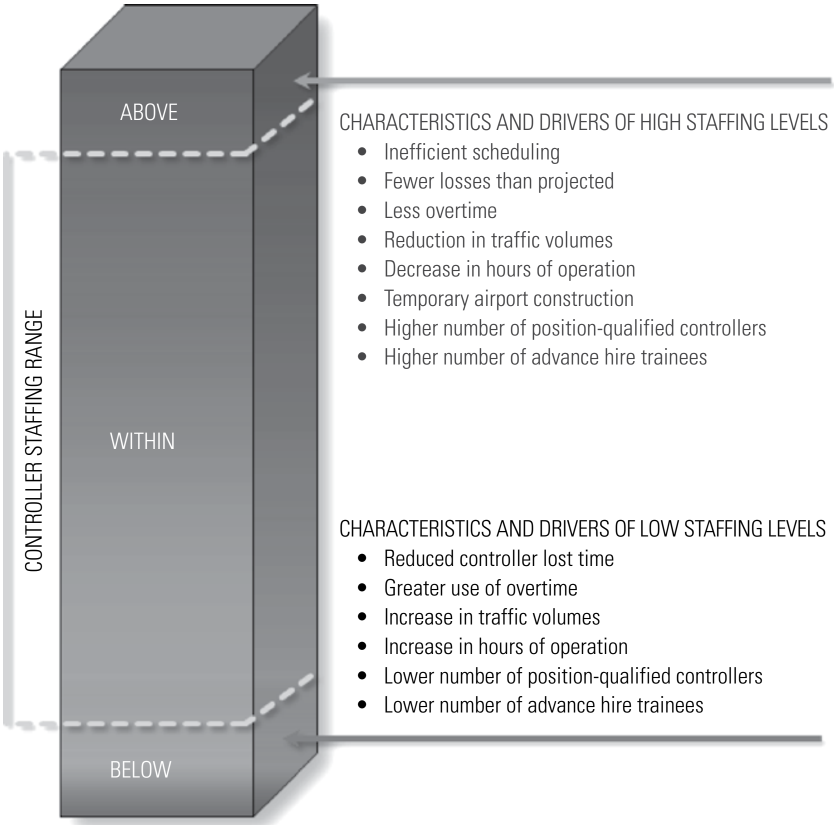

FIGURE 4-1 Illustration of controller staffing range.

TABLE 4-1 Certified Controller Staffing Levels of FAA Facilities (End FY 2012)

	Facilities		CPC + CPC-IT Head Count	
Facility Staffing Level	**Number**	**Percent**	**Number**	**Percent**
Above range	135	43	6,855	53
Within range	102	32	4,319	34
Below range	78	25	1,722	13
Total	315	100	12,896	100

through the workforce. The peak of controller retirements occurred in 2007, but as of FY 2012, about 3,000 controllers were still eligible to retire (i.e., roughly 20 percent). Historical trends indicate that most of this population will not retire until their 7th year of eligibility (FAA 2013, 31), and between 606 and 742 CPCs are expected to retire each year between 2013 and 2017 (FAA 2013, 33). As the wave of retirements continues, FAA expects that many facilities currently above range will fall within range.

Facilities that are below, within, or above the staffing range are of all types—smaller towers that mostly serve general aviation (GA); towers that serve small and medium airports with both GA and commercial traffic; and the largest airport towers, terminal radar approach control (TRACON) facilities, and centers (Table 4-2). Facilities with relatively few staff (12 or fewer CPCs) are particularly sensitive to sudden small changes in numbers of personnel that would change their classification. A large proportion of facilities below the staffing range are towers serving mostly GA and small and medium-sized airports. Nevertheless, some facilities serving important, high-volume airports and airspace fall into this category. A few of these facilities persistently appear in this category and have been deemed as chronically "hard to staff" for a variety of reasons. For example, according to the FY 2013 controller workforce plan, the staffing range for the Oakland, California, en route center is 185 to 226, whereas it has only 154 CPCs. The staffing range of the New York TRACON (serving JFK, LaGuardia, Newark, and Teterboro airports) is

TABLE 4-2 Facility Staffing Relative to Staffing Range, FY 2012

	Below		Within		Above	
Major Facility Type	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Smallest towers, mostly for GA	21	27	16	16	36	27
Small and medium-sized airport towers	45	58	56	55	56	41
Large towers, TRACONs, and en route centers	12	15	30	29	43	32
Total	78	100	102	100	135	100

178 to 218, whereas it has 156 CPCs.[2] Each of these facilities is assigned CPC-ITs and developmental controllers to raise its total staffing level to at least the bottom of the range. However, new personnel are not qualified to staff all the positions at the facilities, and current CPCs must spend time training them. San Juan and Guam, which pose their own unique challenges, are included among the hard-to-staff facilities.

Many staff at facilities that are classified as above the range are located at air route traffic control centers (en route centers). The 23 en route centers have 200 to 400 certified controllers each and represent a large proportion of the fully certified controllers in the system (roughly 44 percent at the end of FY 2012). About half of the centers (12) were in the "above" category at the end of FY 2012. Roughly 30 percent of the CPCs in the centers classified as above the range midpoint were eligible for retirement in FY 2012. These centers tend to have large numbers of CPC-ITs and developmental controllers receiving training to replace CPCs as they retire.

Moving a facility that is classified as above or below the range toward its staffing target is a multiyear process. Each facility's workforce may contain "homesteader" controllers who do not wish to move once they settle into a facility, establish households, and build ties to their communities. Inducing staff to move away from facilities that are within or above the staffing range to those that are below the range can be difficult. Building up a facility that is understaffed requires lead time for bringing new personnel on board (either from other facilities or as new hires) and training them. For both new and transferring employees, the training time varies dramatically with the individual's level of experience.

Data provided by ALA allowed the committee to analyze a variety of additional metrics relative to the above–within–below classifications in the FY 2013 controller workforce plan. The metrics examine workforce composition, overtime usage, and time on position from the perspectives of "working certified positions" and "on-the-job training." Table 4-3 shows how the metrics vary with staffing status.

[2] FAA calculates a facility's staffing status on the basis of combined CPCs and CPC-ITs. In FY 2013, this metric indicated that both the Oakland center and the New York TRACON were below range.

TABLE 4-3 Metrics for FAA ATC Facilities

Metric	Above Range	Within Range	Below Range	Systemwide
Staffing level (CPC + CPC-IT) as percentage of staffing range midpoint	120	100	81	106
Percentage of staff who are CPCs	83	74	83	77
Overtime hours as percentage of all hours worked	1.4	3.5	3.6	2.4
Percentage of time on position performed by CPCs	90	85	80	87
Percentage of CPC time on position also providing on-the-job training to non-CPCs	8	10	11	9
Percentage of non-CPC time on position also receiving on-the-job training	41	35	30	36

NOTE: Non-CPCs = certified professional controllers in training + developmental controllers.

The following are observations on the metrics presented in the table:

- On the basis of the CPC + CPC-IT assessment, the "below" and "above" staffing level percentages are more than 10 percent away from the staffing range boundaries—the group above the range midpoint is roughly 20 percent above and the group below the range midpoint is almost 20 percent below.[3]
- The controller pipeline (all staffing qualification levels except CPC) constitutes 23 percent of the workforce. On the basis of an analysis of ALA-provided data, that number has remained little changed, ranging from 23 to 27 percent during the preceding 5 years.
- As would be expected, overtime usage at sites below the staffing range is more than twice that of sites above the staffing range.
- As the staffing level relative to the staffing range midpoint increases, CPCs perform a greater portion of the total time on position. This implies that in facilities categorized as below range, CPC-ITs and developmental controllers contribute a larger share of productive work because the facilities lack an adequate number of fully qualified CPCs.

[3] These estimates are based on the numbers of staff in each category (the total staff in all facilities that are below, within, or above range compared with the total staff estimated by the staffing range midpoint). The estimates are not based on the average of each facility's rating relative to the staffing range midpoint, since the estimate would be skewed by the small number of small facilities that are substantially below or above the staffing range.

- The proportion of CPC time on position devoted to on-the-job training increases slightly at the facilities categorized as below range. This is likely because CPCs at facilities that are not adequately staffed need to provide developmental controllers with more training time.

Are There Other Methods for Comparing Current Staffing Levels with Staffing Ranges?

The staffing standards process described in Chapter 3 estimates the number of controller positions that need to be staffed during every 15-minute interval and develops nominal schedules, daily staffing, and overall facility staffing strengths to meet these demands. No consideration is given to the extent to which each facility will be staffed by CPCs, CPC-ITs, and developmentals. According to FY 2012 data provided to the committee by ALA, CPCs made up only 77 percent of the workforce; the remainder was made up of CPC-ITs (8 percent), developmentals (10 percent), and recent hires at earlier stages (FAA Academy graduates at the operational sites, 4 percent; candidates at the academy, 1 percent). In FY 2012, some 11,753 CPCs served 10.6 million hours on position (averaging 902 hours per year per controller); the 3,310 CPC-ITs, developmentals, and academy graduates served 1.6 million hours on position (averaging 496 hours per year). This limited comparison suggests that the average non-CPC is "working certified positions" at a rate slightly more than half (55 percent) that of a CPC and that the total non-CPC workforce performs 13 percent of the required time on position.

No clear distinction between the contributions of CPC-ITs and developmental controllers can be made. CPC-ITs typically progress more quickly than developmentals, but many factors can cause differences among facilities. For example, a CPC who transfers from a small tower to an en route center will need to undergo the same extensive training as a new hire would experience and may have a similar chance of successful certification.

Thus, how should actual staffing levels be compared with staffing ranges that were generated, in large part, from the staffing standards? The method used in the controller workforce plan assesses the sum of CPCs and CPC-ITs at each facility, even though the CPC-ITs may not be able to staff each position. Furthermore, carving out CPC-ITs in the baseline assessment of facility staffing status in such a generalized form fails to account for nuances in training progression mentioned above and could result in an inaccurate depiction of facility staffing capacity. A more conservative method would compare the CPCs at each facility with the staffing range. By this method, 113 of the 315 facilities fall below the staffing range minimum and 62 exceed the maximum. However, this method does not consider the impact of the CPC-ITs and developmentals at each facility. This omission can have the following effects:

- The progress of the CPC-ITs and developmentals through the certification process and the contributions of the CPC-ITs and developmentals in terms of the positions that they are able to staff would not be reflected. A comparison of the number of CPCs at a facility with its staffing range would be misleading in a short-term assessment of facility staffing.
- The additional training demands created by the CPC-ITs and developmentals on the facility, notably the on-the-job training provided by the CPCs, would not be reflected. Thus, a comparison of the number of CPCs at a facility with its staffing range may incorrectly imply that it is within or above range.
- The extent to which the comparison of the number of CPCs with the staffing range may change once staff qualify at a facility would not be reflected. A facility that appears to be below range in one year may appear to be within or above range the next, not because its staffing levels have changed but because of successful training of the staff already at the facility.

An assessment based on a more detailed analysis of the certification status of the personnel at a facility would be more relevant. Attrition models could be refined to reflect historical trends in achieving various position certifications at a given type and level of facility (or even at an individual facility). A controller equivalent workforce (CEW) metric could emerge as a measure of a facility's current status given the qualification levels of its controllers. Such a metric would allow for within-year comparisons of staffing levels with the staffing ranges and provide a perspective with regard to planning for hires. Such a comparison could help flag facilities that are lagging in reaching necessary levels.

A CEW metric will require careful analysis and development. Its application should be limited to assessing the capacity of a facility to staff its positions and bring its CPC-ITs and developmentals up to fully qualified status. That capacity may vary with several factors, including facility type and the ratio of CPCs to trainees (i.e., CPC-ITs and developmentals). The notional estimates of relative contributions given above may serve in the aggregate, but the CEW of a facility should be calculated in a manner that reflects the facility's capacity to staff its positions and train its new members.[4]

For example, a facility with a large number of CPC-ITs and developmentals may have difficulty in scheduling them into positions for which they are qualified, which would limit their effective contribution. Furthermore, the CPCs may not be able to staff positions as assumed in the staffing standards while providing on-the-job training (i.e., the CEW of such CPCs may need to be less than 1.0). (Such analysis may substantiate the general axiom within FAA that CPCs must make up at least 65 percent of a facility's workforce.) In contrast, at a facility with a high proportion of CPCs, it may be easier to schedule CPC-ITs and developmentals into positions where they can contribute and easier for CPCs to provide them with on-the-job training.

STAFF PLANNING

The controller workforce at individual facilities is in constant flux. There is a recurring need to reevaluate the staffing status at each facility and identify the strength adjustments required for maintaining or achieving optimal staffing levels. Figure 4-2 provides an overview of the process.

The annual hiring plan is an important strength management tool. The process begins with ALA. For each site, the general approach consists of the following:

- Projecting the population forward to a specified date, with retirements, promotions, developmental failures, and other attrition factored in;

[4] The estimates of time on position by controllers with varied levels of certification discussed in this section are based on data provided by ALA. If the CEW approach to estimating contributions to workload by controllers in training is pursued by FAA, it would need to verify that time on position data are captured accurately.

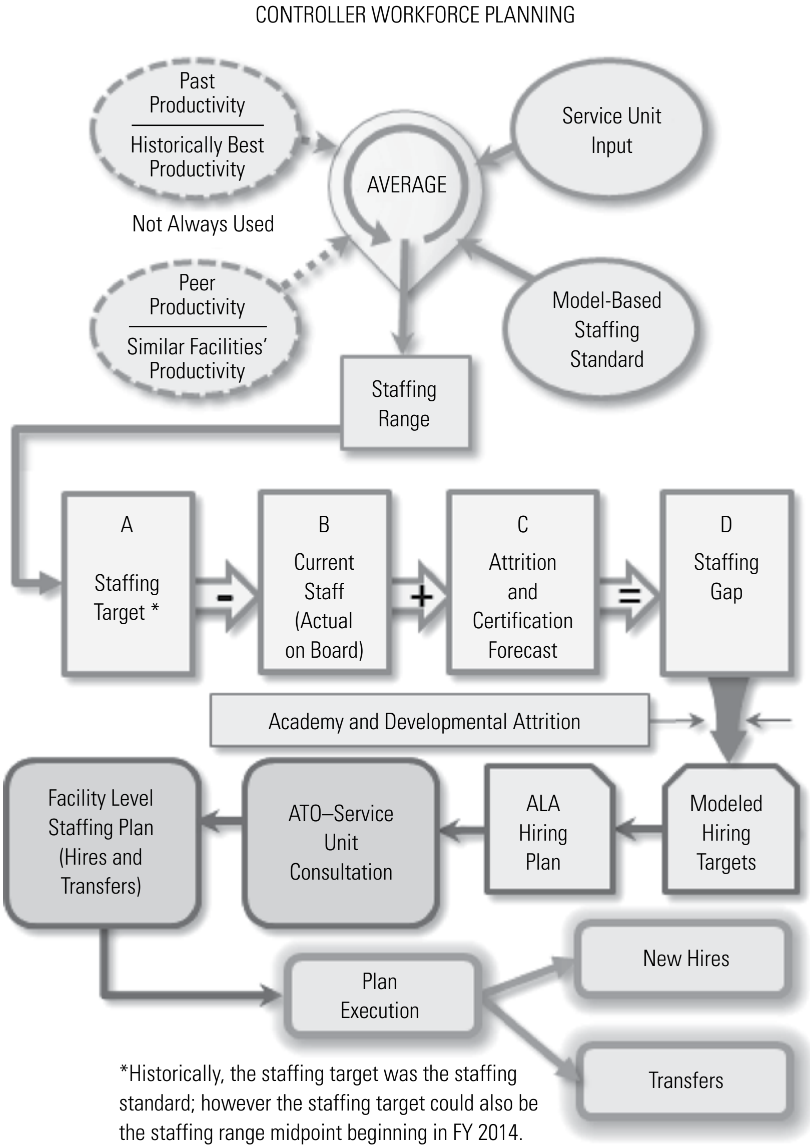

FIGURE 4-2 **Controller workforce planning process from staff planning through achievement of staffing level.**

- Identifying the gap between the result of this projection and the staffing target (be it staffing standard or staffing range midpoint); and
- Estimating the number of new hires needed to close the gap.

Let y denote the year for which the number of new hires is being estimated. For each facility f, define the following:

$t(f)$ = length of the training cycle for facility f

This is the nominal time required for a new hire to achieve full qualification (CPC status) at facility f. ALA uses 1-, 2-, and 3-year values in its planning. Then $y + t(f)$ is the year in which controllers hired in year y would achieve CPC status at facility f.

$p(y+t(f))$ = number of CPCs projected to be at facility f in year $y+t(f)$

The number includes residual CPCs from the beginning of year y and the various non-CPCs who achieve CPC status during the interval. ALA uses historical attrition and developmental data to estimate the surviving population in both categories.

$\text{tgt}(y+t(f))$ = staffing target for facility f in year $y+t(f)$

Before the FY 2014 controller workforce plan, the staffing target was the staffing standard. For the FY 2014 controller workforce plan, both the staffing standard and the staffing range midpoint will be evaluated as the staffing target.

$a(t(f))$ = attrition rate of new hires at facility f over the training cycle

The survival rate of new hires over that interval is thus $1 - a(t(f))$.

$h(y, f)$ = number of new hires planned for facility f in year y

If

$$p(y+t(f)) \geq \text{tgt}(y+t(f))$$

then

$$h(y, f) = 0$$

If

$$p(y + t(f)) < \text{tgt}(y + t(f))$$

then

$$h(y, f) = [\text{tgt}(y + t(f)) - p(y + t(f))]/[1 - a(t(f))]$$

These formulas indicate that, in developing a hiring plan for a facility, ALA takes into account the status of the facility's workforce and how it is expected to change over time, the training cycle appropriate for the facility, and the number of new hires that will be required to meet the staffing target.

ANNUAL STAFFING PLAN

After the hiring plan is complete, ALA gathers ATO's input into what will eventually be an agreed-on staffing plan that will be submitted to the field for execution. The staffing plan consists of a hiring plan (for new hires) and a transfer plan (for current controllers moving between facilities). The annual staffing plan should provide the targets to make the necessary strength adjustments so that each facility can achieve a staffing level consistent with its staffing target. The staffing target in the past has been the number of staff required to meet the projected traffic that is generated by the staffing models (i.e., the staffing standard described in Chapter 3). For FY 2014, the committee was informed that the target could be either the staffing standard or the midpoint of the staffing range. After discussion with ATO staff, the committee could not fully discern the criteria used in determining the staffing target, other than that ATO takes into account unique circumstances that the staffing models do not represent.

According to ALA, ATO staff offer suggestions as to which facilities should be the recipients of transfers ("transfers in") but do not offer the "transfers out" detail. Since transfers in and transfers out must net to zero systemwide, ALA uses historical data to estimate which facilities are traditionally donors of transfers (i.e., transfers out of those facilities). No out–in connection is directly identifiable, but this procedure does generate a planned net change (transfers in minus transfers out) at each facility. A transfer action may require two training cycle events—one for the previously qualified controller at the new facility and one for the replacement controller at the previous site.

TABLE 4-4 Comparison of FY 2012 ALA Hiring Plan and ALA–ATO Staffing Plan

Facility Staffing Level	Number of Sites	ALA Hiring Plan Quantity	ALA–ATO Staffing Plan Hires[a]	ALA–ATO Staffing Plan Transfers In[b]	ALA–ATO Staffing Plan Transfers Out
Above range	135	547	383	252	171
Within range	102	284	373	198	200
Below range	78	71	205	113	192
Total	315	902	961	563	563

[a]The ALA–ATO staffing plan is considered the combined output of the ALA–ATO agreed-on hiring plan and the net of (transfers in minus transfers out).
[b]Although no transfers are planned in the en route environment, many occur. [In addition to the CPC-IT transfer plan (within terminal facilities only), ALA's hiring models include an assumed net transfer plan between en route and terminal facilities.]

Table 4-4 provides a systemwide comparison of the ALA hiring plan with the ALA–ATO agreed-on plan with the above-, within-, and below-range facility staffing level classifications.[5] The committee was surprised by the sizable increase in new hires (59 or 6.5 percent) in the staffing plan over the 902 proposed in ALA's plan. The reasons for the difference are not fully understood. ATO staff indicated that the difference was due to adjustments to account for real-world conditions at facilities but could provide no documentation concerning how the adjustments are made or the criteria used in making them. (A subsequent section of this chapter addresses the need for more transparency in the process by which facilities provide input into the staffing plan.) In addition, the transfer process does not appear to be used proactively to steer facilities toward their staffing targets, as is described in more detail below.

STAFFING PLAN EXECUTION

Even the best staffing plan will not achieve the desired outcomes if it is not executed as planned. To gain a better understanding of the relationship between the staffing plan and execution of the plan, the committee

[5] The data for FY 2013 are available, but the effects of the sequester truncated hiring at midyear and would make the analysis unbalanced.

TABLE 4-5 Planned Versus Executed Staffing Gains in FY 2012

	Facility Staffing Status Relative to Range		
Status	**Below**	**Within**	**Above**
Terminals			
Planned	84	166	170
Executed	79	169	148
Executed/planned (%)	94	102	87
Centers			
Planned	42	205	294
Executed	43	211	275
Executed/planned (%)	102	103	94
Total			
Planned	126	371	464
Executed	122	380	423
Executed/planned (%)	97	102	91

compared planned staff additions and transfers in FY 2012 with what actually occurred. The committee chose FY 2012 rather than FY 2013 for the comparison because the Budget Control Act of 2011 prevented FAA from hiring new staff during a significant part of 2013. (The Budget Control Act of 2011 and its impact on FAA's budget are discussed in Chapter 6.)

The committee examined planned and executed staffing gains at each facility (Table 4-5). For purposes of this table, gains are defined as new hires plus all transfers into a facility less all transfers out. The gains are divided between terminal (tower and TRACON) facilities and en route centers and between facilities that were below, within, and above the staffing ranges (the ALA metric of CPC + CPC-IT was used as the determinant of facility staffing).

Table 4-5 indicates that FAA is executing its hiring and transfer plans as intended in the aggregate. Terminals that fall below the staffing range did not achieve the intended target, but the difference between the target and the number achieved is small (five), so the discrepancy may not be difficult to overcome. Among facilities that fall above the staffing range, the category for which underperformance is appropriate, FAA met 91 percent of the target. Facilities that fall within the range slightly overachieved, but the difference (nine) is small relative to the total workforce.

The impact of staffing is felt at the facility level. In examining facility-level data, the committee noticed cases from FY 2011 through FY 2013 where execution did not meet the plan. The following are examples:

- The Denver (Colorado) TRACON (D01), which is staffed within the staffing range, had an aggregate (3-year) staffing plan (hires plus net transfers) of 25; it executed 15.
- The Dallas–Fort Worth (Texas) tower, which is staffed above the staffing range, executed 10 against a plan of seven in FY 2013 because transfers in exceeded transfers out.
- The Detroit (Michigan) TRACON (D21), which is staffed below the staffing range, executed three against a plan of 13. Transfers went fairly well according to plan, but no new hires were executed against a plan of seven.
- The High Desert (California) TRACON (E10), which is below the staffing range, executed 11 against a plan of five. The overexecution was due to seven new hires in FY 2013 against a plan of one.
- Guam (ZUA), also below the staffing range, executed seven new hires against a plan of nine. No transfers in or out were planned; actual transfers out of seven exceeded actual transfers in of four. The result was an underexecution by five.

Examining staffing plans for any single year in terms of whether a facility is below, within, or above the staffing range could be misleading. As noted above, facility staffing is constantly changing because of retirements, other losses (deaths and attrition), new hires, transfers, and changes in staff capability as developmentals and CPC-ITs achieve CPC status. However, the FY 2012 staffing plan allocates staff to facilities in rough proportion to their current staffing levels, regardless of whether they are classified as below, within, or above the range. Facilities that are below the range represented 13 percent of total staff at the beginning of FY 2012 and were to receive 13 percent of staffing gains according to the plan, facilities that are within the range represented 35 percent of total staff and were to receive 39 percent of staffing gains, and facilities that are above the range represented 53 percent of staff and were to receive 48 percent of staffing gains.

TABLE 4-6 Transfers Between Facilities in FY 2012

	Transfers To, by Staffing Status			
"From" Staffing Status	Below Range	Within Range	Above Range	Total
Below range	3	37	25	65
Within range	22	139	159	320
Above range	46	136	177	359
Total	71	312	361	744

These results contrast with the expectation that staffing plans would assign more staff to facilities classified as below range. The general policy that avoids placing new hires in the most difficult of the below-range, hard-to-staff facilities might account for some of this discrepancy. However, many towers of Level 4 to 8 are below the staffing range.[6] Some of them would, presumably, be appropriate training sites for new hires, who could later transfer into higher-level facilities that are hard to staff.

TRANSFERS

FAA can advertise vacancies and solicit controller transfers, or individuals can make unsolicited employee requests for reassignment (ERRs, i.e., voluntary transfers). Both can help correct staffing imbalances among facilities. In addition, a small percentage of transfers are requested under "hardship" conditions, a subcategory of the ERR pool. The committee reviewed the 744 actual transfers that occurred during FY 2012, which represented about 5 percent of the workforce that year (see Table 4-6).[7] From a staff management perspective, a transfer was deemed not to change facilities' staffing levels overall if a controller moved between facilities categorized as having the same relative staffing; this was the case in 43 percent of the transfers [319 (= 3 + 139 + 177) transfers in FY 2012]. Similarly, transfers were categorized as representing good strength management when controllers moved out of facilities categorized as being above or within the staffing range into facilities categorized as

[6] As indicated in Chapter 2, FAA air traffic facilities have several classification levels, which are based on numerous factors, including traffic volume, complexity, and sustainability of traffic. The levels range from 4 to 12, with 12 being the most complex.

[7] The 744 actual transfers for FY 2012 represent a significant increase from the 563 "agreed-on" transfers included in the FY 2012 ALA–ATO staffing plan (see Table 4-4).

below the range, or out of facilities categorized as being above the staffing range into facilities categorized as within the range; this was the case in 27 percent of the transfers [204 (= 46 + 22 + 136) transfers in FY 2012]. Finally, transfers were categorized as representing poor strength management if controllers moved out of "below" or "within" facilities into "above" facilities, or out of "below" facilities into "within" facilities; this was the case in 30 percent of the transfers [221 (= 25 + 159 + 37) transfers in FY 2012]. Only 9 percent of transfers [68 (= 22 + 46) in FY 2012] moved staff from the "within" or "above" category to the below category.

The rationale behind these transfers is not apparent. Some may have been hardship cases or may have included transfers allowed as part of a progression of training to higher-level facilities. However, the overall pattern suggests the lack of a systematic process within ATO to solicit and approve voluntary transfer requests in a way that moves toward FAA's target staffing ranges.

Several difficulties and disincentives limit FAA's ability to solicit and approve voluntary transfers. Controllers report that the costs of moving between facilities are not fully covered; this is a particularly strong disincentive when controllers are required to move their households.[8] Furthermore, on arrival, the controller will be designated as a CPC-IT and required to train and qualify into the new facility. Transferring to a higher-level facility carries the risk that the controller will not qualify into the facility, with associated uncertainties concerning subsequent reassignment back to a lower-level facility.

Evidence suggests that under the process by which ERRs are reviewed by individual facilities, the first facility to approve the transfer gets the controller. Thus, a facility described as having acceptable staffing may get a controller who had indicated a willingness to transfer to a facility with low staffing. This process may contribute to the discrepancies between staffing targets in the hiring plan and the staffing results in the field.

The composition of staff at facilities changes slowly over time. Although FAA is reported to have a substantial share of controllers who are anxious to move to higher-level facilities offering higher pay as their skills are refined, many may be reluctant to move once they have established

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[8] Andrew LeBovidge, committee member and NATCA representative, personal communication to Safety subgroup of the committee, March 19, 2013.

households. To take a longer time dimension into account, the committee examined plan execution for FY 2011 through FY 2013, for which ALA provided annual comparisons of planned versus executed staffing. The committee categorized the execution of a facility's staffing plan as "under," "proper," or "over" as follows:

- For a small planning value (i.e., calling for fewer than 10 staff changes at the facility), the "proper" range was set at plan ± 1. For example, a staffing plan of 5 executed at 4, 5, or 6 would be considered "proper"; it would be considered "under" if execution < 4 or "over" if execution > 6.
- For a planning value ≥ 10, the "proper" range was set at plan ± 10%, analogous to how ALA defines the staffing range. For example, a staffing plan of 20 executed at 18 through 22 would be considered "proper"; it would be considered "under" if execution < 18 or "over" if execution > 22.

Systemwide, the FY 2011 plan of 829 was executed at 822 and the FY 2012 plan of 961 was executed at 925. The FY 2013 plan of 1,315 was severely underexecuted at 554 because of the sequester of FAA funding. The facility counts by execution category are given in Table 4-7.

Even for FY 2011 and FY 2012, which were not affected by the sequester, there was no apparent management discipline to ensure that execution

TABLE 4-7 Planned Versus Executed Hires and Transfers

	Number of Facilities		
Category	**FY 2011**	**FY 2012**	**FY 2013**
System			
Overexecuted	51	81	53
Properly executed	230	163	138
Underexecuted	34	71	124
Total	315	315	315
Centers			
Overexecuted	0	4	1
Properly executed	22	12	3
Underexecuted	1	7	19
Total	23	23	23
Terminals			
Overexecuted	51	77	52
Properly executed	208	151	135
Underexecuted	33	64	105
Total	292	292	292

was in accordance with the plan: 73 percent of the facilities "properly" executed in FY 2011, and only 52 percent did so in FY 2012. The differences between FAA's staffing plan and execution of the plan emerged late in the committee's deliberations, past the time when further dialogue with FAA staff might have provided explanations for the discrepancies. The committee understands that the execution process is complex and involves considerations by facility managers and higher-level staff within ATO. Furthermore, the committee does not have a full understanding of how the staffing plan is carried out and who makes final decisions on hiring and transfers. Nonetheless, because staffing levels are in flux, poor execution of the staffing plan in a particular year makes it more difficult to achieve the staffing target in a future year. The committee does not know whether the discrepancies between plans and execution are caused by improper execution or by a difference of opinion between ALA and ATO with regard to appropriate staffing levels at individual facilities.

STRATEGIES TO IMPROVE FACILITY STAFFING

FAA faces many challenges in steering staffing levels toward its goals. In the intensely competitive airline industry, carriers can pull out of major facilities on short notice, as in Columbus, Ohio; Memphis, Tennessee; St. Louis, Missouri; Raleigh, North Carolina; and San Jose, California, leaving behind a tower whose staff was built up over many years. Unless controllers are moved against their will, many years of attrition may be required before the facility is rightsized. Voluntary requests for transfers are placed by only a small proportion of the controller workforce, and as noted above, FAA apparently makes little effort to steer the transfer requests from facilities that are above the range to those that are below. Possible opportunities available to FAA that could facilitate the rightsizing of individual facilities are discussed in the following subsections.

Career Advancement Within the Controller Workforce

In theory, controllers have several paths for career advancement. Some include the transition to management and supervisory positions. Of interest here is the progression from lower-level facilities with light traffic demand and simple traffic flows to progressively higher-level facilities serving the busiest airspace with the most complex traffic.

FAA's maximum salaries for controllers appear to be structured in a way that should encourage controllers to move from lower- to higher-level facilities to achieve higher incomes. For example, a CPC who progresses from a Level 8 tower to a Level 12 facility could increase his or her maximum pay by 40 percent. However, controllers express concerns about the cost of moving households, movement into areas with higher costs of living, and the risks of transferring from a lower- to a higher-level facility and then failing to qualify.[9]

Despite the impediments, for those controllers eager to advance, a career progression from lower- to higher-level facilities implies that at least some lower- and midlevel facilities could not only handle their own traffic demand but also help in training controllers for higher-level facilities. Such facilities could serve as the foundation of an apprenticeship model. Staffing plans would need to allocate more developmentals and CPC-ITs from even lower-level facilities to these "training grounds" than are required by the staff-to-traffic philosophy underlying the staffing standard and staffing range described in Chapter 3. The staffing plan could involve the CPCs at the training ground facilities in helping the higher-level facilities select and train suitable candidates for advancement.

For a career progression to work, FAA would probably need to be more explicit with new staff about expectations concerning the need to move to advance their careers, and FAA and the National Air Traffic Controllers Association (NATCA) would need to agree on policies to induce staff movements from facilities that have ample staff to those that do not. Career progression policies might take a different approach at centers, which are large enough to afford internal staff progression opportunities.

The need for an apprenticeship model was demonstrated in the cases of some high-level facilities that required new controllers because of high attrition. Under past policies, new controllers were placed directly into these facilities; the facilities were not able to advertise for and transfer in controllers who had proved capable in facilities one level down in difficulty. The resulting failure-to-qualify rates, especially at hard-to-staff facilities such as the New York TRACON, imposed a significant training burden and wasted resources, and the nonqualifiers had to be replaced in subsequent

[9] Dean Iacopelli and Eugene Freedman, NATCA, presentation to the committee, January 2013; and Andrew LeBovidge, committee member and NATCA representative, personal communication to Safety subgroup of the committee, March 19, 2013.

years' staffing plans at the cost of significant delay.[10] The failure rates also discouraged new controllers from indicating an interest in these facilities. More recently, ATO has avoided the placement of newly hired controllers in high-level facilities. However, ATO has no choice but to place newly hired controllers in some hard-to-staff facilities that do not attract adequate transfers, such as the New York TRACON, in the hope that some will qualify.

FAA has recognized some of the concerns described above and chartered an independent review panel that provided several recommendations in 2011 on candidate selection, hiring, facility assignment, and training within the controller workforce (Barr et al. 2011). FAA, in concert with NATCA, is moving forward with many of the recommendations that are relevant to this section, particularly with regard to strengthening the initial selection and facility assignment by ATO. However, the extent to which facility assignment takes facility staffing into account relative to the staffing standard is unclear. Furthermore, the committee could find no consistent or formal policy for career advancement or for designation of training ground facilities within the staff planning processes, although an informal process appears to be in place under which certain facilities serve as training grounds for higher-level facilities.

Hard-to-Staff Facilities

All facilities have some level of concern with regard to selection and training, transfers, and career advancement. Certain facilities experience these concerns to such a degree that they are chronically understaffed and are considered hard to staff. In the past, FAA sent new hires into these facilities to fill gaps and allowed transfers of CPCs from low-level towers into large TRACONs and centers. The result was unacceptably high attrition, because some hard-to-staff facilities manage traffic that is among the most demanding in the nation.

Recent initiatives at FAA include development and validation of operational assessments to prescreen applicants to specific facilities to maximize training success. They are still considered pilot programs and are

[10] Dean Iacopelli and Eugene Freedman, NATCA, presentation to the committee, January 2013. Rich McCormick, Gene Burdick, and David Burkholder, briefing to a subgroup of the committee at FAA headquarters, August 29, 2013.

not yet institutionalized and available to all the facilities that may benefit from such a program. Additional incentives may be required to encourage more transfers into hard-to-staff facilities.

Selection and Training

FAA's generation and execution of safe, efficient staffing plans are affected by its ability to select and train controllers with confidence that they will qualify into the facility. Selection and training are complicated by differences in the necessary level of skills among facilities: higher-level facilities (those handling more complex, higher-volume traffic) require special skills developed over years of training, and not all controllers may be appropriate for such facilities. New entrants to the controller workforce who have finished at the academy are not considered fully trained. Once they move to an operational facility, they are categorized as developmentals. They require additional training and must qualify on all positions in the facility before they attain CPC status. When controllers transition between facilities, they are categorized as CPC-ITs until they qualify on all positions in the new facility. CPC-ITs also require further training when they move to a higher-level facility, and they may not qualify. The training within the facility must be conducted by CPCs who are certified as trainers.

Staff planning must consider the impact of placing a large number of developmentals and CPC-ITs into a facility in terms of the training burden imposed on the CPCs and the risks of high rates of attrition (Barr et al. 2011). (FAA attempts to limit the proportion of trainees at a facility to 35 percent of total personnel to avoid overburdening CPCs with training duties.) The core of controller training is conducted with the developmental or CPC-IT actively working on an operational position under the direct supervision of a CPC instructor, who is responsible for intervening in case of any problems. While such on-the-job training is necessary, committee discussions with senior FAA safety staff and National Transportation Safety Board investigators indicate that it may create a safety concern if it is not monitored properly. Thus, care must be taken to avoid overloading a facility with more developmentals and CPC-ITs than it can train safely and effectively, and the impact of on-the-job training on safety requires close monitoring.

Efficient Shift Scheduling

As indicated in Chapters 2 and 3, providing a scheduling tool to facilities would benefit safety (in terms of fatigue) and the generation of staffing standards and the staffing plan. The discussion in this chapter reflects the operational aspects of generating efficient schedules. Each facility generates its own schedule. Committee members have seen examples of schedules generated through the use of locally developed white boards and spreadsheets. In many cases, a default schedule template has evolved within a facility over several years and is familiar to supervisors and the controller workforce there. The operational benefits of providing a tool to facilities to assist in maximizing the efficiency of shift coverage and to clarify to the workforce at the facility how schedules are developed are described here.

The benefits with regard to fatigue mitigation and staff planning will only be realized if the facility applies the tool to generate the schedules that are actually used. Such a mandate for facilities to use the tool, and perhaps some constraints on the schedules that they may select from it, must consider the operational realities of each facility. One centralized schedule cannot work for all facilities. First, traffic may be heavy or light for different facilities at different times of day. Second, each facility may have local concerns such as preventing shifts from starting or ending during peak-hour traffic to avoid long commutes during recuperative breaks.

Airservices Australia has completed such an effort, and positive results were reported to the committee. The organization's scheduling capability is integrated with fatigue risk management so that schedules can be created in accordance with fatigue risk management principles and the fatigue risk of any necessary changes can be considered. With regard to providing facilities with a measure of local control and flexibility, each facility has three default schedule templates to select from. If facility management believes that none of the defaults adequately reflects its circumstances, it may propose a fourth to headquarters. As part of fatigue risk management, the scheduling tool helps identify circumstances under which, for example, offering a controller a taxi ride home after an unexpected, unusually long shift may be warranted.

Thus, the scheduling tool can inform and guide the generation of efficient schedules that take into account the principles of fatigue risk management at each facility, yet each facility should be provided with the flexibility to adapt the schedules to local considerations. The schedules can have significant professional and personal impact on controllers, so they will be most effective if they are developed collaboratively with the workforce.

Communication Between Operations and Staff Planning

Generation of the staffing standards and staffing plan is inherently a function of central planning units in ALA and ATO at FAA headquarters. However, the facilities need a well-defined way of communicating their needs in the development of the staffing plan, particularly if unusual or unique circumstances are not reflected in the mathematical models underlying the planning process. Such communication requires clarity with regard to how the facilities' current staffing levels were assessed and how the transition toward the staffing targets will occur.

Several entities need to be involved. In addition to communication up and down the organizational chain from facility to regional service unit to centralized planning at FAA headquarters, the communication should involve the workforce at all levels. Horizontal coordination within the organization between facilities and service units would often be beneficial. Furthermore, independent review panels and working groups that are asked to examine staffing-related concerns need the ability to communicate their findings and recommendations through the organization so that improvements are broadly reflected.

The committee was unable to achieve a clear understanding concerning the communication of facility concerns in the development of the staffing plan. Various processes appear to be involved, and they appear to change over time. A more consistent and transparent communication process is needed.

SUMMARY AND RECOMMENDATIONS

At the end of FY 2012, the majority of FAA facilities were either above (43 percent of facilities) or below (25 percent of facilities) the staffing range established in the FY 2013 controller workforce plan. A reasonable expectation is that FAA intends to move these facilities toward their staffing targets over time.

After ALA uses the staffing targets to develop a hiring plan, ALA and ATO agree on a staffing plan for new hires and transfers that is intended to establish agency goals for these facilities. The staffing plan agreed on by ALA and ATO for FY 2012 is 6.5 percent above what the modeled output suggests is appropriate. Explanations for the discrepancy included the need to account for local circumstances and facility manager judgment, but no documentation or criteria were available to the committee to justify a discrepancy of this magnitude or to indicate that the staffing standard is low. It is certainly appropriate for facilities to provide input into the staffing plan, but a transparent process is needed by which facilities can understand what the various staffing standards, targets, and ranges represent and then provide their input in an informed manner.

The staff hiring determined in the ALA hiring plan and the staff planning methods themselves may be erroneous because FAA's assessment of facility staffing does not appropriately account for non-CPC controllers. If the CEW concept described above is developed and proves effective, FAA would have better insight into a given facility's short- and midterm staffing status.

On the basis of the data the committee examined, FAA appears to execute its staffing plan as intended in the aggregate, but there are difficult-to-understand discrepancies at the level of specific facilities. For example, as indicated in Table 4-7, 73 percent of FAA's facilities successfully implemented planned hires and transfers in FY 2011, but only 52 percent did so in FY 2012. Discrepancies between staffing plans and their execution compound the difficulty of achieving staffing goals.

There was a significant discrepancy between the transfers planned for FY 2012 (563) and the number executed (744). The number of staff transfers allowed annually is roughly two-thirds the number of new hires and about 5 percent of the total workforce. Furthermore, any transfer action may require two training cycle events—one for the person transferring into a new facility and one for the person replacing the transferee. Thus, transfers can influence whether facilities move toward FAA's staffing targets. FAA appears to lack a strategy and mechanisms to influence transfers toward this end.

The committee does not fully understand how the execution of staff planning works in practice and whether it corrects staff imbalances over time. From the data available to the committee, the execution process does not appear to be doing so. This topic is worthy of further examination.

There appear to be enduring differences between the staffing targets developed by ALA and the staffing in the field as executed by ATO. The differences may be caused by poor execution of the annual staffing plans or by a difference of opinion within FAA with regard to the appropriate level of staffing at individual facilities.

Recommendation 4-1. FAA should examine the merits of using a more appropriate analysis of facility demographics (e.g., the CEW concept) in place of the CPC + CPC-IT metric when it assesses facility staffing status and develops its annual staffing plans.

Recommendation 4-2. FAA should develop explicit criteria with regard to when and why the staffing plan for a given year can exceed the hiring plan based on the staffing standard.

Recommendation 4-3. FAA should ensure that the field understands how facilities' staffing levels (current and target) are assessed and offer a transparent process by which facilities can provide input on facility staffing levels established in the annual staffing plan.

Recommendation 4-4. FAA should make more effective use of voluntary transfers to rebalance the workforce among facilities considered to have high staffing levels and those considered to have low levels, particularly where it can leverage controllers' desire to transfer on the basis of hardship, career advancement, or personal circumstances. Such a strategic process would need to include the following:

- Suitable incentives for transfers, developed and agreed on by FAA and NATCA, that would help rectify staffing imbalances, including establishment of a policy for resolving situations in which controllers who are willing to risk transferring to a higher-level facility fail to qualify into that facility; and
- Systemwide processes and management of transfer requests to consider their impact on facility staffing, so that facilities with low staffing levels do not miss voluntary transfers claimed first by facilities with acceptable or high staffing levels.

Recommendation 4-5. FAA should establish and advertise a clear path for the career advancement of controllers. They should be mentored and should understand the expectations on which their advancement will depend, and those expectations should be understood in staff planning and at the training ground facilities.

Recommendation 4-6. FAA should adopt a formal apprenticeship model that reflects the potential of lower-level facilities to serve as training grounds and sources for transfers into higher-level facilities. An informal system appears to be at work across some facilities. A more formal and well-communicated model may work more effectively. Lower-level facilities would need to be staffed in a way that reflects their dual role of serving traffic at the facility and bearing a heavy training burden. FAA and NATCA will need to work together to develop incentives to keep controllers moving upward through the system at an appropriate rate.

To function effectively, such an apprenticeship model must be transparent to the workforce. Clear designation of the facilities is a first step. Controllers should be mentored with regard to furthering their career development. Standard policies or documentation should be available to controllers indicating how long they might be placed in lower- and mid-level facilities and when they would be expected to transfer to higher-level facilities. Controllers would be more motivated to participate in career development if selection processes were in place to reduce the risk that they might not qualify into a new, higher-level facility and if clear policies were in place for handling their reassignment should they not qualify.

Recommendation 4-7. FAA should work with NATCA in developing and implementing special measures to address the concerns of hard-to-staff facilities. Such measures might include

- Incentives to transfer to and reside near the facility;
- Selection processes and policies that would prescreen controllers willing to transfer to facilities and identify controllers likely to qualify (and not qualify);
- Policies for reassignment of trainees who fail to qualify, to remove disincentives for potential applicants to the facility; and

- Methods for training controllers at facilities one level down in difficulty to nearly the level required at the hard-to-staff facility, thus minimizing the training requirement once they are on site.

Recommendation 4-8. In its staff planning, FAA should consider the impact of placing a large number of developmental controllers and CPC-ITs into a facility in terms of the training burden on the facility. FAA should monitor for any safety concerns arising with intensive on-the-job training within facilities. Workforce, facility, and service units should be able to communicate concerns as feedback into the staff planning process.

Recommendation 4-9. FAA and NATCA should collaborate in implementing a scheduling tool and procedures for its use at each facility. They should establish standard schedule templates suitable for each facility's traffic patterns. More than one standard schedule should be available to each facility, and a "request for further consideration of unique circumstances" process should be available to facilities who believe that local circumstances require adjustment to their schedule templates. The scheduling tool and associated procedures should allow each facility to design, revise, and publish schedules that take best practices in efficient shift scheduling and fatigue mitigation into consideration. The scheduling templates used at the facility should be transparent and available to others, including those performing the staffing process. This may be fostered by the scheduling tool having the capability of archiving the scheduling templates in a manner that allows different organizations to access them.

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Abbreviation

FAA Federal Aviation Administration

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5

Staffing Implications of the Next Generation Air Transportation System

The Federal Aviation Administration (FAA) is updating the National Airspace System (NAS) to the Next Generation Air Transportation System (NextGen). Changes in the NAS have been made since the early 2000s, and in 2003, President Bush and Congress initiated NextGen through the Vision 100—Century of Aviation Reauthorization Act (P.L. 108-176). The effort was originally intended to address the then-projected threefold increase in demand for air travel in the United States relative to 2001 levels, an increase that would strain the ability of today's system to function effectively and efficiently.

The changes that NextGen will bring about will have consequences for the policies and procedures of air traffic control and likely for the job of the air traffic controller. NextGen will need to address the emergence of unmanned aircraft systems (UAS), known as drones, as well as other new technologies and operational improvements. Congress has mandated FAA to integrate small UAS into the NAS by 2015, primarily for commercial purposes. The effect of integration on the NAS will be substantial. The broad category of UAS spans a range of aircraft. Large vehicles with performance and capabilities similar to those of current manned aircraft will be flying within controlled airspace, and new types of vehicles with substantially different flight profiles will be operating at altitudes, speeds, and routes not covered by current air traffic procedures and air traffic controller training. Similarly, FAA has established a national space transportation policy and directed the Air Traffic Organization and the Office of Commercial Space Transportation to collaborate in integrating increased commercial space operations into the

NAS.[1] Thus, NextGen may involve not only more operations but also the operation of new types of vehicles, which will change the nature of air traffic controllers' tasks.

This chapter discusses the potential long-term impact of NextGen on controller staffing. It examines how NextGen is addressed in FAA's latest controller workforce plan and considers controller selection and training requirements for NextGen. Staffing pressures associated with NextGen near- and midterm deployment are discussed, and the key role of controllers in NextGen development is highlighted. The chapter concludes with the committee's findings and recommendations concerning the staffing implications of NextGen.

POTENTIAL LONG-TERM IMPACT OF NEXTGEN ON STAFFING

NextGen is intended to allow new types of operations and vehicles within the NAS. Implementation of the initial NextGen features has highlighted the potential for staffing issues. For example, optimized profile descent (OPD) allows aircraft to follow a fuel- and time-optimal profile through their descent and arrival into an airport and is intended to save fuel and flight time (Clarke et al. 2004) in comparison with the usual sequence of "step-down" instructions from controllers. Committee members' discussions with terminal radar approach control (TRACON) personnel in Atlanta, Georgia, indicated that OPD can shorten the "pushes" (periods of high-density arrivals) at their facility. However, multiple facilities must be coordinated before aircraft enter the TRACON's boundaries, and those facilities have not been staffed or structured for such an operation. When neighboring en route centers are required to start aircraft down OPDs into the TRACON, controllers often need to give aircraft "vectors" away from their intended course, at the cost of extra fuel consumption and delay that negates the intended benefits of this NextGen operation. As this example illustrates, an understanding of the impact of NextGen on staffing requires the involvement of controllers at all

[1] Statement of FAA Administrator Michael Huerta on the National Space Transportation Policy, November 21, 2013. See http://www.faa.gov/about/office_org/headquarters_offices/ast/news_announcements/media/NSTP_statement.pdf.

affected facilities. Controller productivity in these operations can be helped or hindered by the new technologies.

FAA is not applying a broad approach that examines controller staffing and productivity in its NextGen plans. In contrast, the human–systems integration (HSI) methodology developed for and used initially by the military and now used in a variety of domains applies such an approach. For example, military standards supporting system acquisition (U.S. Department of Defense 2011) define HSI as "the systems engineering process and program management effort that provides integrated and comprehensive analysis, design, and assessment of requirements, concepts, and resources for human engineering, manpower, personnel, training, system safety, health hazards, personnel survivability, and habitability. These domains are intimately and intricately interrelated and interdependent and must be among the primary drivers of effective, efficient, affordable, and safe system designs." In general, the introduction of new technology can reduce, increase, or have no real impact on staffing requirements. Because any HSI problem involves trade-offs across a number of factors, predicting which of these outcomes will occur is inherently complex and cannot be done with any certainty.

FAA does not appear to be following such a broad HSI approach; thus, the trade-offs between technology, procedures, and workforce for NextGen are not being considered explicitly. Developments as transformative as those targeted by NextGen require that such considerations be taken into account. However, FAA's briefing to the committee indicated that no changes in controller skills and training have yet been identified in connection with NextGen and that assessments of the workforce are not integrated into NextGen plans.[2] In addition, FAA's response to a recent letter from the Research, Engineering, and Development Advisory Committee (REDAC) recommending attention to a broader set of human factors issues observed that "the strategic job analysis has shown there is no change expected in the responsibilities of controllers in the NextGen mid-term."[3]

[2] Steve Bradford, presentation to the committee, January 10, 2013.

[3] Letter from FAA Administrator Huerta to REDAC chair, John Hansman, February 28, 2014.

NEXTGEN CONSIDERATIONS AND THE CONTROLLER WORKFORCE PLAN

FAA's controller workforce plan (CWP) has not yet explicitly considered the ramifications of NextGen within its 10-year time horizon, perhaps because the NextGen plans themselves do not address controller staffing.[4] As noted in the 2013 CWP, "the staffing projections in this workforce plan are based on the current concept of operation" (FAA 2013, 26). There is tacit acknowledgment that NextGen technologies might affect future staffing; the plan notes that the en route staffing models are being examined for the impact of national implementation of the En Route Automation Modernization (ERAM). The inference is that FAA will react to any impacts after implementation. No similar mention is made of tower and TRACON facilities, which are experiencing their own modernization under the Terminal Automation Modernization Replacement project. In the committee's judgment, the omission of NextGen demands on staffing from the current CWP and the plan to react to them as new technologies or operational capabilities are introduced are likely to have adverse effects on NextGen development and deployment. A reactive, as opposed to proactive, approach increases the risk that staffing concerns may arise as NextGen programs are deployed, leading to delay in the adoption of new technologies and capabilities.

EFFECTIVE CONTROLLER TRAINING AND SELECTION FOR NEXTGEN OPERATIONS

An appreciation of the aptitudes and abilities required of a controller to work effectively in the NextGen environment, as well as knowledge of the number of controllers, is needed. Experience indicates that the methods used by FAA have been effective in selecting controllers, especially new hires. For example, the Air Traffic Selection and Training battery has proved to be a valid predictor of training outcome for the incoming generation of air traffic controllers: persons with higher scores were more likely to certify at their first assigned field facility (Broach et al. 2013).

[4] A recent report found that extensive schedule delays are likely to hinder NextGen implementation (GAO 2012).

However, the aptitudes needed in the midterm and in the long term are likely to change. Assessment of the relationship between aptitudes and success in qualifying as a certified professional controller (CPC) should continue throughout NextGen deployment. Research on selection could reduce failure rates as NextGen is deployed, especially at higher-traffic facilities, where the failure rate can be unacceptably high. These facilities typically rely on transfers from lower-level facilities to meet their staffing requirements, and the incoming transfers experience a high failure rate in qualifying for the more difficult operations. As discussed in Chapter 4, the failure rate at higher-traffic facilities is due in large part to certified professional controller in training (CPC-IT) candidates from lower-traffic facilities not succeeding in the more complex environment. Across the highest-level (Level 10+) TRACONs, the failure rate is 16 percent for transfers (CPC-ITs) and 26 percent for new hires (Byrne and Pierce 2014). Under NextGen, the transition to those facilities may be even more difficult as the CPC-IT attempts to master not only more complex traffic but also new technology.[5] The committee anticipates that, in the absence of action to address this challenge, failure rates for transfers will continue to be problematic or will worsen with the introduction of new technologies.

FAA has terminated air traffic controller selection research.[6] The committee views this as unfortunate, given the potential value of such research in identifying (*a*) relevant skills that may be needed in the long term in the NextGen environment and (*b*) the skills that allow a controller to succeed at higher-level facilities. An improved understanding of these matters appears to be critical in planning and executing cost-effective staffing plans that minimize the wasted resources associated with selecting controllers who fail to qualify.

[5] FAA almost always introduces a new technology at facilities with fewer complexities before implementing it at busier or more complex facilities. ERAM, for example, was introduced first at Seattle, Washington, and next at Salt Lake City, Utah. Nonetheless, during the course of NextGen implementation across the NAS, a controller transferring to a higher-level facility may encounter unfamiliar technology, depending on which facility the controller is transferring from.

[6] FAA presentation to Human Factors Subcommittee of REDAC, Washington, D.C., February 26, 2013.

STAFFING PRESSURES WITH NEXTGEN NEAR- AND MIDTERM DEPLOYMENT

Air traffic control facilities will experience strains on their staffing practices as NextGen systems and new procedures are deployed, and proactive measures will be required to ensure a smooth implementation. Even without NextGen, some facilities, particularly those with staffing levels under the targets set in the CWP (see Chapter 4), are wrestling with staffing issues. Many are higher-level facilities with a high degree of uncertainty and long lead times in increasing their staffing because of their reliance on controller transfers (see the preceding section).

Limited coordination between FAA's NextGen architectural plans, the plans for individual NextGen projects, and operational decision making aggravates staffing pressures at facilities when multiple NextGen programs seek to implement new systems and operational procedures within the same time window. For example, the Houston, Texas, en route center has been asked to field several NextGen programs concurrently (Automatic Dependent Surveillance–Broadcast, Required Navigation Performance, ERAM, and Optimization of Airspace and Procedures in the Metroplex).[7] In contrast, the implementation of OPD at the Atlanta TRACON (described earlier) produced no NextGen-related staffing problem at the TRACON itself and reportedly "made time on boards easier," although it apparently increased workloads in neighboring en route facilities. The variation in impact across facilities is not surprising given the lack of strategic planning and coordination among NextGen programs and across facilities within a program.

CONTROLLER PARTICIPATION IN THE NEXTGEN DEVELOPMENT PROCESS

In the committee's judgment, continued controller involvement in the development and deployment of NextGen technologies and procedures offers benefits. It has already helped establish realistic expectations and

[7] Andrew LeBovidge, committee member, personal communication to NextGen subgroup of the committee, February 28, 2013.

facilitated cost-effective implementation (see GAO 2005, 27). It increases the probability of the existing workforce accepting the proposed changes and reduces the need for extensive retraining and new personnel selection criteria.

Other air navigation service providers make explicit staffing commitments in support of new training and technology deployment. Airservices Australia notes the following:[8]

> When it comes to estimating the demand on the ATC [air traffic control] skill set for non-operational projects it is primarily calculated by the project managers. The project managers will identify the tasks to be performed and as such identify the specific ATC skill set required to perform those tasks. This requirement (number and type of resource) is then passed onto the workforce strategy department for inclusion into the broader ATC resource plan. Once it is entered into the plan, the need to satisfy the requirement through the allocation of ATC resource is tracked and monitored in the same fashion as [the allocation of] operational staff [is tracked and monitored] against an operational core/mature requirement. This then drives any additional recruitment activities or cross-training/conversion course requirements to backfill the ATC on project secondment (i.e., a temporary transfer to another job or post within the same organization).

In contrast, FAA's CWP does not formally include short-term or temporary assignments of controllers to NextGen programs to ensure the involvement of controllers in program teams during development and testing. As noted earlier, some facilities (e.g., the Houston en route center) have reported insufficient staffing during the implementation of new technology and procedures. No single office within FAA was able to supply information on the number of controllers working on NextGen-related technologies, so the committee turned to the National Air Traffic Controllers Association for an estimate. Close to 550 controllers are involved in the development and deployment of new technologies as part of NextGen and related initiatives,[9] but their efforts are not part of the CWP or factored into staffing level estimates.

The demands on staffing at facilities during the implementation of NextGen might be mitigated by staffing levels that allow for the

[8] Personal communication, Rodd Sciortino, Airservices Australia, September 2, 2013.
[9] Personal communication, Andrew LeBovidge, committee member, November 5, 2013.

formation of a cadre of controllers and support personnel within each NextGen program. The cadre could plan an implementation process that works with a facility's staffing level and coordinate with the facility with regard to the phases of implementation. It could then move among facilities as needed to supplement their staff and facilitate training during implementation of each NextGen program. The cadres could provide training that is consistent across facilities and a phased implementation designed to prevent problems with controller workload and staffing, and they could help ensure that the need for local operational knowledge is recognized. The cadre concept was used in the late 1980s during the rehost project, which replaced the hardware of the controller workstations in the en route centers.

FINDINGS AND RECOMMENDATIONS

Finding 5-1. If NextGen is to meet its goal of transforming the operation of the NAS, significant changes in controllers' tasks are to be expected, particularly in the longer term (beyond a 10-year time horizon). In the near and midterm (within a 10-year time horizon), staffing plans do not explicitly support the controller involvement necessary for the successful development, evaluation, and implementation of NextGen products.

Recommendation 5-1. FAA should accelerate ongoing research into NextGen developments that are likely to affect controller staffing to (*a*) help predict their impact on controller staffing, (*b*) identify where staffing concerns may pose technical risks to NextGen developments, and (*c*) determine where NextGen may support controller productivity.

Recommendation 5-2. FAA should refine the CWP in a manner that raises the visibility and addresses the controller staffing implications of NextGen development and implementation. The plan should first address near- and midterm concerns. Since NextGen is to be implemented incrementally, each facility will deploy various NextGen technologies and updated procedures over the next several years. Staffing pressures due to the new systems and procedures will recur rather than being a one-time issue, and they need to be addressed proactively. The staffing plan should explore new or revised models and tools that can examine how staffing levels will be influenced by alterations in controller tasks, time on task, and workload, especially with longer-term, broader-reaching changes in operations.

Recommendation 5-3. FAA should enhance its NextGen implementation plans by (*a*) defining when and where development and testing activities are to take place and (*b*) coordinating efforts to avoid simultaneous deployment of new technologies at a particular facility.

Recommendation 5-4. The CWP should explicitly incorporate the need for involvement of controllers in the development, testing, and implementation of NextGen products and procedures. Cadres of controllers might be established to support the development and testing of specific NextGen programs; as each program is ready to be deployed, the cadres would move from facility to facility to support training and contribute their knowledge about the most effective, least disruptive implementation process.

Finding 5-2. The changes in controllers' duties and tasks accompanying the implementation of NextGen are likely to change the aptitudes needed for an individual to qualify as a CPC. A better understanding of the evolving relationship between controller aptitudes and qualification is needed to avoid the costs associated with high failure rates in training and in transferring from lower- to higher-level facilities.

Recommendation 5-5. FAA should continue to support research into how NextGen may change the tasks of the air traffic controller to identify improvements in training and selection criteria for controllers. The research should consider not only the training and selection of new controllers but also the transfer of controllers from lower- to higher-level facilities.

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GAO	Government Accountability Office

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6

Current and Estimated Budgets for Air Traffic Control Staffing

As part of the congressional charge for this study, the committee was asked to consider "the Administration's current and estimated budgets and the most cost-effective staffing model to best leverage available funding." This chapter focuses on the "current and estimated budgets" elements of the charge. It describes the costs of the air traffic control (ATC) workforce in the context of the Federal Aviation Administration's (FAA's) total workforce and budget and establishes a baseline for "available funding." Assessment of the cost-effectiveness of FAA's models called for in the congressional charge is provided in the Summary.

The first three sections of this chapter examine the costs of current and future ATC budgets and the estimated revenue streams available to support them. Options for reducing the cost of ATC staffing and increasing revenues are discussed. These options are presented for illustration only and should not be interpreted as committee recommendations for alternative staffing strategies. The summary section places the cost of the ATC workforce in the context of the larger FAA budget issues facing the administration and Congress.

CURRENT BUDGET

This section relies on the President's FY 2014 and FY 2015 budget submissions for FAA. Estimated future budgets are taken from agency-level tables presented in an online appendix to the *Analytical Perspectives* appendix to the President's FY 2014 and FY 2015 budget submissions.[1]

[1] *Fiscal Year 2014 Analytical Perspectives, Budget of the U.S. Government*, http://www.whitehouse.gov/sites/default/files/omb/budget/fy2014/assets/spec.pdf, accessed September 3, 2013. Detailed tables and out-year budget estimates for FAA were taken from Table 32-1, Federal Budget by

This chapter of the report was largely drafted during calendar year 2014, during which the President and Congress were engaged in a dispute over the federal budget and deficit. For the first 3 months of FY 2014, FAA operated under a continuing resolution that was based on the appropriated budget approved by Congress in FY 2012, as reduced by the Budget Control Act of 2011 (also referred to as sequestration).[2] In January 2014, the President signed the Consolidated Appropriation Act of 2014, which implemented the Bipartisan Budget Act of 2013. That act, agreed to by the President and Congress in December 2013, brought an extended period of contentious debate about the federal budget to a temporary close. It established agency budget targets for FY 2014 and FY 2015 and set aside, for FY 2014 and 2015, significant cuts to discretionary portions of the federal budget that were otherwise required under the Budget Control Act of 2011. That act and its past and potential impact on FAA's budget will be discussed in more detail later in this chapter.

The President's FAA budget proposals for FY 2014 and FY 2015 provide the administration's current view of budgetary needs; the appendices to the budget submission indicate the administration's views with regard to budgets and aviation trust fund revenues in future years. The budget requests made in FY 2014 and FY 2015 are similar, with an important exception. During FY 2014, the administration revised its forecast of aviation trust fund revenues, which has important consequences for ATC staffing, as described later in this chapter. The funding ultimately appropriated by Congress for ATC for FY 2014 in the Consolidated Appropriation Act corresponds to the President's request, and the amounts for FAA Operations as a whole are consistent. Tables in the chapter provide detail concerning requested and appropriated (enacted) amounts for FY 2014 and the President's requests for FY 2015.

Agency and Account, http://www.whitehouse.gov/sites/default/files/omb/budget/fy2014/assets/32_1.pdf (see page 268 of 449), accessed September 3, 2013.

2 The Budget Control Act (P.L. 112-25) requires automatic reductions to most federal discretionary budgets if Congress is unable to reach agreement on a deficit control strategy (Elias et al. 2013). Sequestration cuts to FAA's FY 2013 budget totaled $636 million, of which $486 million came from FAA Operations. During FY 2013, Congress approved legislation allowing FAA to use unspent capital funds in the Airport Improvement Program to cover part of this cut.

TABLE 6-1 FAA FTE Staff, FY 2013–2015

Category	FY 2013, Actual	FY 2014, Enacted	FY 2015, Requested	Percentage of Total FY 2015 Requested[a]
Operations	41,055	40,471[b]	40,925	87.3
Facilities and Equipment	2,733	2,670	2,733	5.8
Research, Engineering, Development	248	249	249	0.5
Grants-in-Aid for Airports	555	605	608	1.3
Other	2,035	2,069	2,362	5.0
Total	46,626	46,064	46,877	100.0

[a]Detail does not sum to total because of rounding.
[b]Includes 14,900 controllers.
SOURCE: President's FY 2014 and FY 2015 budget submissions, FAA, Exhibit II-8.

Staffing

FAA had a workforce of about 46,000 full-time equivalent (FTE) personnel in FY 2014.[3] The ATC workforce accounts for about 14,900 of these FTEs, or about 31 percent of the total workforce (Table 6-1). Overall FAA and ATC staffing levels have been fairly consistent since at least 2012.

Budget

Operations accounts for 64 percent of FAA's total budget (Table 6-2).[4] It includes much more than simply the ATC workforce. As shown in Table 6-3, the Air Traffic Organization (ATO), of which ATC is a part, is the largest component of the Operations budget, accounting for three-quarters of the Operations total. Aviation Safety, the next-largest component, accounts for 12 percent of FAA's budget, and Finance and Management accounts for 8 percent (Table 6-3).

The total Operations budget was about $9.4 billion in FY 2013 and about $9.7 billion in FY 2014; ATO's FY 2014 budget of $7.3 billion

[3] Although requested staffing levels are available for FY 2015, this chapter refers to FY 2014 staffing levels to be consistent with data presented in previous chapters and with detailed information about the cost of the ATC workforce for 2012 through 2014 provided by FAA; these data are not available in the President's budget submissions. Staffing levels are reasonably consistent between FY 2014 and 2015, as shown in Table 6-1.

[4] Budget data presented throughout this report are in current dollars.

TABLE 6-2 FAA Budget Authority by Function, FY 2013–2015

	Budget ($ thousands)				
Category	FY 2013 Actual	FY 2014 Requested	FY 2014 Enacted[a]	FY 2015 Requested	Percentage of Total FY 2015 Requested[b]
Operations	9,148,465	9,707,000	9,651,422	9,750,000	63.8
Facilities and Equipment	2,613,627	2,777,798	2,600,000	2,603,700	17.0
Research, Engineering, Development	158,792	166,000	132,608	156,750	1.0
Grants-in-Aid for Airports	3,343,300	2,900,000	3,480,000	2,770,000	18.1
Total	15,264,184	15,550,798	15,864,030	15,280,450	100

[a]Does not reflect transfer of $253 million from Airport Improvement Program to Operations to fund air traffic controllers who otherwise would have been furloughed because of sequestration.
[b]Detail does not sum to total because of rounding.
SOURCE: President's FY 2014 and FY 2015 budget submissions, FAA, Exhibit II-1.

TABLE 6-3 FAA Operations Appropriation Line Items, FY 2013–2015

	Budget ($ thousands)				
Line Item	FY 2013 Actual	FY 2014 Requested	FY 2014 Enacted	FY 2015 Requested	Percentage of Total FY 2015 Requested
ATO	7,270,538	7,331,790	7,331,790	7,396,654	75.9
Aviation Safety	1,217,552	1,204,777	1,204,777	1,215,458	12.5
Commercial Space Transport	15,420	16,311	16,311	16,605	0.2
Finance and Management	551,669	807,646	762,462	765,047	7.8
NextGen	56,989	59,782	59,696	60,089	0.6
Human Resource Management	93,687	107,193	296,366[a]	296,147[a]	3.0
Staff Offices	189,810	199,801			
Total	9,395,665	9,727,300	9,671,402	9,750,000	100

NOTE: NextGen = Next Generation Air Transportation System.
[a]The Human Resource Management and Staff Offices line items were combined in FY 2014 Enacted and FY 2015 Requested.
SOURCE: President's FY 2014 and FY 2015 budget submissions, FAA, Exhibit III-1.

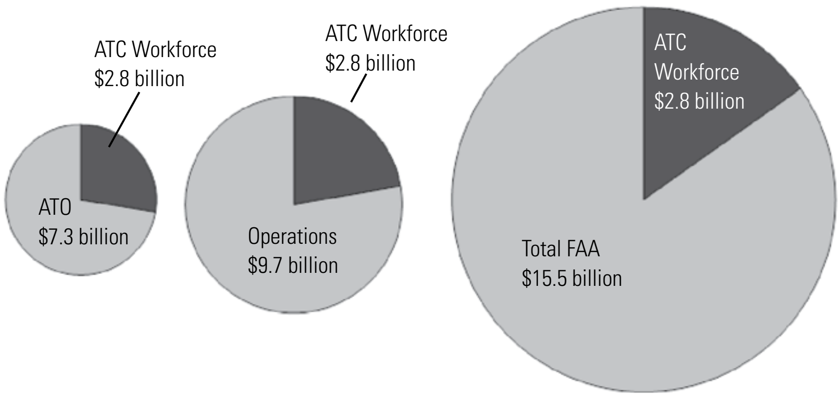

FIGURE 6-1 Cost of FAA workforce as a share of FY 2014 ATO, operations, and total budgets.

accounts for 76 percent of the latter amount (Table 6-3). According to figures provided by FAA, the cost of the ATC workforce covered in the controller workforce plans was $2.575 billion (for 15,100 controllers) in 2012, was $2.795 billion (for 15,000 controllers) in 2013, and was estimated to be $2.787 billion (for 14,900 controllers) in 2014. The $2.787 billion for the ATC workforce in 2014 represents about 38 percent of ATO's FY 2014 budget, 29 percent of the Operations budget, and 18 percent of the total FY 2014 FAA budget (see Figure 6-1).

The ATC workforce is the main component of the ATO workforce and of the line item En Route and Oceanic and Terminal Services in ATO's budget (Table 6-4). The total ATC workforce in FY 2014 is about 14,900, or about three-quarters of the FTEs shown in the En Route and Oceanic and Terminal Services row in Table 6-4. About 5,000 other personnel—supervisors, managers, and administrative personnel—who are not a part of the unionized workforce are included in that row.

The next largest category of the ATO budget is accounted for by Technical Operations, which maintains ATC computers, radars, communications, and other equipment. Technical Operations represents about a quarter of ATO's personnel and budget. These personnel are represented by a different bargaining unit and are not included in the ATC workforce considered in this report.

TABLE 6-4 ATO Budget and FTE Staff

	Budget ($ thousands)				FY 2014 FTE	
Line Item	FY 2013 Actual	FY 2014 Requested	FY 2014 Enacted	FY 2015 Requested	Number	Percent[a]
En Route and Oceanic and Terminal Services	3,941,762	3,987,582	3,860,044	3,942,430	19,946	64.3
Technical Operations	1,664,199	1,716,181	1,586,695	1,587,678	7,923	25.5
System Operations	288,559	288,104	309,601	308,752	452	1.5
Safety and Technical Training	227,409	271,146	274,879	274,229	519	1.7
Mission Support Services	266,126	284,821	292,642	292,028	1,363	4.4
Management Services	276,632	170,355	326,341	327,287	239	0.8
Program Management Organization	605,851	655,675	661,589	664,250	575	1.9
Program Adjustment		(62,074)				
Total	7,270,538	7,311,790	7,311,791	7,396,654	31,017	100

[a]Detail does not sum to total because of rounding.
SOURCE: President's FY 2014 and FY 2015 budget submissions, FAA.

REVENUES

Since 1970, FAA has been funded mostly by the Airport and Airway Trust Fund (AATF). The fund is derived from a variety of taxes and fees imposed on aviation system users (see Table 6-5). Other funding is provided by the General Fund, which depends on tax receipts not dedicated to Social Security, Medicare, or other nondiscretionary programs and on federal borrowing. Shares of FAA funding covered by trust fund revenues and by the General Fund in the past and proposed for FY 2015 are shown in Table 6-6.

Most federal tax receipts to the General Fund come from individual federal income taxes; thus, loosely speaking, the general taxpaying public is

TABLE 6-5 Funding Sources and Tax Rates, AATF

Aviation Tax	Comment	Tax Rate
Domestic passenger ticket tax	Ad valorem tax	7.5% of ticket price
Domestic flight segment tax	Segment is one takeoff and one landing; segment fee does not apply to flights to or from rural airports	$4.00 per passenger in CY 2014 (indexed)
International arrival and departure tax	Head tax assessed on passengers arriving from or departing for foreign destinations (and U.S. territories that are not subject to the domestic passenger ticket tax)	$17.50 (indexed)
Flights between continental United States and Alaska or Hawaii		$8.70 international facilities tax plus applicable domestic tax rate (indexed)
Frequent flyer tax	Ad valorem tax assessed on mileage awards (e.g., credit cards)	7.5% of value of miles
Domestic cargo and mail		6.25% of amount paid for the transportation of property by air
General aviation fuel tax		Aviation gasoline: $0.193 per gallon Jet fuel: $0.218 per gallon Fractional ownership surcharge: $0.141 per gallon (starting 3/21/2012)
Commercial fuel tax		$0.043 per gallon

NOTE: CY = calendar year.
SOURCE: http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf/media/14.1.17ExciseTaxStructureCalendar2014.pdf.

TABLE 6-6 Trust Fund and General Fund Budget Authority, FAA Operations

	Budget ($ thousands)			
Source	FY 2013 Actual	FY 2014 Requested	FY 2014 Enacted	FY 2015 Requested
General Fund	4,352,475	3,223,000	3,156,214	709,150
AATF	4,795,989	6,484,000	6,495,208	9,040,850
Total	9,148,464	9,707,000	9,651,422	9,750,000

SOURCE: President's FY 2014 and FY 2015 budget submissions, FAA, Exhibit II-4.

TABLE 6-7 AATF Revenues by Type of Tax

AATF Tax	FY 2012 Revenues ($ millions)	Share of Total (%)
Transportation of persons by air	8,711.0	69.5
Transportation of property	492.0	3.9
Use of international air facilities	2,729.0	21.8
Aviation fuel commercial use	390.0	3.1
Aviation fuel (other than gasoline)	161.0	1.3
Aviation gasoline	39.0	0.3
Any fuel used in fractional ownership flight	11.0	0.1

SOURCE: http://www.faa.gov/about/office_org/headquarters_offices/apl/aatf/.

the main source of federal income taxes that are dedicated to the General Fund.

The 7.5 percent ticket tax on commercial aviation users provides about 70 percent of the revenues into the AATF (Table 6-7). The tax rate has been unchanged since 1997 legislation (which phased in a reduction in the rate from 10 percent in 1996 to 7.5 percent by 1999). Other taxes that make up a modest share of total revenues (domestic flight segment tax, international arrival and departure tax, and a tax on flights between the continental United States and Alaska and Hawaii) have been pegged to the Consumer Price Index since January 1, 2002. The only new tax since 1997 is the surcharge on fractional ownership. It was introduced in March 2012 and accounts for 0.1 percent of total AATF revenues. As shown in Table 6-7, fuel taxes account for a small share of total revenues (about 5 percent), while ticket taxes and taxes on the use of international facilities account for 92 percent.

Aviation taxes and fees are imposed on National Airspace System users, but not in proportion to their use of the system (Table 6-8). Commercial aviation accounts for 62 percent of ATC operations but pays 98.3 percent of AATF user fees. General aviation (GA) accounts for 38 percent of ATC operations but pays only 1.7 percent of AATF user fees.[5]

[5] For the purposes of this analysis, the committee defined GA as comprising both piston-engine aircraft powered by aviation gasoline and turbine-engine aircraft powered by kerosene when operated under Part 91.

TABLE 6-8 Share of Taxes Paid and Share of ATC Operations by User Type, 2012

	Share (%)				
	Taxes Paid to Trust Fund	ATC Operations	Tower Operations	TRACON Operations	ARTCC Operations
General aviation (Part 91)	1.7	38	54	38	17
Commercial aviation (Part 121 and 135)	98.3	62	46	62	83

NOTE: TRACON = terminal radar approach control; ARTCC = air route traffic control center.

For many years, Congress and various administrations have debated the extent to which user fees (revenues of the AATF) should cover aviation system costs (Elias 2010, 13). In the 110th Congress, the Bush administration proposed an increase in user fees and a requirement that the AATF cover most aviation system expenses (Elias 2010). These proposals were not adopted by Congress. The 111th Congress debated various proposals to raise user fees and taxes, including those on GA, but the result was a stalemate. The FAA Modernization and Reform Act of 2012 ultimately left tax rates unchanged, with the exception of the increased tax on fuel for fractionally owned aircraft mentioned previously.

In its FY 2014 budget submission, the Obama administration proposed raising a variety of taxes and fees related to aviation, several of which are not revenue sources dedicated to the AATF.[6] (One of the administration's proposals, to increase fees for airline security from $2.50 to $5.00, was adopted in the Bipartisan Budget Act of 2013.) With regard to AATF revenues, the administration also proposed a new fee of $100 per flight, which it repeated in its FY 2015 budget submission. The fee would apply to all aircraft that fly in controlled airspace except

[6] Included would be an increase in the security fee (from $2.50 to $5 per one-way segment), international custom duties (from $5.50 to $7.50), immigration services fees (from $7 to $9), and an allowance for large airports to raise passenger facility charges to $8 while reducing large airport eligibility for Airport Improvement Program funds. Security, customs, and immigration fee increases would help defray the costs of security screening of passengers and cargo at airports, customs inspections, and immigration services that are covered by general revenues paid by taxpayers. Passenger facility charges would allow large airports to increase fees to pay for airport facilities and services.

for piston aircraft, military and government flights, air ambulances, and Canadian aircraft overflights. The administration's premise is that aviation users who consume ATC services should pay for them, as opposed to taxpayers paying through the General Fund. Both commercial and GA interest groups strongly oppose the administration's aviation tax increase proposals, including the per flight fee, which Congress has rejected in previous years.

The administration proposal leaves the 7.5 percent ticket tax unchanged. Over the past 10 years, however, airlines have limited increases in the cost of tickets by introducing ancillary fees for a growing range of services, including checked baggage, meals, blankets and pillows, early boarding, seat selection, and in-flight entertainment. The Internal Revenue Service has determined that many of these ancillary fees are exempt from the 7.5 percent excise tax that provides revenue to the AATF. Hence, "airlines increasing reliance on fees reduces the proportion of their total revenue that is taxed to fund FAA" (GAO 2010, 1). For example, if ancillary fees for checked baggage had been subject to taxation, the associated AATF revenue would have been approximately $248 million in 2013.[7] The revenue losses associated with tax-exempt fees led the Government Accountability Office to raise the possibility that Congress "may wish to consider amending the Internal Revenue Code to make mandatory the taxation of certain or all airline imposed fees and to require that the revenue be deposited in the Airport and Airway Trust Fund" (GAO 2010, 35).

Opinions have varied over time about the share of FAA Operations that should be covered by the trust fund (Fischer 2008). When the AATF was established in 1970, spending on operations was allowed, but the following year the Airport and Airway Development and Revenue Acts Amendments of 1971 (P.L. 92-174) effectively banned such operations spending. Shortly thereafter, in 1976, Congress amended the legislation to allow for partial coverage of FAA operating expenses by aviation trust

[7] The U.S. Department of Transportation's Bureau of Transportation Statistics (2014) reports that U.S. passenger airlines took in $3.3 billion in baggage fees in 2013, resulting in an estimated revenue loss of about $248 million ($3.3 billion × 7.5 percent = $247.5 million). An increase in taxes would reduce demand slightly, but the effect would likely be small because of the small increase in the ticket price ($50 × 7.5 percent = $3.75).

fund revenues. For 1 year, FY 2000, the AATF covered the full expenses of FAA, both capital and operating, but otherwise, some operating expenses have been covered by the General Fund.[8] With the enactment of the Aviation Investment and Reform Act for the 21st Century (AIR21) in 2000, Congress made clear that capital expenditures—Facilities and Equipment and the Airport Improvement Program (AIP)—had first call on trust fund revenues (GAO 2012a, Footnote 18). Any residual AATF revenues would be available to cover a share of the cost of Operations.[9] Since enactment of AIR21, from 2001 through 2010, the General Fund covered between 8 and 33 percent of FAA's total appropriation (between 16 and 57 percent of FAA Operations expenses) (GAO 2012a, 6).

As Fischer (2008) points out, most observers have concluded that a share of FAA's operating expenses should be paid by the General Fund to cover activities such as ATC services provided to the military.[10] GA and corporate jet operators have contended that ATC provides a safety function that is a public good and should therefore be paid for by the general public. In this report, the committee makes no judgment as to the appropriate share of FAA's expenses to be covered by the General Fund or how much various user groups should pay.

The ATC workforce is not the only component of the FAA Operations budget that is partly supported by General Fund revenues. ATO received about $3.55 billion in General Fund support in 2013, or about 80 percent of the $4.4 billion in General Funds appropriated for FAA Operations.[11] About $1.3 billion in General Fund revenues was used for ATC staffing in FY 2013, or about 37 percent of ATO's total General Fund support and 29 percent of the total General Fund revenues for FAA Operations. These shares remain the same for FY 2014, but the total amount of Gen-

[8] Congress deliberately covered Operations out of the AATF in 2000 to draw down the balance in the fund, which had built up over previous years.

[9] AIR21 and subsequent legislation also required that AATF revenues be appropriated so that user taxes credited to the AATF would not build up substantial unobligated balances in the trust fund, as had happened during some years in the past.

[10] Fischer (2008, 12–13) provides a good overview of the economic arguments about whether ATC is a "public good" and therefore should be funded by all taxpayers rather than only by aviation users.

[11] FAA—President's 2014 budget submission, page 52 of 826. According to FAA, the share of General Funds for Operations (about 47 percent in 2013) is applied equally to all the subcomponents of the FAA Operations budget, including ATC.

eral Funds appropriated, $3.2 billion, is considerably below the amount required in FY 2013, and the administration requests significantly less in FY 2015. The increase in trust fund support for FAA Operations in FY 2014 was made possible by growing revenues to the fund. Although total operations and total commercial flights have declined over time, as discussed in previous chapters, commercial flights have been holding steady and are operating with much higher load factors. Thus, more passengers are paying the ticket tax than in recent years, and the ticket tax is the main source of AATF revenues.

FUTURE REVENUES

Both the administration (through the Department of the Treasury) and Congress [through the Congressional Budget Office (CBO)] forecast AATF income (receipts from taxes and interest). The forecasts are based on macroeconomic trends as opposed to aviation activity. The forecasts initially made in FY 2014 differ substantially. By 2018, for example, the administration initially forecast AATF receipts (and interest) to total $15.8 billion, compared with CBO's forecast of $18.7 billion. In late 2013, Treasury staff indicated that they had adjusted their forecast of AATF receipts. In the President's FY 2015 budget submission, the Treasury forecasts AATF receipts for FY 2018 of $17 billion, which is $1.2 billion more than forecast in the FY 2014 submission. The administration's revised forecasts, if realized, would result in a reversal of the substantial dependence of FAA Operations on the General Fund and substantially ease the budgetary pressure caused by the ATC workforce.

Over time, a rebound from the slow-growth economy since the recession of 2008–2009 will improve AATF revenues as more tickets are purchased for an increasing number of flights and carriers purchase more fuel and equipment (as noted, 70 percent of AATF revenues comes from ticket taxes). Demand for aviation services tracks closely with overall measures of economic activity. The administration's FY 2014 forecast for the AATF to 2018 assumes an average annual growth rate of about 5 percent, consistent with its forecast for growth in gross domestic product. Its revised FY 2015 forecast assumes an average annual growth rate of 6.7 percent. AATF revenues are forecast to rebound from $11 billion in 2013 to $18.7 billion by 2018 according to CBO's May 2013 estimates.[12] Such an increase would require an average annual growth rate of 7.5 percent, well in excess of the administration's FY 2014 forecasts. The difference matters considerably, because CBO's forecasts indicate that the AATF would have sufficient revenues to cover FAA's capital and all its operating expenses as early as FY 2017. The administration's revised forecast for FY 2015 is reflected in its FY 2015 budget request for General Fund revenues for Operations, which, at $709 million, is $2.4 billion less than required in FY 2014 (see Table 6-6). Whether the administration's revised forecasts (which are based on the 6.7 percent growth rate mentioned above) will hold is open to question. FAA's 2013 forecast of revenue passenger miles, an indicator of future ticket tax revenue, has an average annual growth rate of only 3 percent. Trust fund revenues have grown substantially in recent years, even though total flights have held steady, because of increasing load factors. With most flights operating close to maximum capacity, however, opportunities for further load factor growth are limited. Hence, future revenue growth will depend on the strategies adopted by the airline industry to meet growing demand.

The administration's original FY 2014 forecasts (prerevision) are more conservative than those of CBO and are more consistent with FAA's assumptions about future aviation activity. In its 2013 forecast of aerospace activities, FAA estimates that U.S. commercial carrier revenue passenger miles (both domestic and international) will grow by an average annual rate of 3.2 percent through 2018 (FAA n.d., Table 6). However, FAA's forecast of ATC workload—total operations—grows by only 1.3 percent through 2018, which is consistent with the trend toward higher load factors and the use of larger aircraft.[13] Forecasts of air traffic growth from airplane manufacturers are more modest than the forecasts from the administration and CBO. Both Airbus and Boeing anticipate world traffic growth of about 5 percent annually but expect lower growth rates in the advanced economies of Europe and North America.

[12] CBO Reestimate of President's 2014 Budget Request. AATF Projection of Trust Fund Balances, May 2013. Table provided by CBO.

[13] Between 2013 and 2022, estimated annual average rates of change are as follows: for air carrier operations, growth of 2.6 percent; for air taxis and commuters, a decline of 0.6 percent; for GA, growth of 0.4 percent; and for military, growth of 0.8 percent.

For North America, Airbus forecasts a 3.0 percent growth rate and Boeing a 2.7 percent growth rate (Airbus 2013; Boeing 2013).

ANTICIPATED ATO BUDGETS

As part of *FY 2015 Analytical Perspectives* (Table 29-1), the administration forecasts budget authority and outlays for FAA, but only at the level of major budget category. Hence, it is only possible to review estimates at the level of future FAA Operations budget authority (authority to obligate current and future year expenditures) rather than the budget for ATC staffing. The administration reports FAA Operations budget authority of about $9.6 billion in 2013, which is estimated to grow to $10.6 billion by 2018. The average annual growth rate of 2 percent is fairly consistent with an estimated 1.3 percent average annual growth rate in workload (on the assumption that some of the higher rate for budget authority is accounted for by inflation).

As noted, between 2003 and 2012 FAA's Operations budget received between $2 billion and $4 billion annually from the General Fund (GAO 2012a, Figures 7, 8). As shown in Table 6-6, this figure reached $4.4 billion in 2013 but dropped to $3.2 billion in FY 2014. The President's FY 2015 budget submission indicates that the General Fund contribution would drop to $709 million in FY 2015, nearly $4 billion less than required as recently as FY 2013. In the final appropriation for FY 2014, Congress appropriated $3.2 billion in General Funds (Table 6-6), which it achieved through a combination of a substantially increased allocation from the AATF compared with 2013 and a slightly reduced budget for FAA Operations, as explained in the following text. Congress cut FAA's Operations FY 2014 budget by $56 million compared with the amount requested (Table 6-3), while it funded ATO at the level requested. [Cuts in the Operations budget were made to requested funds for administrative expenses (Table 6-3).] Congress also cut Grants-in-Aid for Airports, but not as much as the administration requested; the amount appropriated for the AIP for FY 2014 is $3.48 billion (about the same as provided for FY 2013 and $580 million more than the administration requested for FY 2014). Instead of allocating $3.3 billion from the General Fund, Congress appropriated $3.2 billion, while increasing the contribution from the AATF from $4.8 billion in FY 2013 to $6.5 billion in 2014, as the President requested (Table 6-6).

The Appendix to the 2015 *Analytical Perspectives* indicates that the administration expects the General Fund to cover only $709 million of FAA Operations budget authority in FY 2015, and the administration expects the General Fund's contribution to stay below $800 million until 2021.[14] If these forecasts hold, the demand for General Fund revenues to cover FAA Operations expenses may not be as significant a budget issue as it has been in the past.

The administration's FY 2014 and 2015 budget submissions would manage the future growth in Operations expenses, in part, by reducing the AIP from $3.35 billion in FY 2013 to $2.9 billion in FY 2014 and holding the AIP constant at that level in coming years.[15] During 2013, Congress did allow FAA to divert funding from AIP to avoid furloughs of ATC staff and closure of many low-activity contract towers, as would have been required under sequestration. However, the AIP is popular in Congress and has strong advocates, so whether Congress will agree with that strategy in the long term is unknown. Of course, Congress could make other choices within its capital budget. For example, it could stretch out the period for implementation of the Next Generation Air Transportation System (NextGen) to make more aviation trust revenues available for FAA Operations.[16]

Late in 2013, Congress enacted the Bipartisan Budget Act of 2013, which guides appropriations for FY 2014 and 2015. Under this legislation, non-Defense domestic programs are funded at $468 billion for FY 2014, which is $24 billion more than allowed under the 2013

[14] Until FY 2011, forecasts of AATF receipts were made by FAA, but they are now made by the Department of the Treasury. Between 2001 and 2010, FAA forecast AATF receipts that were more than $9 billion in excess of actual receipts (GAO 2012a, Figure 4).

[15] See Table 32-1 in Appendix to *Analytical Perspectives*, page 270. At the time of this writing there was an obligation limit on AIP of $2.9 billion for FY 2014, but it would increase to $3.55 billion by 2023. The administration proposes to hold AIP at $2.9 billion through 2023, so Congress would have to agree to cut future AIP appropriations below the obligation limit. The administration pairs its cut to AIP with a proposal to allow large airports to increase passenger facility charges dedicated to airport improvements.

[16] The Government Accountability Office has been critical of FAA's estimation of the cost and schedule for the NextGen program and its ability to meet proposed schedules for NextGen implementation (GAO 2012b).

continuing resolution. The Bipartisan Budget Act of 2013 provides relief for 1.5 years from the automatic, across-the-board budget cuts required by the Budget Control Act of 2011 (P.L. 112-25). This legislation requires automatic reductions to most federal discretionary budgets until Congress reaches agreement on a deficit control strategy as required under the law (Elias et al. 2013). Sequestration cuts to FAA's FY 2013 budget totaled $636 million, of which $486 million came from Operations. Potential budget cuts from sequestration complicate any forecast of agency budgets beyond FY 2015. If Congress is unable to agree on a long-term plan to reduce the deficit and thereby allows sequestration to continue in that year, the cuts to ATC staffing would be unprecedented in scope and impact relative to the demand for aviation. Five years of sequestration cuts of approximately 5 percent annually, for example, applied proportionately on FAA's budget, would reduce the FY 2014 ATC budget of $2.787 billion by nearly $700 million, or 25 percent. Such a cut would require a commensurate reduction in staffing of approximately 3,725 controllers.

The roughly $2.8 billion cost of the ATC workforce for FY 2014 could be reduced if the size of the workforce was reduced, but the budgetary savings would be modest for plausible reductions in the number of controllers, while the impact on system performance could be significant. The following "thought experiment" is provided to make this point. As mentioned in Chapter 3, FAA staffs for the 90th percentile busiest day, but it could staff for the median day (the 50th percentile day) instead. Use of the 50th percentile for planning purposes means that half of the time there would not be sufficient personnel to respond to demand, which would result in flight delays or cancellations during peak periods. The safety effects are uncertain, since FAA would limit the number of flights to what ATC could manage. The point of this discussion is not to propose staffing at the 50th percentile, but merely to observe that the savings from staffing at that level would be modest. Use of the 50th instead of the 90th percentile busiest day in the staffing calculations would reduce the number of ATC staff needed by only about 8 percent. The budgetary savings from an 8 percent cut in ATC staff would be in the range of $223 million (8 percent of $2.787 billion), which represents about 1.4 percent of FAA's annual budget and only 7 percent of the General Fund revenues proposed for FAA Operations in 2014.

POLICY OPTIONS

The policy conundrum for FAA and Congress has been that the agency has required a growing level of support from the General Fund to cover the cost of its operations. If the administration's revised forecasts of AATF revenues hold, this trend would be reversed, but whether the forecasts will hold is unknown.

The ATC workforce received approximately $1.3 billion of the $4.4 billion in General Fund revenues allocated to FAA in FY 2013, a sizable proportion. General Fund revenues are in demand across the entire discretionary budget. In this context, FAA and Congress have limited choices: cutting services (and costs), raising revenues, or increasing deficit spending.

A politically less difficult choice would be to cut costs without reducing services commensurately. For example, FAA and Congress could adjust to a lower level of funding from the General Fund by making many other changes in the overall FAA budget—such as stretching out the NextGen program or agreeing to administration proposals to cut funding allocated to the AIP—rather than by cutting ATC staffing levels. Congress has done so as recently as 2013 to avoid FAA's planned furloughs of ATC staff and the closing of low-activity contract towers in response to the first round of cuts under sequestration. In addition, FAA will be able to reduce the cost of ATC staff in coming years as a consequence of the pending retirement of the large number of controllers hired to replace those fired in the 1981 Professional Air Traffic Controllers Organization strike (a lower proportion of the remaining employees will have the most seniority). In anticipation of these retirements, FAA has hired many trainees so that they will be fully trained before the retirements occur. Other options would be to cut overhead expenses by reducing the number of ATC managers and supervisors[17] and to cut costs by increasing the number of contract towers and consolidating services into fewer facilities. Options for enhancing the revenues needed to support ATC services could also be considered.

[17] The FAA Modernization and Reform Act of 2012, Title VI, Section 604, calls for an independent study of frontline manager staffing. It had not been released at the time of this writing.

Contract Towers

As noted in Chapter 1, ATC services at some low-activity towers are provided by private-sector organizations under contract to FAA. The agency has operated its Federal Contract Tower program for more than 30 years, and as of 2014, there were 252 towers in the program. The Office of Inspector General (OIG) of the U.S. Department of Transportation estimates that contract towers cost about $1.5 million less on average than low-activity towers managed by FAA (OIG 2012a). The OIG attributes this to (*a*) contract towers having fewer total personnel (10 fewer ATC personnel on average than comparable FAA-operated towers) and (*b*) contract tower controllers being paid significantly less than FAA controllers.[18] In addition, contract towers operate at times with a single controller, whereas FAA requires its towers to operate with a minimum of two controllers in most circumstances.

As indicated in Chapter 2, the committee has reservations about the OIG's conclusion that contract towers offer a level of safety comparable with that of FAA-operated towers (OIG 2012a). The committee's reservations center on the difficulty of establishing analogous groups of FAA towers and contract towers for comparison purposes and on differences in safety reporting practices at the two types of tower. The assumption, for purposes of illustration, that the safety levels of FAA-operated and contract towers are equal implies that FAA could contract out more low-activity towers to reduce its costs without reducing safety. As noted in Chapter 2, most of the reduction in operations since the peak in 2000 has occurred in GA rather than in commercial operations, which suggests that demand on low-activity towers has decreased. The OIG found that of the 315 FAA-operated facilities, about 90 towers had traffic density levels similar to those of contract towers. This implies that, given the average $1.5 million lower annual operating cost of contract towers, FAA could save about $135 million annually by contracting out operation of these towers (90 comparable FAA-operated towers multiplied by the

[18] Many contract tower employees are former FAA or military controllers who may be drawing a pension and have less need for a salary comparable with that of controllers in FAA-operated towers. Both groups are represented by the National Air Traffic Controllers Association.

$1.5 million average lower operating cost at contract towers). Doing so would require a reduction in FAA's controller workforce of about 900 (90 facilities times 10 more ATC personnel in comparable FAA-operated towers than in contract towers). Such a strategy would likely arouse strong opposition from the National Air Traffic Controllers Association, as in 1998, when an attempt was made to privatize 22 towers. The strategy would reduce the number of controllers by 6 percent and the cost of the ATC workforce by 5 percent. The savings would be less than 1 percent of FAA's budget. Whether such savings could be achieved without compromising safety is questionable. Much more modest, but less controversial, savings could be achieved by curtailing 24-hour staffing at FAA towers with low activity (OIG 2013).[19]

Another cost-saving option for FAA could be to close the lowest-activity towers, including contract towers, although experience suggests that this option would face strong opposition from Congress. In anticipation of the sequester budget cuts, FAA announced its intention to close up to 238 low-activity towers, including 195 contract towers. The agency subsequently announced that it would close 149 contract towers for a 4-week period beginning in April 2013 but later deferred the proposed closures by 2 months to address objections from a range of stakeholders (Elias 2013). The situation was resolved at the beginning of May 2013 by the passage of the Reducing Flight Delays Act (P.L. 113-9), which allowed FAA to transfer money from the AIP to keep open the 149 contract towers slated for closure. A letter to the Secretary of Transportation and the FAA Administrator from a bipartisan group of 25 senators clarified the objective of the legislation, noting that "[c]ongressional intent is clear: the FAA should prevent the slated closure of 149 contract towers by fully funding the contract tower program" (as cited by Elias 2013, 2). In light of this statement, any suggestion that local funding be increased to keep low-activity towers open also appears unlikely to receive congressional support, particularly since Congress has limited the local share under

[19] The OIG (2013, 20) has recommended that FAA "identify the terminal air traffic facilities that do not meet the established minimum criteria for midnight shift operations, and (*a*) evaluate the safety risks and benefits of reducing their hours of operation, and (*b*) develop milestones for implementation of the reduction of operating hours at the selected facilities and report the status and justification for each selected facility to the OIG in 180 days."

the Federal Contract Tower program to not more than 20 percent of a tower's costs (Elias 2013).

Facility Consolidation

FAA must consider consolidation of facilities for a variety of reasons: some of its outdated buildings housing ATC services must be replaced or significantly upgraded (OIG 2012b), installation of NextGen technologies will require new facilities when older ones cannot accommodate the new physical demands, and overall budget pressures force the agency to reduce operating costs. FAA is directly responsible for 425 facilities hosting ATC en route and terminal services. Most are in fair to good condition, but some require replacement (GAO 2013; OIG 2012b).[20]

As required by the FAA Modernization and Reform Act of 2012 (Title VIII, Section 804), FAA is developing a long-term facilities consolidation report to simplify the transition to NextGen and to "reduce capital, operating, maintenance, and administrative costs of the FAA where such cost reductions can be implemented without adversely affecting safety." Consolidation of facilities could, in principle, reduce the demand for the number of controllers. With a larger number of staff at the same facilities, managers would have more options for filling duty rosters in response to planned and unplanned leave. For this option to work, a sufficient number of controllers would need to be trained and certified to cover multiple positions. In some past consolidations, such as the Potomac Terminal Radar Approach Control facility, FAA combined staff from multiple facilities, but controllers did not certify on positions in sectors other than those they formerly controlled. Hence, the larger workforce did not provide additional flexibility to managers in making assignments (OIG 2012b). In addition, when consolidations have merged controllers trained to handle complex, high-volume air traffic with those accustomed to handling light traffic in nearby facilities, many controllers in the latter category have not been able to certify on the positions requiring control of more complex traffic. However, past consolidations have allowed for reductions in administrative staffing.

[20] FAA operates in more than 1,200 facilities—centers, towers (including contract towers), administrative offices, and training and research offices. Most are leased.

Although FAA has a long history of consolidating facilities as technology has advanced and opportunities have arisen, recent large-scale consolidations have not achieved anticipated efficiencies because of such factors as renegotiated wage rates, relocation expenses, transfers of controllers unable to certify, construction cost overruns, and other technical challenges (OIG 2012b, Table 6).

Most consolidations have been planned with the intent of improving capacity and efficiencies in airspace management. Other benefits cited have been cost reductions in administrative staffing and maintenance of facilities. However, it is much easier and safer to begin operation in a new facility with known airspace and procedures that were in place in the facilities being consolidated. Once staff have been assimilated into a new facility and have become familiar with new equipment and working arrangements, managers can assemble groups of users and workers to begin developing the more efficient airspace and procedures that were envisioned. Airspace redesigns are necessarily done in phases. Each phase is developed, reviewed, and simulated in conjunction with labor unions and users, and when that process is completed, the workforce is trained. Both airspace users and organized labor must participate in the development of any redesign and agree on the changes to be made. The final approved changes often differ from those proposed since they take account of local conditions. Planned improvements in airspace design and any associated staffing efficiencies envisioned as part of a facility consolidation will not materialize until managers, controllers, and users can work out the details in the new facility. Thus, it is not surprising that the outcomes of consolidations have not always matched expectations.

In the future, technology may allow for the provision of some air traffic services at low-activity airports from remote locations through the use of surface surveillance systems to control aircraft rather than through visual means (the controller looking out of the window). Thus, the operations at a number of low-activity stand-alone towers could be consolidated at a single remote facility. This option may offer operational cost savings, although start-up costs could be high and the level of service provided to pilots operating under visual flight rules might be reduced. FAA is investigating technologies for such staffed NextGen towers, and similar initiatives are under way in Scandinavia and Australia. However, remote ATC tower facilities are unlikely to be "ready for routine operation at U.S. airports in the near future" (Elias 2013, 8).

In the long term, the implementation of NextGen may afford FAA the opportunity to undertake more extensive consolidations and to move facilities out of some high-cost-of-living areas that are difficult to staff. Air route traffic control center and terminal radar approach control facilities, for example, could be geographically separated from the areas they serve. However, the feasibility of such consolidations and relocations would depend on the availability of funding, the anticipated benefits versus the likely cost, and political considerations. As noted elsewhere in this report, FAA has reported that no direct impacts on the overall workforce resulting from NextGen have yet been identified. Hence, FAA appears not to be planning for significant cost savings in ATC staff as a result of consolidation or relocation of facilities for NextGen.

An additional factor may be congressional concerns with regard to gains and losses of controller jobs among members' districts. Losses of controller jobs have been particularly controversial and have made some consolidations difficult to enact.

Enhanced Revenues

The mainstay of the AATF—the 7.5 percent ticket tax—has not been increased since 1999. Since that time, the revenues produced by the tax have declined because the tax base has been eroded by airline practices of unbundling and charging fees for ancillary services. In view of the challenges facing the commercial aviation industry, Congress may continue to be reluctant to increase taxes that dampen demand, although the increase in security fees approved as one part of the Bipartisan Budget Act of 2013 indicates that modest increases in user fees are possible. Other administration proposals—to raise aviation-related taxes and fees for customs and immigration services and to impose a $100 per flight fee that would more fairly charge business and private jet users for ATC services provided—have not been enacted. As noted above, commercial aviation bears almost the complete burden of paying AATF taxes but receives less than two-thirds of ATC services. GA, in contrast, consumes more than one-third of ATC services and pays only 1.7 percent of AATF taxes.

SUMMARY

One of the policy questions that gave rise to this study—the affordability of the ATC workforce at its current level of $2.78 billion for FY 2014—cannot be answered in isolation from the broader trends in demand for ATC services and interrelated policy issues. The cost pressures on staffing for ATC services may persist. The budget environment is complicated and constrained. Across-the-board cuts in discretionary budgets required by the Budget Control Act of 2011 have been postponed until FY 2016, but if Congress remains unable to reach a long-term plan to reduce the federal deficit, sequestration cuts to ATC services, compounded annually, would be extraordinary in their impact on aviation. Demand for air transportation will grow as the economy recovers, but by how much is unclear. At current fee levels and tax rates, the growth in AATF revenues as traffic rebounds may not be sufficient to cover the growth in FAA's operating costs. The assumptions underlying the administration's FY 2015 budget forecasts with regard to growth in AATF revenues are more optimistic than FAA's forecast growth in commercial aviation activity.

Illustrative options for managing cost pressures related to the ATC workforce in the event of lower-than-forecast AATF revenues were described, but they would require substantial effort by FAA. Consolidation of facilities, in principle, could reduce the number of controllers needed, but recent consolidations have not been successful in this regard. In addition, FAA does not appear to be planning on economies in controller labor costs as part of the facility consolidations for NextGen. As indicated above, an 8 percent reduction in staffing (about 1,200 controllers) could be achieved by staffing for the 50th rather than the 90th percentile day, which would imply annual savings in the range of $223 million, or 1.4 percent of FAA's budget. However, such a reduction would impose economic costs associated with delay and canceled flights and would have unknown effects on aviation safety. Contracting out more low-activity towers would be consistent with the considerable decline in GA operations since 2000; FAA might be able to reduce its workforce by as many as 900 and save $135 million annually (less than 1 percent of its budget). However, the impact on safety would be unknown, and strong opposition from organized labor would be certain.

Congress could also consider ways to increase fees charged to the consumers of air traffic services. Airline practices with regard to charging ancillary fees for baggage handling, a service formerly included in overall ticket costs and subject to the ticket tax, effectively cause the AATF to lose on the order of $248 million annually in tax revenue. Furthermore, GA is a large consumer of ATC services requiring considerable ATC staffing at lightly used airports. The cost of these controllers is paid for by taxpayers and passengers using commercial aviation rather than by GA users.

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GAO	Government Accountability Office
OIG	Office of Inspector General, U.S. Department of Transportation

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7

Findings and Recommendations

This study has examined whether the methods used by the Federal Aviation Administration (FAA) in estimating staffing needs for air traffic controllers ensure the safe operation of the National Airspace System (NAS) in the most cost-effective manner. The committee considered the mathematical models used in generating the initial staffing targets and the staffing plan and how the plan is executed to ensure distribution of the intended number of staff to the right facilities. The effects of the Next Generation Air Transportation System (NextGen) and of current and estimated budgets and available funding on generation and execution of the plan were also considered.

This chapter summarizes the key insights from the detailed descriptions, findings, and recommendations provided in the preceding chapters. The chapter concludes with the committee's major recommendations.

SAFETY AND CONTROLLER STAFFING

The first requirement of the air traffic control (ATC) system is to ensure safety. This requirement drives the key functions assigned to air traffic controllers. ATC has been identified as a causal or contributing factor in only a few aviation accidents, according to reports from the National Transportation Safety Board (NTSB). However, nationwide assessments of safety mask differences in accident rates across industry segments: most notably, the rate of ATC-related accidents[1] for general aviation (GA), although small, is about eight times that for commercial aviation (see Chapter 2). In

[1] The rate of ATC-related accidents is defined as the number of ATC-related accidents per 10 million ATC operations.

addition, the committee's relatively simple analysis indicated that loss of separation[2] was not the most frequent cause of the few fatal ATC-related accidents between 1990 and 2012. In many of these accidents, including many involving GA, NTSB reports (see Chapter 2) indicate that aircraft were put in a hazardous situation by controllers' failure to provide safety alerts, including weather alerts, terrain alerts, and minimum safe altitude warnings. The level of ATC staffing may be related to these accidents in terms of whether controllers' workload allows them to deliver both the required safety alerts and the other safety-related services that they provide when circumstances permit. FAA recognizes that controller workload may limit the ability to provide these additional services (FAA Order 7110.65, Paragraph 2-1-1). In analyzing accident and incident reports, it may be worthwhile to examine whether controller workload may also limit or impede controllers' ability to provide the required separation and safety alert services.

Furthermore, evidence indicates that fatigue—defined as a physiological state of reduced mental or physical performance capability—is a risk factor for errors and accidents in work of the type performed by air traffic controllers. Such work requires constant attention and is often complex and demanding. The need for many ATC facilities to sustain operations 24/7 necessitates shift work, with associated disruption of controllers' sleep patterns.

Rare but highly publicized incidents of controllers falling asleep on the job have drawn attention to the risks associated with controller fatigue. As a result of these incidents, night shifts with a single controller on duty are no longer permitted in most circumstances. Other prescriptive limitations on controllers' work schedules and duty times (e.g., limits on number of hours worked in any 24-hour period, mandatory break and lunch periods during a shift) aim to mitigate the risks associated with controller fatigue. In 2011, the Article 55 Fatigue Risk Management Work Group, which included representatives from FAA and the National Air Traffic Controllers Association (NATCA), issued a series of fatigue-related recommendations aimed at increasing the safety of the NAS and

[2] For purposes of the committee's analysis, loss of separation refers either to loss of separation between two aircraft in the air or on the ground or to loss of separation between an aircraft and a ground vehicle.

improving the health and well-being of the controller workforce. One recommendation led to the 9-hour rule, which requires controllers to have a minimum of 9 hours off duty preceding the start of a day shift.

FAA's Fatigue Risk Management Group continues to investigate and assess fatigue-related hazards associated with controller staffing levels and practices, as well as mitigation strategies, but budget constraints associated with the sequester resulted in a dramatic curtailment of these efforts in 2013. The group no longer has the resources to ensure that policy changes are being enacted throughout the enterprise and are having the desired effect. In addition, operational facilities lack a scheduling tool capable of evaluating schedules (and adjustments to them) for their fatigue risk and suggesting fatigue mitigations. For these reasons, FAA is not achieving the full benefits of a fatigue risk management program.

The committee is concerned about shift schedules that contribute to fatigue. In particular, under the counterclockwise rotating 2-2-1 schedule, controllers work five shifts in less than four 24-hour periods, the last one being a midnight shift. The schedule compresses the workweek and allows controllers 80 hours off at the end of the rotating schedule. Although the schedule is popular among controllers, it likely results in severely reduced cognitive performance during the midnight shift because of fatigue. Other recent studies have suggested the potential for perverse side effects of the policies that have been implemented to date, such as controller responses to new schedules that can cause greater fatigue risk when factors such as peak-hour commuting times are taken into account.

FAA is contracting with the same vendor used by air navigation service providers (ANSPs) in other countries to implement a new scheduling tool, but the timeline of its implementation at all facilities is not fixed.[3] As noted earlier in the report, the following are among the potential benefits of the sophisticated scheduling software:

- Providing a consistent basis for establishing work schedules that minimize or mitigate the safety risks associated with controller fatigue;

[3] FAA's target date for implementing the new scheduling tool at 15 facilities (the end of FY 2013) appears to have slipped.

- Ensuring that diverse facilities are all capable of generating efficient schedules, particularly at larger facilities where economies of scale may be possible; and
- Providing a consistent basis for informing the development of staffing standards at FAA headquarters and the creation of work schedules at the facility level.

In view of the limited understanding of the relationship between safety and staffing in general and the partial and unvalidated efforts being taken to address fatigue in particular, caution is needed before major changes in controller staffing levels or practices are implemented. Current staffing levels appear to ensure adequate safety, but FAA does not collect the information required for more detailed insights and data-driven decision making with regard to changes in controller staffing, including those associated with the transition to NextGen.

A better understanding of the relationship between safety and staffing can be fostered by involving controllers in discussions of staffing. Such discussions can both help ensure safety and involve the controllers in determining alternative staffing solutions. Addressing issues highlighted by controllers, for example through training or visible changes in policy, and providing prompt feedback to controllers about actions taken in response to their suggestions are important features of a strong safety culture. One mechanism for such discussions is the reporting of safety concerns by controllers via the Air Traffic Safety Action Program. However, FAA could not describe to the committee a coherent process for using these reports and other safety data to assess staffing, other than examination of fatigue concerns.

The safety of FAA's ATC services depends not only on the performance of individual controllers but also on the agency's collective safety culture. Effective communications founded on mutual trust are generally recognized as contributing to a positive safety culture. In the present context, the committee was concerned about the lack of transparency in controller staffing and scheduling decisions, sometimes to the point of appearing arbitrary. Attempts to foster reporting by controllers and participation by controllers in safety councils at both local and national levels are important aspects of safety culture, yet they place additional demands on controllers and must be supported by adequate staffing.

FAA's PROCESS FOR ESTIMATING CONTROLLER STAFFING NEEDS

FAA uses a multistep process to determine the numbers of controllers needed to staff each of its ATC facilities in a given year. The process is described in Chapters 3 and 4 and summarized in the following sections. The desired controller staffing ranges for the coming year are given in annual updates to the agency's controller workforce plan (see, for example, FAA 2013), together with information on the numbers of fully qualified and trainee controllers currently employed at each facility. The staffing ranges are used to develop FAA's controller hiring plan for the coming year. The overall objective is to create a controller pipeline that ensures the availability of an appropriate number of controllers at each facility to meet forecast demand for services.

Traffic Forecasting

Forecasts of air traffic operations are inputs to the agency's controller staffing standards and subsequent staffing and hiring plans. Forecasting air traffic operations accurately is a challenging task. For commercial aviation, for example, estimates of future passenger demand at individual airports need to be converted into numbers of aircraft operations on the basis of assumptions with regard to such items as airline fleets and load factors. Air traffic can suddenly decrease in response to unexpected events, such as the September 11, 2001, terrorist attacks and the financial crisis of 2008–2009. Changes in air carrier operations can significantly affect local facilities. In recent years, for example, airline mergers and network consolidations have resulted in reduced demand at airports in St. Louis, Missouri; Cincinnati, Ohio; and Memphis, Tennessee.

Since 2000, FAA has consistently forecast more air traffic operations than have materialized, often by significant margins. The forecasting models used are evolving and loosely documented. The impact of the overpredictions each year is muted by the fact that hiring plans are revised annually, so overhiring one year can in principle be rectified by reduced hiring in subsequent years, at least from a national perspective. However, overstaffing can be created at individual facilities that do not experience sufficient attrition to remedy staffing levels and result in a lasting impact.

Staffing Standards

FAA's Office of Labor Analysis (ALA) generates staffing standards by using a sequence of mathematical models to estimate the number of position-qualified controllers required to meet the demands for air traffic services at each facility. The first mathematical model (on-position staffing model; see Figure 3-1) assesses the number of controllers needed on position at each facility to meet last year's traffic demand in each 15-minute interval through representative days. The committee found that FAA's mathematical models for terminal facilities [towers and terminal radar approach control (TRACON) facilities] are mostly reasonable for their purpose, as discussed in Chapter 3. The models relate key markers of the demands imposed by air traffic to requisite controllers' activity in a comprehensible manner, and the results are substantiated and validated by operational data.

In contrast, the committee shares the concerns of an earlier committee report with regard to the model used in estimating the number of controllers required on position to perform traffic-driven tasks at en route facilities (TRB 2010). The earlier report criticized the methods used in deriving model parameters and in converting the modeled task load into estimates of the number of controllers needed. It recommended a series of actions aimed at improving and validating the model. FAA[4] has made only limited progress in addressing the recommendations, and this committee is unable to report any significant improvement in the model to address the concerns articulated in the 2010 report. This committee had the broader charter of examining the entire staff planning process. In that context, the committee questions the approach of the task load model for en route facilities. Rather than representing higher-level tasks that can be observed and validated easily, this model attempts to represent many highly detailed cognitive activities. The level of detail is not commensurate with the model's role in staffing standards generation, and validating all the model parameters and their collective output is costly and difficult. For the purposes of staffing estimates, which combine model outputs with expert judgment, a simpler model based on

[4] The task load model for en route facilities was developed by MITRE Corporation under contract to FAA.

data that can be readily observed might prove more appropriate and cost-effective.

The second mathematical model (shift coverage model; see Figure 3-1) used in generating the staffing standards, a scheduler, was a cause of major concern for the committee. This model examines the time on position of certified controllers provided by the previous models in 15-minute increments throughout a range of representative traffic days. It generates schedules for work shifts for controllers, generally 8 hours long, on the assumption that all controllers are qualified to work all positions. To generate an effective staffing standard, the schedules should reflect day-to-day operational realities at the facilities, including constraints derived from FAA orders and the collective bargaining agreement with NATCA.[5] For example, controllers may work a maximum of 10 consecutive hours in a shift and are required to have a 30-minute meal break within a specified window in the shift. The scheduler can, in principle, factor in these constraints, but it cannot apply constraints across shifts that start one day and finish the next (i.e., that cross midnight). The legacy scheduling model that FAA uses for estimating the numbers of controllers needed at each facility has several key limitations in its ability to include scheduling constraints. In contrast, ANSPs in other countries, including Australia, Canada, and Germany, have replaced their legacy scheduling tools with sophisticated software capable of incorporating all constraints while generating efficient controller schedules. FAA has contracted with the provider used by these other countries and is working to implement a similar scheduling tool, known as Operational Planning and Scheduling (OPAS). The intent is to use OPAS as a consistent basis for informing both the development of staffing plans at FAA headquarters and the creation of work schedules at individual facilities. FAA had planned to implement OPAS at roughly 5 percent of its facilities by the end of FY 2013 (OIG 2013), but this schedule has slipped to unspecified dates. OPAS is not yet being used as part of FAA headquarters' staffing standards process.

[5] Some of the schedule constraints connected to the collective bargaining agreement are facility-specific.

The third mathematical model (daily staffing forecast model; see Figure 3-1) applied in generating the staffing standards scales the estimate of required controllers to manage the traffic forecast for the 90th percentile traffic day (i.e., the day when traffic levels are higher than on 90 percent of other days over the course of a year). This model incorporates traffic forecasts for the year (which can be 1, 2, or 3 years ahead) when hires made now can be trained and qualified into the facility.

The fourth, final mathematical model (availability factor model; see Figure 3-1) is simple: it scales the minimum workforce required for the scheduled shifts by a factor of 1.76. This is a reasonable and common method of accounting for the usual practice of working five shifts in a 7-day week and for required leave, vacation, and other off-position activities.

The above models collectively apply two key assumptions or tradeoffs. First, the choice of scaling the staffing standards to 90th percentile traffic is conservative. Other ANSPs are similarly cautious in their staffing estimates. Different choices would not substantially alter the estimated staffing levels but would change how often any facility could meet traffic demand. The committee's analysis showed that staffing levels would increase by about 9 percent if the agency staffed to the busiest traffic day (the 100th percentile day, i.e., the facility would be expected to meet traffic demand at all times) and would decrease by about 8 percent if it staffed to the median traffic day (the 50th percentile day, i.e., traffic flow through the facility would need to be limited one-half of the time).

Second, the staffing models assume that all on-position traffic management tasks are performed by position-qualified controllers, some of whom may not be fully qualified [i.e., who may not be certified professional controllers (CPCs)]. In FY 2012, 13 percent of the required time on position managing traffic was performed by trainee (non-CPC) controllers under general supervision (as opposed to one-on-one on-the-job training). The impact of this assumption about the role of trainees on staffing estimates depends on the number of trainees in the workforce, which in turn should anticipate controller losses with enough lead time to train replacements. In FY 2012, about 22 percent of the workforce were not fully qualified in their facilities but contributed to managing traffic at positions for which they were qualified.

Operational Input: Service Unit Input and Productivity Data

The staffing estimates derived by ALA [which is outside of the Air Traffic Organization (ATO)] are then averaged with operational data. Two inputs assess past productivity and peer productivity; outliers are ignored for these inputs.

The third input is service unit input (subject matter expert input), which helps to ensure that the calculated staffing ranges reflect each facility's unique operational requirements. The methods used in generating this input are not well documented, but FAA appears to have made progress recently in clarifying the purpose of service unit input for experts in the field and in obtaining consistent and informed inputs from them. In some cases, mathematical models are used to capture a facility's historical staffing in response to traffic in a clear and consistent manner, and the results are used as guideposts by field focus teams in establishing their service unit input values. However, this approach appears to be applied inconsistently, with many changes in the past year. For example, in the past en route facilities have used the staffing standard output as their service unit input (i.e., they have not treated the service unit input as an independent assessment of staffing needs from the field). In contrast, recent estimates by en route facilities—their own assessments of service unit input—have differed considerably from both the staffing standard outputs and the results of the En Route Validation Tool. The generation of service unit input is another aspect of the staff planning process that does not appear to have a consistent, established, and clearly understood basis and thus can appear to be an arbitrary adjustment to the mathematically generated staffing standard process.

STAFF PLANNING AND EXECUTION OF STAFFING PLAN

FAA uses the output from its staffing models to develop a staffing plan that specifies how many new hires and net transfers (transfers in minus transfers out), or staffing gains, each facility should receive. Efficient execution of this plan depends on the agency's ability to select and train individuals who will go on to qualify as controllers in a timely manner and to use voluntary transfers of controllers from one facility to another to help reduce imbalances in staffing at specific facilities.[6]

One of the challenges FAA faces in assigning controllers to specific ATC facilities is the wide variation in the volume and complexity of traffic. Sending new FAA Academy graduates to the most demanding facilities has historically resulted in high failure rates, and this practice has now been largely discontinued. Even some fully qualified controllers are not well suited to the work at high-level facilities. Another consideration is that both trainee and fully qualified controllers require additional training when they arrive at a new facility. The latter are categorized as certified professional controllers in training (CPC-ITs) until they have been certified on all positions at the new facility and again achieve CPC status. Transferring controllers between facilities typically involves a lead time of at least 1 year as controllers recertify at the new facility. Therefore, transfers are not an immediate solution to problems of under- or overstaffing resulting from changes in demand for ATC services. Nonetheless, appropriate incentives for transfers, developed and agreed on by FAA and NATCA, could help the agency make more effective use of voluntary transfers in rectifying staffing imbalances.

The complications associated with moving controllers between facilities have resulted in two other areas of concern. First, career progression opportunities within the controller workforce are limited, particularly since there is no clear policy with regard to controllers from lower-level facilities who attempt to qualify at higher-level facilities but fail to do so. Under these circumstances, many controllers are unwilling to take the risk of failing to qualify. In addition, facility managers may be unwilling to relinquish controllers seeking to transfer if their facility is likely to be left understaffed. Second, a small number of the nation's highest-level facilities, including the New York TRACON, have become chronically hard to staff because they are too demanding for new FAA Academy graduates and do not attract controllers interested in transferring from other facilities. Understaffing at these facilities is a major concern

[6] Requests for transfers are initiated by controllers themselves, and FAA makes no attempt to persuade controllers to transfer to understaffed facilities or from overstaffed facilities to rectify staffing imbalances.

because of its potential impact on operational efficiency across the NAS. ATC facilities are not all equal in terms of their systemwide impact, and operations at a facility such as the New York TRACON affect the overall efficiency of the network more than operations at small towers in geographically remote areas with little traffic.

The committee's suggestions for (*a*) communicating a clear path and expectations for controllers' career advancement, (*b*) establishing an apprenticeship model designed to facilitate career progression, and (*c*) creating special measures to help remedy staffing deficiencies at hard-to-staff facilities are described in Chapter 4.

The creation of operational work schedules provides opportunities for increasing the efficiency of FAA's controller staffing process at the facility level. Currently, each facility generates its own schedule. A variety of methods are used, ranging from white boards to more sophisticated spreadsheets. One problem with this ad hoc approach is that it creates difficulties in ensuring that the schedules used by individual facilities are compatible with the assumptions incorporated into planning processes at FAA headquarters. In the committee's judgment, the full benefits of a careful and informed staff planning process will only be realized if FAA headquarters and the individual facilities use the same scheduling tool. The tool should incorporate general and facility-specific constraints, as well as overarching requirements for safety, including policies aimed at mitigating risks associated with controller fatigue.

The committee also examined how well the staffing plan is executed. Analysis of FY 2011 and FY 2012 data[7] shows that, in aggregate, FAA executed its staffing plans fairly well, achieving 94 percent of planned staffing gains. However, when the execution of staffing plans for individual facilities is taken into account, the picture looks much different. In FY 2011, only 73 percent of facilities properly executed their plans, and in FY 2012 only 52 percent of facilities did so. (The term "properly executed" is used here to mean that an individual facility experienced a staffing gain within ±10 percent of what was specified in the staffing plan.)

The annual number of staff transfers is roughly two-thirds the annual number of new hires and about 5 percent of the total workforce. Thus,

[7] The committee did not analyze FY 2013 data because sequestration halted hiring for part of the year.

transfers are an important means by which FAA can move facilities toward its staffing targets. FAA appears to lack a strategy and mechanisms to influence transfers toward this end. For example, in FY 2012, 30 percent of transfers were from facilities below the staffing range to those at or above the staffing range, and only 9 percent of transfers were from facilities that were within or above the range to those that were below.

The committee understands that the execution process is complex and involves considerations by facility managers and higher-level staff within ATO. Nonetheless, poor execution of the staffing plan in any given year makes it more difficult to achieve the intended staffing level in future years. The committee does not know whether discrepancies between plans and execution are caused by poor execution of facility staffing plans or a difference of opinion within FAA divisions as to whether the staffing standards and staffing plan generate the appropriate targets. Either cause would be a source for concern.

NEW TECHNOLOGY AND OPERATIONS WITH NEXTGEN

NextGen is a complex, multiyear initiative aimed at transforming the nation's air traffic management from ground-based radar to a satellite-based system. The overall intent is to improve safety and efficiency while meeting anticipated demands for increased capacity (OIG 2014). Much is uncertain about the future of NextGen, particularly since key efforts have experienced "significant cost increases and schedule delays" (OIG 2014, 1). Nonetheless, if NextGen is to achieve its promised benefits, controllers will need to have the skills to support related operations and procedures, as well as a workload compatible with these support activities.

FAA's 2013 controller workforce plan (FAA 2013) acknowledges the need for controller training to support the implementation of NextGen. However, the agency makes no explicit allowance for the demands placed on controllers by NextGen-related activities in developing its controller staffing plans. The staffing standards used by FAA headquarters do not make any provision for NextGen and how it might affect future staffing levels, even though a significant number of controllers are involved its development and implementation. Whether the service unit input generated by experts in the field makes any provision for NextGen-related efforts is unclear. Other ANSPs, in contrast, make explicit plans for controller staffing needs associated with technology development, training, and deployment. For example, Airservices Australia incorporates detailed resource estimates for nonoperational technology initiatives into its controller workforce plans.

OVERALL CONSISTENCY, TRANSPARENCY, AND COMMUNICATION WITH REGARD TO CONTROLLER STAFFING

Taken as a whole, FAA's planning process for controller staffing is difficult to understand. Part of the reason is its inherent complexity, but a more significant reason is lack of documentation (or consistent application of documented processes) at several key points. Some elements, such as the staffing standards for towers and TRACONs, are clearly documented, but others, such as the methods used for generating service unit input, are confusing because of the lack of clear, consistent documentation. In addition, the outputs from the planning process presented in the annual updates to the controller workforce plan are not all clearly explained. The committee had difficulty getting a clear and consistent explanation from FAA of what the staffing range numbers in the plan mean in practice. Do they refer to the total number of controllers (fully qualified plus trainees) at a facility, or do they refer to the numbers of CPCs and CPC-ITs, with lower-level trainees excluded? The resulting confusion was a source of frustration for the committee, which became increasingly concerned that the lack of clarity and transparency could adversely affect FAA's relations with its controller workforce and other stakeholders. Reaping the full benefits of a robust, science-based method for estimating controller staffing needs requires not only a sound methodological approach but also clarity and transparency in communicating the process to stakeholders.

The committee also had concerns with regard to the effectiveness of FAA's internal communications. An earlier report recommended the establishment of a headquarters-level oversight process to reconcile different staffing estimates. It noted that "the procedures and methods adopted by the oversight team should be well documented and clearly articulated to the regions and the facilities" (TRB 1997, 8). After ALA develops a hiring plan, ALA and ATO work together to reconcile differences in facility staffing estimates between the staffing standard outputs and the service unit input and to develop the final staffing plan, which incorporates new hires and transfers. These activities, including the decision criteria used in the reconciliation process, do not appear to be documented, and the committee saw no evidence of the procedures and methods being clearly communicated to groups outside of FAA headquarters.

CONTROLLER PRODUCTIVITY AND TRAFFIC ACTIVITY

The total number of FAA controllers in FY 2012 was almost the same as in FY 2000 (just over 15,000), although the total number of ATC operations fell by 23 percent over the period (Table 7-1). This observation has raised questions about FAA's strategy of "staffing to traffic." However, the committee found that these highly aggregated systemwide data provide neither an accurate picture of trends in controller productivity nor the level of detail needed to examine controller staffing levels in an informed manner.

The committee's analysis indicated important variations in controller productivity across facility types, as well as changes in the makeup of the controller workforce and the nature of air traffic over time that complicate comparisons of controller productivity. In addition, although controllers handled more traffic in 2000 than in 2012, the performance of the NAS in 2000 was not satisfactory in terms of on-time arrivals. Flight delays were a major concern, and there was a focus on NextGen as a means of alleviating capacity constraints. With the drop in traffic, flight delay minutes dropped from 80 million in 2000 to 64 million in 2012 (BTS Transtats database, http://www.transtats.bts.gov).[8]

[8] These delays are attributable in large part to constraints inherent in the physical structure of the NAS. However, the same physical structure (e.g., number of runways, number of airspace sectors) limits the number of positions controllers can work, so the addition of controllers could not by itself have eliminated the delays in 2000 or 2012. Thus, the physical structure of the NAS and controller staffing are tightly linked, and together they can affect flight delays.

TABLE 7-1 Comparison of Numbers of ATC Operations and Controller Head Count, FY 2000 and FY 2012

Parameter	FY 2000	FY 2012	Percentage Change, FY 2000–2012
Highly Aggregated Systemwide Data			
Total number of controllers	15,100	15,063	–0.3
Total number of operations	152,092,000	117,324,000	–23
Operations per controller	10,100	7,800	–23
Centers Versus Terminals			
Centers			
Number of controllers	6,718	6,278	–7
Number of operations	46,795,000	40,850,000	–13
Operations per controller	7,000	6,500	–7
Terminals			
Number of controllers	8,382	8,785	+5
Number of operations	106,067,000	76,409,000	–28
Operations per controller	12,700	8,700	–31
Composition of Workforce			
Number of CPCs	12,772	11,753	–8
(percentage of total)	(85%)	(78%)	
Number of CPC-ITs	1,388	1,143	–18
(percentage of total)	(9%)	(8%)	
Number of developmentals	940	2,167	+131
(percentage of total)	(6%)	(14%)	
Total number of trainees[a]	2,328	3,310	+42
(percentage of total)	(15%)	(22%)	

[a]CPC-ITs plus developmentals.
SOURCE: Controller head counts were provided by FAA (personal communication from ALA); operations data are from FAA's Air Traffic Activity Data System online database.

At en route facilities, controller head count and the number of operations fell between FY 2000 and FY 2012, but the decreases were modest, and the number of operations per controller fell by only 7 percent. In contrast, the controller head count at terminal facilities increased slightly (by 5 percent) between FY 2000 and FY 2012, while the number of operations fell by 28 percent; thus, the number of operations per controller fell by 31 percent. Even this level of analysis masks important variations; terminal facilities include both large towers and TRACONs with 100 or more controllers and small towers with fewer than 30 controllers. At some of the smallest facilities, schedule constraints associated with business rules or the collective bargaining agreement mean that staffing levels cannot be substantially reduced even if traffic falls. Several of the larger facilities, on the other hand, have proven chronically hard to staff for a variety of reasons (see Chapter 4).

The composition of the controller workforce also changed considerably between FY 2000 and FY 2012. The former was more experienced than the latter. CPCs made up 85 percent of the workforce in FY 2000 but only 78 percent in FY 2012, and the proportion of trainees increased correspondingly. The presence of a relatively high proportion of trainees has implications for overall controller staffing levels at a facility. Trainees under general supervision make an important contribution to managing traffic (see Chapter 4), but they are not qualified to work all positions. In addition, a higher proportion of trainees requires CPCs to spend a greater proportion of their time providing on-the-job training.[9] Consequently, development of schedules for a facility where the workforce includes a large proportion of trainees is subject to more constraints than if nearly all controllers at the facility are fully qualified.

The nature of the traffic and its distribution across facility types changed considerably between 2000 and 2012, with implications for the workload of controllers at a given facility. Declines in air carrier and air taxi and commuter ATC operations were modest at about 13 percent and 10 percent, respectively, whereas the decline in GA operations was far greater at about 30 percent.[10] Nonetheless, GA still accounted for about 38 percent of total ATC operations in 2012.

In light of these observations about the changing nature of the controller workforce and the traffic to be managed, more detailed examination of staffing levels at individual facilities is needed to investigate reasons behind the apparent drop in controller productivity between FY 2000 and FY 2012. The preceding discussion also indicates that establishing cost-effective controller staffing levels may require different solutions at different facilities.

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[9] For safety reasons, FAA limits the number of trainees at a facility to 35 percent of the facility's total controller workforce.

[10] Military operations, which make up a small fraction of total ATC operations, declined by about one-third between 2000 and 2012.

AFFORDABLE CONTROLLER STAFFING

The controller workforce is the main component of ATO and of the En Route and Oceanic and Terminal Services division of ATO. The latter accounts for 64 percent of the ATO budget and includes the 15,000-strong unionized controller workforce as well as about 5,000 nonunionized supervisors, managers, and administrative staff. The next largest division of ATO, Technical Operations, makes up 26 percent of the ATO budget and employs almost 8,000 people to maintain ATC equipment (computers, radars, and other communications equipment).[11] In 2014, the budget for the workforce covered in FAA's controller workforce plan (i.e., the unionized controller workforce) is $2.8 billion (18 percent of the total FAA budget and 29 percent of the Operations budget).

Congressional concerns about the cost-effectiveness of FAA's staffing models are driven, in part, by the growing cost of the ATC staff and the growing reliance of the FAA Operations budget on general revenues over the past decade. Continuing to depend on the General Fund makes FAA Operations vulnerable to budget cuts. Revised forecasts of rebounding aviation trust fund receipts by the Congressional Budget Office (CBO) in 2013 and the administration in 2014 imply that growing Airport and Airway Trust Fund (AATF) revenues will be able to reverse the demand for General Fund revenues. The administration is requesting $700 million in General Fund revenues for the AATF for FY 2015, as opposed to the $4.4 billion required in FY 2013. Whether the administration's and CBO's revised forecasts will hold is unknown. Both forecasts imply aviation demand growing faster than gross domestic product and faster than FAA's projected rate of increase in revenue passenger miles.

If the AATF does not prove to be as robust as forecast, FAA will be competing against all other discretionary items of the federal budget for General Fund revenues. Plausible reductions in the number of air traffic controllers would result in small savings relative to FAA's overall budget. As discussed earlier, a decision to be less conservative and staff for the 50th percentile (median) traffic day rather than for the 90th percentile day would result in an 8 percent reduction in staffing (about 1,200 controllers) but only a 1.6 percent reduction in FAA's budget. The impacts

[11] Technical Operations staff are not included within the ATC workforce.

of such a reduction in controller staffing on safety are unknown, as are the impacts on the performance of the NAS. Economic costs and inconvenience to travelers as a result of delayed and canceled flights appear likely, but the extent of such disruptions is unclear.

Other ways of reducing the cost of FAA's controller workforce are to contract out more low-activity towers and consolidate ATC facilities. Both these options face challenges, as discussed in Chapter 6. ANSPs in other countries are also exploring ways to reduce costs and put controllers to work more flexibly. Ideas being discussed by Deutsche Flugsicherung, for example, include increasing the number of positions each controller is able to work at centers so that staff can be moved around more easily, providing new controllers with part-time rather than full-time contracts, and working smaller towers remotely out of a "tower-center" (Hoefel 2013).

If receipts to the AATF are less than anticipated, Congress could consider increasing fees charged to the consumers of air traffic services, rather than focusing exclusively on ways of reducing the cost (and size) of the controller workforce. The AATF is effectively losing tax revenue—on the order of $248 million annually—because of airline practices with regard to charging ancillary fees for baggage handling that were formerly included in overall ticket costs and covered by the ticket tax. In addition, GA is a large consumer of ATC services requiring considerable ATC staffing at lightly used airports. In 2012, GA contributed less than 2 percent of taxes to the AATF but accounted for 38 percent of ATC operations. Commercial aviation contributed more than 98 percent of taxes to the AATF and accounted for 62 percent of ATC operations. Thus, the cost of controllers serving general aviation is currently borne by taxpayers and air carrier passengers rather than by GA users.

RECOMMENDATIONS

The committee was unable to determine whether FAA's current controller staffing model is the most cost-effective, as required by its task statement. Such a determination requires safety and performance metrics that remain to be defined, and there are no conclusive methods for relating safety to controller staffing levels. Commercial aviation in the United States is now the safest it has ever been, a feature that needs to be maintained in the face of pressure to reduce the costs of ATC services. As noted earlier, care is needed before major changes in controller staffing levels or practices are implemented, given the current limited understanding of the relationships between staffing and ATC-related accidents and incidents.

There are also different perspectives on the meaning of cost-effectiveness. From a budgetary perspective, the most cost-effective controller staffing could be defined as the minimum number of controllers needed to meet expected air traffic demand, but commercial air carriers and GA pilots are likely to have different views about the types and levels of service that ATC should provide. Commercial carriers need ATC services that allow them to keep to flight schedules with minimal delays, even when these schedules involve short periods of high activity at hub airports interspersed with quiet periods en route. GA pilots, on the other hand, often lack the sophisticated equipment routinely available on commercial aircraft and so require controllers to provide weather and other advisories on an as-needed basis. GA is typically the industry segment most concerned about which small towers provide services and at what hours.

The committee's ability to assess the cost-effectiveness of FAA's overall staffing process, rather than only the staffing standards (mathematical models), was limited further by a lack of information about and clear documentation of some of the methods and criteria, particularly those used by ATO.

The following major recommendations target areas where the committee identified important opportunities for FAA to improve its staffing processes. In each case, the numbers in braces at the end of the recommendation refer to related recommendations in preceding chapters.

Recommendation 1

FAA should explore the relationships between controller staffing and safety by

- **Analyzing the wide range of data that can identify relationships between staffing and safety, including accident and incident reports, voluntary reports by controllers from ATSAP, and other databases**

that, if properly integrated, can relate safety to staffing concerns (e.g., records of actual shifts worked); and
- Involving the controller workforce in staffing decisions, particularly as knowledge concerning relevant safety issues emerges.

FAA should use insights gained from these activities to inform decisions about controller staffing levels associated with the transition to NextGen and any other policies likely to result in changes in historically safe staffing levels. {2-5, 5-5}

Recommendation 2
FAA should reassess its approach to developing an improved staffing model for en route facilities and make any necessary changes, potentially including the adaptation or formulation of a new model likely to be developed and validated in a timely manner and at reasonable cost. Any new model should be constructed in such a way that it can be updated as NextGen operations are implemented. {3-2}

Recommendation 3
FAA should take steps to ensure that the planning and execution of its air traffic controller staffing process are clear, consistent, and transparent to a range of stakeholders. Stakeholders include but are not limited to the following:

- The controller workforce, which needs to engage with FAA in the collaborative development of improved staffing plans and their execution to ensure overall cost-effectiveness; and
- Congress, which needs to make informed decisions about future budgets for controller staffing. {3-3, 4-2, 4-3}

Recommendation 4
FAA should, as a matter of priority, continue its efforts to develop an improved scheduling tool capable of creating efficient controller work schedules that incorporate fatigue mitigation strategies. The agency should collaborate closely with NATCA in implementing this improved scheduling capability, notably in adopting schedules that reflect science-based strategies for managing the risks associated with controller fatigue. {2-3, 3-1, 4-9}

REFERENCES

Abbreviations

FAA	Federal Aviation Administration
OIG	Office of Inspector General, U.S. Department of Transportation
TRB	Transportation Research Board

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APPENDIX

Federal Aviation Administration's Methodological Approach to the Preparation of Terminal Area Forecasts

This appendix summarizes the methodological approach of the Federal Aviation Administration (FAA) in preparing the terminal area forecasts (TAF) of demand for aircraft operations at terminal facilities. The approach is undergoing significant changes. Up to 2013, the TAF were prepared under an approach (referred to as Legacy TAF) that forecasts passengers and operations at individual airports. The approach applied in 2014 and beyond, called Terminal Area Forecast Modernization (TAF-M), focuses on forecasting passengers and operations at a finer level of granularity—at the level of origin–destination pairs, of routes serving specific airport pairs, and of flight segments connecting pairs of airports directly.

LEGACY TAF

For commercial traffic, the Legacy TAF approach uses "passenger enplanements" as the starting point. For the 30 busiest airports (which together accounted for more than 70 percent of national enplanements in 2012), locally originating enplanements are forecast by coupling historical data with local-level forecasts of such input variables as personal income (or, more recently, disposable income), employment, population, and local fares. Enplanements of connecting passengers and of international passengers are forecast separately by considering the status of an airport (hub, nonhub, international gateway) and historical trends.

Forecasts of enplanements at second-tier airports (approximately 80) are obtained through a less detailed procedure relying primarily on econometric models. For the remaining roughly 390 towered airports, forecasts rely primarily on projections of historical trends and reviews of local conditions.

To convert enplanement forecasts to estimates of commercial air traffic activity, the number of aircraft departures is estimated on the basis of projections of aircraft characteristics (e.g., seating capacity, range) and of load factors. Short-term (1- to 1.5-year) forecasts of commercial aircraft operations are prepared for the busiest airports. They are strongly influenced by detailed information concerning recent-month and near-term projected flight schedules, aircraft mix, and so forth at the subject airport.

Forecasts of all-cargo flights rely primarily on projections of historical trends. They have been exhibiting a slow growth rate at an aggregate level during the past decade and account for a small percentage of air traffic activity in the United States.

Because of a relative paucity of data, forecasts of general aviation (GA) air traffic activity are primarily based on time-series models that are less advanced than those used for forecasting commercial traffic. In addition, GA, which is typically associated with smaller aircraft and recreational flying, has exhibited a high degree of volatility and has been hit particularly hard by the various economic downturns of the past dozen years. Business GA activity, especially activity involving jet aircraft, has been more stable, but even this segment was strongly affected by the financial crisis of 2008 and 2009 and has been recovering at a slow rate.

The TAF also play a critical role in forecasting en route traffic, that is, traffic handled by air route traffic control centers (ARTCCs). The number of commercial aircraft operations handled at each ARTCC is estimated by (*a*) multiplying by two the number of forecast commercial (air carrier plus commuter and air taxi) instrument flight rules (IFR) departures from airports located within the region covered by the ARTCC and (*b*) adding to this a forecast of the number of IFR itinerant operations (overflights) for that ARTCC. The forecast of IFR itinerant operations is based on analyses and projections of historical data at each ARTCC. Forecasts of GA aircraft handled are based on historical trend modeling. Military aircraft handled are assumed to remain at their most recent annual level throughout the forecast period.

In the course of preparing each year's TAF, the team from the Office of Aviation Policy and Plans consults with the regional and local facilities of FAA to obtain additional data, insights, and feedback based on local developments. For example, the establishment of a new flight school near an airport is likely to increase the number of local operations there. Consultation with airlines and GA organizations may also take place.

TERMINAL AREA FORECAST MODERNIZATION

TAF-M adopts an approach different from that of Legacy TAF by focusing on origin–destination pairs and segment-level forecasts. As in the case of the Legacy TAF, the TAF-M process begins by projecting numbers of passengers. Econometric models are used to forecast the number of passengers flying between origin–destination airport pairs in major markets. Inputs to the models include fares, demographics (e.g., populations of end cities), forecast income levels, distance between origin and destination, competition on the segment, season, and so forth. Assignment algorithms are used to allocate passengers among the alternative routes available between origin–destination pairs. In this way, estimates of passenger flows are obtained for individual flight segments. As a result, TAF-M provides forecasts of passenger flows in individual major markets (e.g., Miami–Los Angeles), specific routes (e.g., Miami International Airport–Atlanta International Airport–Los Angeles International Airport), and flight segments (e.g., Atlanta International Airport–Los Angeles International Airport). Such route- and segment-specific outputs are better suited for use as inputs to typical studies of the National Airspace System (e.g., traffic simulations) because of their finer granularity.

Commercial aircraft operations at the segment level are estimated next by combining (*a*) the route- and segment-level passenger demand forecasts, (*b*) historical information about the aircraft fleet and airline schedules on the segment, and (*c*) econometric models that project aircraft fleet choices by the airlines. Inputs to the econometric models include number of passengers, distance between the end airports of the segment, performance characteristics of candidate aircraft types (e.g., seating capacity, range), aircraft operating costs, end airport characteristics (e.g., size, hub or spoke), and season when the flight takes place.

TAF-M is limited at this time to forecasting commercial passengers and commercial aircraft operations. In the TAF published in January 2014, the forecasts of passenger and commercial aircraft operations at the 141 busiest airports will use the TAF-M approach; Legacy TAF will be used for the remaining FAA-towered airports and for forecasts of GA and military traffic everywhere.

Tests indicate that the use of different growth rates in each year at each airport by TAF-M generates slightly lower passenger forecasts (by 2 to 3 percent) for 2030 for the 141 hub airports in the aggregate than the forecasts prepared with the Legacy TAF approach. The difference may vary from airport to airport.

The forecast of IFR aircraft handled for en route traffic (ARTCC) takes advantage of the fact that TAF-M generates segment-level forecasts of the number of commercial aircraft operations for each of the principal individual markets (city pairs). Thus, the number of aircraft handled is estimated as the sum of (*a*) twice the number of forecast commercial IFR departures from airports located within the region covered by the ARTCC, (*b*) the number of commercial aircraft operations on all the flight segments that traverse the ARTCC (overflights), and (*c*) a historically based forecast of GA aircraft handled. As with the Legacy TAF, the number of military aircraft handled is assumed to remain at its most recent annual level throughout the forecast period.

Study Committee Biographical Information

Amy R. Pritchett, *Chair*, is the David S. Lewis Associate Professor of Cognitive Engineering in the School of Aerospace Engineering, Georgia Institute of Technology. She holds a joint appointment in the School of Industrial and Systems Engineering. Dr. Pritchett has led numerous research projects sponsored by industry, the National Aeronautics and Space Administration (NASA), and the Federal Aviation Administration (FAA). She has served as the director of NASA's Aviation Safety Program. Dr. Pritchett was responsible for planning and execution of the program ($75 million to $82 million per year), which was conducted at four NASA research centers and sponsored about 200 research agreements. In that role, she served on the Aeronautics Science and Technology Subcommittee of the Office of Science and Technology Policy and on the executive committees of the Commercial Aviation Safety Team and the Aviation Safety Information Analysis and Sharing program. She has published more than 170 papers in conference proceedings and in scholarly journals such as *Human Factors*, *Journal of Aircraft*, and *Air Traffic Control Quarterly.* She has won the William H. Jackson Award of the Radio Technical Commission for Aeronautics (RTCA) and, as part of Commercial Aviation Safety Team, the Collier Trophy, and the American Institute of Aeronautics and Aviation has named a scholarship for her. Dr. Pritchett is the editor-in-chief of the *Journal of Cognitive Engineering and Decision Making.* She is a member of FAA's Research, Engineering, and Development Advisory Committee (REDAC) and chairs REDAC's Human Factors Subcommittee. Dr. Pritchett received bachelor's, master's, and doctor of science degrees in aeronautics and astronautics from the Massachusetts Institute of Technology (MIT). She is a licensed pilot.

Mathias Basner is Assistant Professor of Sleep and Chronobiology in Psychiatry at the University of Pennsylvania Perelman School of Medicine. Dr. Basner trained at the Institute for Applied Physiology at the University of Bochum and worked as a Research Associate at the German Aerospace Center (DLR), Institute of Aerospace Medicine, Flight Physiology Division from 1999 until 2006 before moving to the United States to pursue his research interests in the neurobehavioral consequences of sleep loss as a research associate. He returned to DLR in 2008 to head the Flight Physiology Division for 2 years. At that time, he was coinvestigator on a Deutsche Flugsicherung (German Air Traffic Control) study investigating workload effects in Croatian air traffic controllers. In January 2010, Dr. Basner assumed the position of assistant professor of sleep and chronobiology in psychiatry at the University of Pennsylvania. He was awarded the German Aerospace Center Science Award in 2007 and the Science Award of the German Academy for Aviation and Travel Medicine in 2010. He is a member of the American Academy of Sleep Medicine and its sleep deprivation steering committee. He is also a member of the Sleep Research Society and the German Sleep Research Society. Dr. Basner is Deputy Editor of the journal *Sleep*, on the editorial boards of *Noise and Health* and *PLOS ONE*, and ad hoc reviewer for 40 scientific journals. He has reviewed proposals for the National Institutes of Health, the U.S. Department of Veterans Affairs, the European Space Agency, the Australian Antarctic Science Program, and the German Research Foundation. Dr. Basner received a degree in medicine and a doctorate in research from the University of Bochum, Germany, and a master of science degree in epidemiology from the University of Bielefeld, Germany.

Peter J. Basso retired as chief operating officer and business development director of the American Association of State Highway and Transportation Officials (AASHTO) in February 2013. Before joining AASHTO in 2001, he served as assistant secretary for budget and programs and as chief financial officer of the U.S. Department of Transportation. Mr. Basso's 34 years of service as a career official included assignments as deputy assistant secretary for budget and programs of the Department of Transportation, assistant director for general management of the Office of Management and Budget, deputy chair for management of the National Endowment for the Arts, and director of fiscal services for the Federal Highway Administration. He received a bachelor of science in business administration from the University of Maryland.

Lawrence M. Cole is an aviation professional with 38 years of experience in the field of air traffic control (ATC). He began his career in 1968 as a U.S. Air Force radar air traffic approach controller. This was followed by 18 years in positions of increasing responsibility at operational Federal Aviation Administration (FAA) terminal radar approach control facilities and towers and as an instructor at the FAA Air Traffic Control Academy. During his last 17 years with FAA, he served at the agency's national headquarters, where his responsibilities included managing the ATC Human Factors (HF) Research Program, the Technical Operations HF Research Program, and the Runway Safety HF Program in support of long-term agency plans and objectives. For the past 6 years, Mr. Cole has been self-employed as an aviation and HF consultant affiliated with Aloft Aviation Consulting, LLC. He has a master of business administration degree from Western New England College and a bachelor of arts degree in psychology from West Virginia Wesleyan College.

Mary (Missy) L. Cummings is an associate professor in the Duke University Department of Mechanical Engineering and Materials Science and the Duke Institute of Brain Sciences, and she is the director of the Humans and Autonomy Laboratory. Her research interests include human–unmanned vehicle interaction, human–autonomous system collaboration, human–systems engineering, public policy implications of unmanned vehicles, and the ethical and social impact of technology. A naval officer and military pilot from 1988 to 1999, she was one of the Navy's first female fighter pilots. Dr. Cummings received her bachelor of science in mathematics from the U.S. Naval Academy in 1988, her master of science in space systems engineering from the Naval Postgraduate School in 1994, and her doctorate in systems engineering from the University of Virginia in 2004.

Francis T. Durso is Professor of Psychology, Georgia Institute of Technology. His areas of recent and current research include (*a*) an exploration of how the human factors consequences of the Next Generation Air Transportation System and related automation of some tasks could affect air traffic controller strategies for managing workload, situation understanding, and performance and (*b*) development of a taxonomy of human–automation coordination strategies and the consequences of those strategies for the development of new technologies. Dr. Durso is the current president of the Human Factors and Ergonomics Society and a member of the National Research Council Board on Human–Systems Integration. He has coauthored several articles dealing with aviation safety; air traffic controller selection criteria; air traffic control; task analysis; and management of workload, performance, and situational awareness in aviation. He received a doctorate in psychology from the State University of New York at Stony Brook.

John J. Fearnsides is Chief Executive Officer and Chief Strategist, MJF Strategies, LLC. Until 1999, he was senior vice president and general manager of the MITRE Corporation and director of its Center for Advanced Aviation System Development. He worked at the U.S. Department of Transportation from 1972 to 1980, serving as deputy under secretary and chief scientist, executive assistant to the secretary, and acting assistant secretary for policy and international affairs. He was a National Science Foundation Fellow and is a Fellow of the Institute of Electrical and Electronics Engineers and the National Academy of Public Administration. He has served on numerous National Research Council and Transportation Research Board committees, including the Committee for a Review of the En Route Air Traffic Control Complexity and Workload Model and the Committee for a Study on Air Passenger Service and Safety Since Deregulation. Dr. Fearnsides received bachelor of science and master of science degrees in electrical engineering from Drexel University and holds a doctorate in electrical engineering from the University of Maryland.

Andrew LeBovidge has been an air traffic control specialist with the Federal Aviation Administration at the Houston Air Route Traffic Control Center (ARTCC) from 1992 to the present. He has also served as a representative for the National Air Traffic Controllers Association (NATCA) since 1998, area representative from 1998 to 2000, principal facility representative at the Houston ARTCC (local president) from 2000 until the present, and alternate regional vice president for NATCA's Southwest Region from 2003 until the present. He has worked on several national and regional committees focusing on staffing and placement within the air traffic control system. He is recognized by both management and labor for his expertise. Mr. LeBovidge received a bachelor of arts degree in history from the University of Pennsylvania.

Amedeo R. Odoni is Professor in the Department of Aeronautics and Astronautics and the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology (MIT). He has served as codirector of the Global Airline Industry Center at MIT (1999–2009) and of the Federal Aviation Administration's National Center of Excellence in Aviation Operations Research (1996–2002). Previously, he was head of the Systems Division of the Aeronautics and Astronautics Department (1991–1996) and codirector of MIT's Operations Research Center (1985–1991). Dr. Odoni is the author or coauthor of three textbooks and about 100 professional publications as well as coeditor of six books. He served as editor-in-chief of *Transportation Science* from 1985 to 1991 and is a current or past member of the editorial boards of many professional journals. Dr. Odoni is a member of the National Academy of Engineering, a Fellow of the Institute for Operations Research and Management Science, and the recipient of many awards for his teaching and research. He has served as consultant to national and international organizations and to many of the busiest airports in the world on projects related to practically every aspect of airport planning and design and of air traffic management. He received bachelor and master of science degrees in electrical engineering and computer science and a doctorate in operations research, all from MIT.

Norman T. O'Meara is a senior fellow at the Logistics Management Institute, where, over the past 20 years, he has analyzed manpower, workforce planning, and resource allocation issues for a number of top-level governmental entities with emphases on the cabinet-level Departments of State, Defense, and Transportation. Dr. O'Meara served on a congressionally directed National Research Council committee to study the Federal Aviation Administration's methods for estimating air traffic controller staffing requirements. He led the analytical team for the Department of Defense's Joint Cross Service Group for Depot Maintenance in support of the department's base realignment and closure recommendations and testimony before the commission. Dr. O'Meara served with the Army Science Board to identify the resource alternatives necessary for Army transformation. He received a bachelor of science degree from the United States Military Academy, master of science degrees in mathematics and operations research and statistics from Rensselaer Polytechnic Institute, and a doctor of science degree from George Washington University.

Clinton V. Oster, Jr., is Professor Emeritus and former Associate Dean for Bloomington Programs at the School of Public and Environmental Affairs, Indiana University. His research has centered on aviation safety, airline economics and competition policy, energy policy, and environmental and natural resource policy. He has coauthored five books on various aspects of air transportation, including *Deregulation and the Future of Intercity Passenger Travel* with John Meyer and *Managing the Skies: Public Policy, Organization, and Financing of Air Navigation* with John Strong. He is a coauthor of the transportation chapter in *Climate Change Impacts in the United States: The Third National Climate Assessment.* He has chaired and served on numerous National Research Council committees. He was chair of the Committee for the Study of Traffic Safety Lessons from Benchmark Nations, chair of the Committee on the Federal Employers' Liability Act, chair of the Committee on the Effects of Commuting on Pilot Fatigue, and cochair of the Committee on the National Aeronautics and Space Administration's National Aviation Operational Monitoring Service Project. He was a member of the Committee for Guidance on Setting and Enforcing Speed Limits and the Committee for a Study on Air Passenger Service and Safety Since Deregulation. He holds a bachelor's degree in engineering from Princeton University, a master's degree in public affairs from Carnegie–Mellon University, and a doctorate in economics from Harvard University.

Roger Wall has more than 50 years of air traffic management (ATM) and control experience and has been self-employed as an independent consultant with the Washington Consulting Group since 2011. He has focused primarily on international efforts in China with the U.S.–China Aviation Cooperation Program, including teaching classes to Chinese transportation and civil aviation personnel on U.S. air traffic control (ATC) policies and procedures. Mr. Wall retired from his position as

Federal Aviation Administration (FAA) Coordinator and ATM Projects Manager for FedEx Corporation in 2008, having served 10 years with FedEx. Before joining FedEx, he was director of air traffic operations for FAA, having risen from air traffic controller. At FAA, Mr. Wall held management positions at ATC facilities, FAA regional offices, and FAA headquarters. He began his career as an air traffic controller for the U.S. Navy in 1959. From 1996 to 2008, he served as chairman of the Free Flight Select Committee of the Radio Technical Commission for Aeronautics (RTCA) and the Air Traffic Management and Airport Systems Requirements and Planning Working Group. He was honored with RTCA's Lifetime Achievement Award in 2008. He holds a private pilot, single-engine land rating. He served on the Committee for a Review of the En Route Air Traffic Control Complexity and Workload Model. He is a graduate of the Government Senior Executive Service Program.