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JOB DESCRIPTION FOR THE NEXTGEN MID-TERM ATCT CONTROLLER

DELIVERABLE 2A UNDER CONTRACT DTFAWA-09-A-80027: APPENDIX A

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The views expressed in this report are those of the authors. They do not necessarily reflect the views of the Department of Transportation (DOT), the FAA, NATCA, or any other organization.

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Executive Summary

The development of this description of the job of the Air Traffic Control Specialist (ATCS) as it will exist in the Next Generation Air Transportation System (NextGen) mid-term time frame (2018) in the Airport Traffic Control Tower (ATCT) environment represents a unique and substantive challenge; much is still unknown regarding NextGen and the specific technologies, automation, and procedures that will support it. However, it also represents an important and timely opportunity to inform the pre-employment selection and training processes that are required to ensure that the workforce will be ready and able to perform the job effectively in 2018. It also provides the opportunity to identify potential risks so that they may be evaluated by NextGen system engineers, hardware and software developers, human factors researchers, and other aviation professionals.

Methodology

The research methodology employed by the American Institutes for Research (AIR) to develop this future-oriented job description involved data collection, data synthesis, and data projection. First, AIR collected data from many NextGen-specific documents and from in-person interviews with NextGen subject matter experts (SMEs). Next, AIR synthesized these data with its understanding of the current job and used the resulting knowledge to evaluate the impact of the ATCT-specific NextGen technologies, automation, and procedures (i.e., Drivers) that are proposed to exist in 2018. The result is this description of the ATCT controller job as it will be performed in 2018 and beyond. Note that the research in this report describes the impact of NextGen on the certified professional controller (CPC) managing live traffic at an ATCT workstation. It does not include the impact of NextGen on an ATCS's training or supervisory responsibilities.

Because NextGen supports changes to an existing job (as opposed to creating a new job) and because the resulting changes to the job are relatively subtle, this job description—presented below and supported by more detailed information in the rest of the report—consists of an explanation of how the 2018 ATCS job will be different from the 2011 ATCS job. Consequently, this description requires an understanding of the current job, and more important, of how the current job analytic data are organized. The work that ATCSs perform on the job is captured in terms of Tasks, which are grouped into categories called Sub-Activities and Activities. The characteristics required of workers to perform the job are captured in terms of Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs). The Tools and Equipment used on the job are also identified. These lists are provided in Appendix A.

Job Description of the NextGen Mid-Term ATCS

This Job Description of the NextGen Mid-Term ATCS working in the ATCT environment is based on the NextGen technologies, automation, and procedures (i.e., NextGen ATCT Drivers), which will have an impact on the job responsibilities, KSAOs, and the work environment more generally.

NextGen ATCT Drivers

AIR's research identified eight primary NextGen Drivers that will influence the ATCT work environment in 2018:

- 4-Dimensional Weather Data Cube (4-D Wx Data Cube)
- Airport Surface Detection Equipment-Model X (ASDE-X)
- Automatic Dependent Surveillance-Broadcast Out (ADS-B Out)
- Data Communications (Data Comm)
- Integrated Arrival, Departure, and Surface (IADS)
- Terminal Automation Modernization and Replacement, Phase 3 (TAMR 3)
- Tower Flight Data Manager (TFDM)
- Wake Turbulence Mitigation for Departures (WTMD)

Although at least some of these Drivers do not require satellite-based technology, they are in many cases being supported directly or indirectly by satellite technology. However, they will not affect all ATCT facilities equally. For example, WTMD will affect only facilities that have closely spaced parallel runways (CSPRs) and only when crosswinds are favorable for reducing wake turbulence. Consequently, it will affect only controllers working in these facilities during these situations. Note that AIR was compelled—*by necessity*—to make certain assumptions regarding these Drivers in order to determine their impact on the job. These assumptions are described in the report.

NextGen ATCT Tasks

AIR's analysis suggests that these eight ATCT NextGen Drivers will have an impact on the ATCS job as it will be performed in 2018. However, the actual Tasks performed by line controllers will change very little by 2018. That is, few additions, deletions, or modifications will need to be made to the existing list of 390 current ATCT job Tasks, with two exceptions:

- Addition of 10 new Tasks across two Drivers.
- Modification of four Tasks in one Driver. Note that these modifications represent a minor change, which is to remove the word *radar* from all the Tasks associated with the transfer of radar identification because identification is no longer technically solely a radar function.

This lack of substantive change required to the Task list is due in part to the nature of the NextGen Drivers; they are designed to help controllers do their current job more efficiently rather than to substantively change what controllers do. It is also due in part to the structure and format of the job analytic data; Tasks typically describe what work gets done, not how the work gets done, and are written at a level of specificity that is not designed to illuminate changes of this nature.

Although relatively few changes are called for in terms of changes to the existing ATCT Task list, there will be a number of changes regarding *how* the job Tasks on that list are performed. The eight Drivers influence between 12 and 70 Tasks each, with many Tasks being affected by more than one Driver. Based on the number of Tasks affected, the implementation of 4-D Wx Data Cube, ASDE-X, Data Comm, and TFDM—which affect 54 or more Tasks each—will arguably effect the most change. 4-D Wx Data Cube will affect 70 Tasks in nine ATCT job

Activities. Data Comm will affect 65 Tasks in 10 Activities. ASDE-X will affect 55 Tasks in six Activities. Finally, TFDM will affect 54 Tasks across six Activities. For example, Data Comm is a new tool and its introduction will change how controllers establish and transfer situation awareness; it will have a large impact on how controllers manage communications; and it will continue to change the options available for issuing departure clearances and revisions.

Net Impact of NextGen on Tasks Required of ATCT Controllers

A summative evaluation of the impacts of the Drivers described in detail in Section V of this report suggests several net effects of the NextGen technologies, automation and procedures on the Tasks of the ATCT controller. First, ATCT controllers will use more automation than ever before. They will also use new procedures to perform their work. These new tools and procedures will give them access to more information and also more accurate information, which will improve their situation awareness and decision making. For example, the implementation of ASDE-X will provide controllers with more information and more accurate information about ground operations than they have access to currently, especially during low visibility conditions. This will allow them to space aircraft and vehicles more precisely and to identify conflicts more accurately, especially in movement areas that are not currently visible from the ATCT window.

Some Tasks will be performed more often and others will be performed less often in 2018 as a result of ATCT Drivers, but the net effect will be an increase in efficiency for ATCT controllers, which will ultimately lead to NAS-wide improvements in efficiency of operations. For example, TFDM supports several decision support tools (DSTs) that will provide optimized taxiway and routing options, including options for sequencing and scheduling from the gate to the runway. Not only will controllers spend less time developing and evaluating sequencing options, but the DST-provided routes will be optimized for efficiency. These positive effects are realized again when responding to a disruption, such as an aircraft being delayed in its departure from the gate. Instead of the controller developing a potentially complex solution to resequence all the aircraft to take this delay into account, the DSTs will help develop the rerouting solution.

Finally, the implementation of the Drivers adds more decision branches that controllers must navigate to conduct various Tasks. For example, controllers will need to consider whether aircraft are equipped with Data Comm and determine which method of communication (i.e., voice or data) is appropriate before communicating with these aircraft. Similarly, dynamic changes in the required wake turbulence separation minima that result from the implementation of WTMD will require controllers to determine the appropriate standard before spacing aircraft for departure on CSPRs.

NextGen ATCT KSAOs

In addition to having an impact on job Tasks, the eight ATCT NextGen Drivers will also affect the requirements of individuals who perform the ATCS job. However, as with the job Tasks, the actual list of KSAOs required will change very little, with these exceptions:

- Addition of two new Knowledges across multiple Drivers.
- Addition of one new Skill across multiple Drivers.
- Addition of one new Other Personal Characteristic across multiple Drivers.

As with the Tasks, the lack of impact of the Drivers on the KSAOs is due partly to the characteristics of the Drivers themselves and partly to how the KSAOs are written. For example, the Knowledges and Skills required for the job represent the end Knowledges or Skill required; their purpose is not to capture training content or the curriculum required to teach it.

Although the Drivers require few changes to the list of KSAOs, the eight ATCT Drivers do have a significant impact on various properties of existing KSAOs. More specifically, the training curriculum required to teach the Knowledges and Skills associated with the Drivers will need to change. In addition, some KSAOs will be used more or less often or will otherwise become more or less important as a result of the implementation of a NextGen Driver(s).

The eight ATCT Drivers influence the properties of between 22 and 58 KSAOs each, with many KSAOs being affected by more than one Driver. Data Comm, WTMD, and ASDE-X, which affect 46 or more KSAOs each, will arguably effect the most change. For example, Data Comm affects 58 KSAOs. Its implementation will require the addition of a new Other Personal Characteristic to capture the requirement for ATCT controllers to have positive attitudes toward and be willing to use Data Comm technology (*New O-Technology Acceptance*) to take advantage of its positive benefits. They must be comfortable using it to perform their job efficiently. WTMD affects 52 KSAOs; it will require that controllers be taught new Knowledges associated with communicating the shift between two different wake turbulence separation standards. Finally, ASDE-X affects 46 KSAOs. Controllers will need practice to further develop their Skills at quickly shifting attention between scanning the ASDE-X display and looking out the window.

Net Impact of NextGen on KSAOs Required of ATCT Controllers

A summative evaluation of the impact of the Drivers as described in Section V of this report suggests several net effects on the KSAOs required of ATCT controllers. First, it will increase the Knowledges and Skills required of ATCSs. Substantive additional training content will be required to prepare these controllers to perform in 2018. Even in cases where technology, automation, or procedure will reduce the need for a particular Knowledge or Skill, that impact is not a net effect but is instead a function of that individual Driver. Consequently, the increases in training requirements are accompanied by few if any reductions or eliminations in training requirements. The additional curriculum required is detailed in this report.

ATCT Drivers will have a more limited impact on the Abilities and Other Personal Characteristics required of ATCT controllers. No new Abilities are required, and only one new Other Personal Characteristic (i.e., being comfortable using technology). Instead, the Drivers have individual effects on Abilities and Other Personal Characteristics, increasing or decreasing their frequency of use or importance. One important net effect is that the Abilities associated with verbal communication will be used less often in the mid-term as a result of ATCT Drivers. More specifically, several Drivers either reduce the need for verbal communications directly (i.e., Data Comm) or otherwise create shared situation awareness through the sharing of information (i.e., 4-D Wx Data Cube, ASDE-X, ADS-B Out, IADS, TFDM), thus reducing the need for Abilities that support verbal communication.

Another net impact is that the job of ATCT line controllers will become more dynamic and therefore the Abilities associated with maintaining job performance in this new work environment will become more important. The change in the work environment will be due to the addition of new technology, automation, and procedures to the facility; to mixed aircraft equipage; and to the introduction by some ATCT Drivers of requirements for controllers to switch quickly and often between two Tasks or ways of performing Tasks. For example, WTMD requires controllers to shift between applying two different wake turbulence separation standards. ADS-B Out and Data Comm are implemented on board only some aircraft and controllers must make this determination for each aircraft before performing air traffic operations. The Abilities that are likely to increase in importance include but are not limited to perceptual speed and accuracy, working memory, time sharing, flexibility, and learning.

Finally, as the job becomes more automated, controllers will need to believe that they have an influence over and are responsible for outcomes; controllers need to believe that they are in control, not the automation.

Potential Risks

NextGen adds new technologies, automation, and procedures to the National Airspace System (NAS), which brings with it the possibility for threats to safety and efficiency. AIR identified 17 potential risks as a result of the implementation of seven of the eight ATCT Drivers in the mid-term (see Appendix B).[1] These risks range from challenges associated with technology (e.g., improper design); new policies and procedures (e.g., best equipped, best served); new work environment (e.g., more dynamic work environment); and with individual performance (e.g., skill decay, lack of/inadequate training).

The Drivers are affected by varying numbers of risks, with some having only a few potential risks and others having many potential risks. The number of risks cited per Driver ranges from 6 to 12 (out of seven Drivers being considered), with IADS only having six identified risks. ADS-B Out, Data Comm, and TFDM have the most associated risks at 11 or 12 each. Similarly, the 17 risks have a differential impact, with some being associated with only a few Drivers and others being associated with many Drivers. The number of Drivers ranges from 1 to 7, with Improper Allocation of Tasks to Automation, Loss of Party Line Information, and Unknown Impact of Experience each being associated with only one Driver. Degradation/Failure of Equipment or Systems, Lack of/Inadequate Training, and Technology Development and Maturation are associated with all seven ATCT Drivers.

Net Impact of ATCT NextGen Drivers

In summary, although 15 is a substantial number of risks, three represent the primary potential threats to safety and efficiency of the NAS: a lack of/inadequate training, improper design or implementation of technologies, and mixed aircraft equipage. All NextGen Drivers require that developmental- and CPC-level ATCSs receive training and practice on Knowledges and Skills. Even though the impact of some ATCT Drivers is very limited (e.g., WTMD applies only to ATCTs serving airports with CSPRs and relatively stable crosswind patterns), this will still create a substantive overall impact on the Federal Aviation Administration (FAA). In addition, if controllers do not receive training or implement the training they receive, they will perform less

[1] TAMR 3 is primarily an upgrade to existing automation. It adds only two new functionalities: data communications and electronic transfer of flight plan information. Because these functionalities are part of other Drivers, their impact and potential risks were described as part of those Drivers resulting in the total number of Drivers assessed for risks to be seven instead of eight.

efficiently and be more likely to make errors, and the benefits the Drivers were intended to create will not be realized.

The improper design of technology includes both the design of the hardware and software components that must work reliably and in concert with other NAS components and the design of the human interface. If either is not done well, it will create inefficiencies, increase the possibility of error for controllers, and reduce the likelihood that the benefits proposed by the Driver will be realized.

Finally, mixed aircraft equipage is considered a substantive risk for two reasons. First, controllers will be required to have access to current information regarding equipage of each individual aircraft and to take this information into account when making control decisions. This adds complexity. Second, the best equipped, best served strategy, which is proposed as a benefit for aircraft with certain equipage, is not currently well defined. However, although the specifics of the strategy have not yet been agreed upon, as conceptualized by AIR, the shift from first come, first served to best equipped, best served puts a burden on the controllers to balance what may be competing goals between ensuring the safe and efficient flow of traffic and giving preferential treatment. Again, with the proper evaluation and research and development, these risks can likely be remediated.

Section I. Introduction

BACKGROUND

In 2003, Congress passed the VISION 100—Century of Aviation Reauthorization Act (P.L. 108-176) establishing and empowering the Joint Planning and Development Office (JPDO) to lead a combined public-private initiative titled the Next Generation Air Transportation System (NextGen). By leveraging existing and new technology, including satellite-based surveillance and navigation, NextGen is intended to support significant increases in capacity and improve efficiency. The American Institutes for Research (AIR) is supporting NextGen by developing a vision of the job of Air Traffic Control Specialists (ATCSs) as it is proposed to be conducted in 2018.

Information regarding the future job will inform two important human resource processes: pre-employment selection and training. More specifically, identifying a vision of the ATCS job as it will exist in 2018 and any associated changes in the Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs) required of line controllers to perform the job will help inform whether and how the pre-employment selection process should be modified. Similarly, identifying potential changes to the job will help identify whether and how training should be changed. This vision of the NextGen mid-term job is being developed in advance of the implementation of the NextGen tools and equipment that will be the impetus for the job changes to ensure adequate time for the pre-employment selection and training systems to be modified and validated.

PROJECT OVERVIEW

To develop the vision of the work of the NextGen mid-term controller, AIR conducted a strategic job analysis which is a systematic process of identifying and describing the important aspects of a new or changing job, as well as the KSAOs required to perform it. A strategic job analysis differs from a traditional job analysis in that job incumbents do not exist and cannot contribute to the process (Schippmann, 1999). Instead, a different process must be employed.

AIR began this strategic job analysis by conducting an extensive review of existing information about the job of the ATCS. The next step involved updating the most recent job analysis, which was conducted by AIR in 2007. Once the job analysis of the current ATCS was complete, the next step involved reviewing NextGen documentation (e.g., NextGen Concept of Operations, Operational Improvements) and conducting interviews with a wide variety of NextGen subject matter experts (SMEs). The final task was to synthesize this information and use it to identify changes in the characteristics of the work (i.e., job Tasks) and changes in the characteristics of the worker (i.e., KSAOs) required for successful job performance in 2018.

Several products have resulted from this research. First, updated job analysis information for the current ATCS job for the Airport Traffic Control Tower (ATCT), Terminal Radar Approach Control (TRACON), and Air Route Traffic Control Center (ARTCC) was released. Next, job descriptions for the ATCS job—again as it is performed in these three facility type—with proposed changes to the job Tasks and worker characteristics were developed. The descriptions reflected AIR's summative interpretation of changes to the job itself as well as to the characteristics of the ATCS who perform the job.

Note that the work to design and build NextGen tools, equipment, and processes is complex and ongoing. In addition, the work requires the coordination and cooperation of a large and diverse group of stakeholders and a substantial financial investment. Consequently, the information in deliverables must be based on the information available at the time. It is fully expected that the information in any given report or deliverable will need to be modified as the NextGen technologies, automation, and procedures mature and are implemented.

Structure of the Report

This report captures the job description of ATCSs working in ATCT facilities in the NextGen mid-term, defined as the year 2018. In addition to this Introduction (Section I) and a description of AIR's Methodology (Section II), this report includes the following:

- *Characteristics of Current ATCT Work and Workers:* Section III describes the current ATCS job and the characteristics of the workers required to perform it well. While most readers are likely familiar with the ATCS job, this report is organized according to the FAA's current job analysis data. A review of these data and how they are organized will facilitate the reader's understanding of the 2018 job as it is described in this report.

  ATCS Job responsibilities[2] are captured in hierarchical fashion. *Tasks* capture the most detailed aspects of the job and are grouped into higher-level categories called *Sub-Activities*, which are further grouped into higher-level categories called *Activities*. In this section, work behaviors are summarized by job Activity. This section also includes a description of the characteristics of the worker required to perform the job successfully in today's environment. These worker requirements include (a) bodies of factual, technical, or procedural information a person uses to perform a job (i.e., Knowledges); (b) human capabilities, developed through training or practice, to perform job Tasks (i.e., Skills); (c) general human traits individuals possess that give them the capacity to carry out physical and mental acts required by a job's Tasks (i.e., Abilities); and (d) attitudes, preferences, or personality traits that influence how well a person can carry out job Tasks (i.e., Other Personal Characteristics).

- *Drivers of the NextGen ATCT Work Environment:* The Drivers described in Section IV refer to the NextGen technologies, automation, and procedures that are proposed to be in place in 2018 and that are anticipated to influence the work environment of the ATCS working in the ATCT. The Drivers are critical in that they provide the basis for the changes that are proposed to occur to the ATCS job and to the requirements needed to perform it.

[2] Job responsibilities capture behaviors ATCSs engage in to perform their job. Some of these behaviors are associated with outcomes for which they are both accountable and liable.

- *Characteristics of NextGen ATCT Work and Workers*: Section V describes how the job is proposed to change as a result of the introduction of NextGen technologies, automation, and procedures. More specifically, AIR identifies how the Tasks and the required KSAOs will change.

- *Conclusions and Next Steps:* Section VI presents conclusions including limitations of the current research, and next steps.

Note that the information presented in this report is based on information available to AIR as of January 2011.[3] It is fully expected to change as NextGen concepts mature and as NextGen technologies are developed and implemented.

[3] An exception is that the Operational Improvements referenced in this report are from November 2010.

Section II. Methodology

Overview

As stated in Section I, AIR's approach to developing a description of the job of line controllers working in the Next Generation Air Transportation System (NextGen) mid-term Airport Traffic Control Tower (ATCT) environment was to conduct a strategic job analysis. Whereas a traditional job analysis involves gathering information from job incumbents, a strategic job analysis requires a different process because job incumbents do not yet exist (Schippmann, 1999). Instead, the strategic job analysis typically involves gathering information from policy experts and other subject matter experts (SMEs) to develop a concept of the job (Schneider & Konz, 1989). For this analysis, AIR collected, reviewed, and synthesized data and then used the resulting knowledge to project the impact of the changes to the job.

Data Collection

AIR began by evaluating four primary sources of information:

- Information regarding how the job is currently performed
- Documentation regarding NextGen
- Input from SMEs regarding NextGen
- Academic literature regarding specific topics

Each of these sources brought unique insights to AIR's conceptualization of the NextGen job.

Update Current Job Analysis

First, AIR reviewed existing information regarding the current job. The primary source for this information was the 2007 Air Traffic Control Specialist (ATCS) job analysis, which was completed by AIR (Krokos, Baker, Norris, & Smith, 2007). This job analysis consists of a hierarchical description of work behaviors in terms of Activities, Sub-Activities, and Tasks. This job analysis report also included a list of Knowledges and Abilities. However, those lists were simply reproduced as a courtesy to the reader from their original sources which were the CTA Assessment (Ammerman, Fairhurst, Hostetler, & Jones, 1989), and the Separation and Control Hiring or SACHA assessment (Nickels, Bobko, Blair, Sands & Tartak, 1995) respectively; they were not vetted by SMEs as part of the 2007 research. Finally, a full list of Skills did not exist, nor did a list of Tools and Equipment. To complete the current research, AIR needed comprehensive, current, vetted, and separate lists of Activities, Sub-Activities, Tasks; Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs); and Tools and Equipment. Consequently, AIR developed drafts of these documents (if draft versions did not exist) and worked with SMEs to edit them.

AIR gathered input from SMEs who are experts in the job and from AIR job analysts working on the project. The goal was to ensure that the information captured in the lists was comprehensive, up-to-date, technically accurate, and organized appropriately. The work with SMEs was conducted in two parts. First, AIR conducted a series of focus groups in 2010 and 2011 during which the lists were reviewed and edited. In total, the focus groups consisted of 30 SMEs, 19 of whom are currently certified. In addition to these formal focus groups, AIR conducted numerous

informal telephone interviews. These interviews allowed AIR to gather the information needed to refine the lists. The majority of these informal communications were conducted with individuals who participated in the focus groups. AIR also gathered input from an AIR team member who has over 30 years experience in air traffic control, and who is also a human factors researcher and a pilot.
The edits to the job Activities, Sub-Activities, and Task lists did not result in substantive changes to the core ATCS job responsibilities. However, the lists were reorganized to be more logical; reordered where appropriate to more closely follow the temporal sequence of the job; reworded to be more consistent with today's air traffic control culture; and edited to follow the proper format. The edits to the KSAOs and the Tools and Equipment were more substantive. The existing or draft lists were updated to be more consistent with today's air traffic control work; sorted into separate files; reorganized to be more logical; and reworded to be clearer. Finally, AIR checked for correspondence between the lists. That is, AIR ensured that the Knowledges required to perform Tasks were captured in the Knowledges list and the Skill needed to perform the Tasks was captured in the Skills list. Substantive effort was made to make the lists across facility type (i.e., Airport Traffic Control Tower [ATCT)], Terminal Radar Approach Control [TRACON], and Air Route Traffic Control Center [ARTCC]) consistent—but only if the actual Tasks were indeed the same across facility type. For example, the Tasks associated with assuming position responsibility are largely the same across facility type and were modified to be more consistent. The final lists of Activities, Sub-Activities, and Tasks; KSAOs; and Tools and Equipment are available in both Microsoft Excel workbook form (American Institutes for Research, 2011a) and as part of a more detailed technical report (American Institutes for Research, 2011b).

These newly revised job analytic data for the current job ultimately served multiple purposes. First, these data provided the information required for AIR's description of the current job in this report. Second, these data served as the baseline against which AIR applied information about the NextGen Drivers and other NextGen information, which in turn served as the basis for AIR's evaluation of whether and how the job will change by 2018. This approach was taken because the purpose of this strategic job analysis is to describe how an existing job—the ATCS job—will change, rather than to describe a completely new job that does not yet exist.

Review NextGen Documentation

After updating the description of the current job, AIR began developing the vision for the job as it will exist in 2018. This substantive research process comprised several steps. First, AIR reviewed the available NextGen documentation, including the Federal Aviation Administration's (FAA) 2009 and 2010 NextGen Concept of Operations; multiple iterations of the Operational Improvements (OIs); the FAA's 2009 and 2010 NextGen Implementation Plans; RTCA's 2009 NextGen Mid-Term Implementation Task Force Report and the FAA's response to it; and many others as identified in Appendix C. These documents helped AIR understand the FAA's goals and priorities for the implementation of NextGen automation systems, the benefits associated with each, and the implementation timeline of the technologies, automation, and procedures.

Despite the informative nature of the NextGen documentation, these documents captured NextGen at a high level and did not contain the detailed information needed to build a vision for how the job of the ATCS would change. For example, AIR needed information about how the technologies, automation, and procedures will be implemented. Consequently, the next step was to interview NextGen SMEs to elicit this information.

Conduct Subject Matter Expert Interviews

AIR researchers interviewed 18 NextGen experts in the Washington, DC, area who have specific and direct conceptual knowledge of the NextGen initiative, as well as specific information regarding how the initiative will be operationalized. These interviews were conducted between March 2010 and November 2010. The interviewees include senior NextGen engineers and policymakers. The job titles of the SMEs who participated can be found in Table 1.

Table 1. Job Titles of SMEs Interviewed by AIR in the Washington, DC, Area

Job Title
Chief System Engineer of Terminal
Air Traffic Control Subject Matter Expert, FAA Contractor
Director NextGen Facilities, NextGen & Operations Planning
NextGen Automation Integration Manager, NextGen & Operations Planning
NATCA Representative, NextGen & Operations Planning
Senior Human Factors Engineer, FAA ARTCC Contractor
En Route NextGen Planning and Engineering Manager
Systems Engineer, En Route & Oceanic Services
Systems Engineer, Terminal Services
Lead Human Factors Engineer, Terminal Services
General Engineer, Terminal Services
Program Manager, Staffed NextGen Towers
Chief System Engineer and eight current team members, En Route & Oceanic Services
Aerospace Engineer and eight current team members, En Route & Oceanic Services
Human Factors Engineer, NextGen & Operations Planning
Chief Scientist, NextGen & Operations Planning
Manager, NextGen & Operations Planning
Lead System Engineer, Terminal Services

A standardized, semi-structured interview protocol was designed to gather SMEs' expert opinions concerning NextGen initiatives as well as their vision of how the ATCS job would change.

In addition to interviewing SMEs in the Washington, DC, area, AIR traveled to the FAA's William J. Hughes Technical Center in Atlantic City. The goal of the site visit was to interview additional NextGen automation experts and air traffic controllers and to view demonstrations of ongoing human factors evaluations of ATC equipment. AIR's first visit took place in May 2010 and included interviews with five human factors and air traffic control experts. AIR's second visit occurred in July 2010 and included interviews with two additional SMEs. The job titles of these seven SMEs are shown in Table 2.

Table 2. Job Titles of SMEs Interviewed by AIR at the FAA's Technical Center

Job Title
Technical Lead for Air Traffic Control Human Factors Research & Engineering, NextGen & Operations Planning
Engineering Research Psychologist, NextGen & Operations Planning
Engineering Research Psychologist, NextGen & Operations Planning
Engineering Research Psychologist, NextGen & Operations Planning
Engineering Research Psychologist, NextGen & Operations Planning
Air Traffic SME, NextGen & Operations Planning
Air Traffic SME, NextGen & Operations Planning

Although these in-person interviews yielded a great deal of useful information, AIR found at their conclusion that additional detail regarding specific topics, particularly those related to the NextGen 2018 Drivers, was needed. The Drivers are complex and rapidly changing. Often, little formal documentation regarding them was available. Consequently, in addition to the formal in-person interviews, AIR conducted many informal communications over the telephone, via email, and during NextGen and human factors meetings in order to describe and define the Drivers in more detail. These communications took place in late 2010 and early 2011 with SMEs who were initially interviewed as well as with other individuals recommended by the FAA and other stakeholders.

Review Academic Literature

The last stage in the data collection process involved conducting a targeted review of the academic literature on various topics, including human performance and automation and the effects of the loss of party line information associated with the use of Data Communications (Data Comm).

DATA SYNTHESIS AND PROJECTION

The analysis of the current job, NextGen documents, SME interviews, and academic literature yielded a large volume of information regarding NextGen and the job of the ATCS. Once these data collection steps were complete, the next step was to synthesize the information into a coherent package that could be used as the foundation for evaluating and describing how the ATCS job will change by 2018. The primary consideration in this process was determining how to synthesize and present the multiple sources of information, which were written or gathered at different stages in the NextGen timeline, by different stakeholders, and at varying levels of specificity, into a framework that could guide the writing of the job description for the future job.

Several specific challenges came to light during this process. These included questions concerning the

- mapping of NextGen information to facility type,
- comprehensiveness of the draft list of Drivers,
- differences in tower facilities,
- conceptualization of the future job, and
- presentation of job changes.

AIR addressed these challenges with the solutions described below.

Map NextGen Information to Facility Type

First, it was unknown how the NextGen information collected mapped onto the three facility types: ATCT, TRACON, and ARTCC. That is, not every concept discussed in the NextGen Concept of Operations (ConOps) or the OIs or identified in the SME interviews is relevant to every facility type. Unfortunately, with one exception, the NextGen documents reviewed by AIR job analysts did not specify which facility types will be affected by the NextGen technologies, automation, and procedures. This information was needed because AIR intended to build job descriptions separately for each job option. The exception was a working road map developed by the FAA's Human Factors Research and Engineering Group that linked OIs to facility type. However, upon review, it was determined that the working road map was built on an older release of the OIs than the November 2010 version being used by AIR. Given the highly evolving nature of NextGen, AIR conducted an internal exercise in January 2011 to map the OIs to facility type.

Four AIR researchers who had been working on the project since its inception worked independently to identify the facility type or types that will be most directly affected by the 51 near-term and mid-term OIs listed on the FAA's Enterprise Architecture website as of 17 November 2010. Then, the researchers met and discussed their individual results until they reached consensus. A final review of the results was conducted in May 2011 with a fifth AIR researcher who has 30 years experience in air traffic control, and who is also a human factors researcher and a pilot. Minor edits were made during this process. The final results for ATCT are shown in Table 3. Note that these results overlap significantly with the FAA-generated assignments. Discrepancies are related to the fact that AIR included near-term OIs in this list and the FAA included only mid-term OIs and to the fact that AIR assigned NextGen improvements associated with aircraft arrival to the TRACON environment, whereas the FAA assigned them to the ATCT environment.

Table 3. OIs With Direct Impact on ATCSs Working in the ATCT Environment

OI No.	OI Name
102137	Automation Support for Separation Management
102140	Wake Turbulence Mitigation for Departures (WTMD): Wind-Based Wake Procedures
102141	Improved Parallel Runway Operations
102406	Provide Full Surface Situation Information
103116	Initial Improved Weather Information from Non-Ground Based Sensors
103119	Initial Integration of Weather Information into NAS Automation and Decision Making
103207	Improved Runway Safety Situational Awareness for Controllers
103208	Improved Runway Safety Situational Awareness for Pilots
103305	On-Demand NAS Information
104102	Flexible Entry Times for Oceanic Tracks
104117	Improved Management of Arrival/Surface/Departure Flow Operations
104123	Time Based Metering Using RNAV and RNP Route Assignments

OI No.	OI Name
104207	Enhanced Surface Traffic Operations
104209	Initial Surface Traffic Management
105208	Traffic Management Initiatives with Flight Specific Trajectories
107115	Low Visibility/Ceiling Takeoff Operations
107117	Low Visibility/Ceiling Departure Operations
107118	Low Visibility/Ceiling Landing Operations
107119	Expanded Low Visibility Operations using Lower RVR Minima
107202	Low Visibility Surface Operations
109305	Improved Safety for NextGen Evolution
109402	Remotely Staffed Tower Services
102123	ADS-B Separation
107103	RNAV SIDS, STARS and Approaches

Determine Comprehensiveness of Draft List of Drivers

Reaching consensus regarding which OIs are most relevant for which facility types allowed researchers to focus on those OIs when evaluating the impact on the job for a specific facility type. Another challenge, however, was understanding how the specific changes to the ATCS work environment that AIR had already begun drafting related to this list of OIs. That is, AIR had already identified a list of technologies, automation, and procedures that have been proposed to occur in the NextGen mid-term and that will most likely and most directly affect the work environment (and hence the job) of the ATCS in the ATCT environment:

- 4-Dimensional Weather Data Cube (4-D Wx Data Cube)
- Airport Surface Detection Equipment-Model X (ASDE-X)
- Automatic Dependent Surveillance-Broadcast (ADS-B)
- Data Communications (Data Comm)
- Integrated Arrivals and Departures (IADS)
- Terminal Automation Modernization and Replacement (TAMR)
- Tower Flight Data Manager (TFDM)
- Wake Turbulence Mitigation for Departures (WTMD)

To ensure that this list of Drivers was comprehensive, AIR researchers independently assigned these Drivers to the OIs identified for the ATCT environment and then reconvened and discussed them to reach consensus. The results suggest that the list of Drivers was complete. All the ATCT Drivers were mapped onto at least one OI. With the exception of one OI (OI 105302-Continuous Flight Day Evaluation), each OI had at least one ATCT Driver mapped onto it. Although the strategic analysis required to support continuous flight day evaluation is likely to be the responsibility of system engineers, it is not clear whether or how line controllers will be required to contribute to this improvement. Note that some OIs require a Driver that will not be fully operational by 2018. For example, OI 102118 (Delegated Responsibility for In-Trail Separation) will require Automatic Dependent Surveillance-Broadcast In (ADS-B In), which will not be widely available by 2018.

Account for Differences in Tower Facilities

As discussed in Section I, the primary impetus for the NextGen initiative is increasing the capacity and efficiency of the National Airspace System (NAS). Additional benefits include reduced environmental impact and noise. Although these benefits are relevant for all ATCTs, they are arguably most important for those facilities that have large volumes of commercial air traffic. Consequently, AIR presumed at this stage that NextGen mid-term Drivers will affect the work environment at ATCT facilities disproportionately, with the larger facilities that manage more dense and complex airspace—and hence the controllers working in those facilities—being affected most directly. AIR decided, where appropriate, to describe in the report which facility types (e.g., towers with complex airspace and dense traffic) will most likely be affected by the NextGen technologies, automation, and procedures.

Conceptualize the Future Job

AIR's research plan for developing the concept of the future job involved combining the NextGen information gathered with existing information about the current job and then using the resulting knowledge as the foundation for considering the impact of each Driver on the job. A particular concern at this stage was ensuring consensus among AIR researchers regarding whether and how the NextGen Drivers will affect both ATCT job responsibilities and the KSAOs required to perform the job.

To ensure this consensus, AIR researchers worked independently to complete a NextGen Driver by Activity matrix and a NextGen Driver by KSAOs matrix. These exercises required researchers to identify whether the implementation of each ATCT NextGen Driver will require adding to, deleting from, or modifying the language in the existing list of Tasks or the existing list of KSAOs. Second, researchers identified whether the NextGen Driver will change *how* an Activity, Sub-Activity, or Task will be conducted in 2018 or whether some characteristic or property will change. For example, researchers endeavored to identify whether and how the curriculum required to teach the Knowledges and Skills will change, whether the frequency with which an Ability might be required will change, or whether the relative importance of an Other Personal Characteristic will change. In each case, researchers were required to explain the rationale for their decision.

After the researchers completed their exercises, they conducted a meeting where they discussed their independent results to reach consensus. The individual rating exercises and consensus-building meetings resulted in a shared vision of what the job will be like in the mid-term. These results were then used to write this ATCT NextGen job description.

Present the Job Changes

A final concern surfaced regarding the presentation of the synthesized data. AIR researchers had originally planned to describe the future job by following the hierarchy used for describing the current ATCT job, which uses Activities, Sub-Activities, and Tasks to describe increasingly detailed work statements. However, it became clear during early drafts that the report would be repetitive and likely confusing if AIR explained how the job will change by Activity. For example, when describing ATCT Activity 1, *Establish Situation Awareness*, AIR would be required to list and describe Driver impacts that would need to be repeated in other job Activities (e.g., Activity 5, *Resolve Conflicts*). Consequently, the team decided to first present information regarding how the job is currently performed by job Activity followed by a description of the future job organized by NextGen Driver.

SUMMARY

NextGen is a complex initiative consisting of a conglomeration of interrelated concepts supporting a vision of increased NAS efficiency and throughput. However, as of November 2010, much of the documentation was still written in very high level terms. AIR's data collection, review, and synthesis processes described above were designed to operationalize those ideas. This process ultimately resulted in a list of NextGen Drivers that are likely to affect the job of ATCT line controllers in the mid-term, which were then evaluated to determine their impact on the job in 2018. However, before the Drivers and their impact on the job are described, an explanation of the organization of the FAA's current job information is presented in Section III to help readers familiarize themselves with the structure because it is also used to organize information about the job as it will exist in the NextGen mid-term.

Section III. Characteristics of Current ATCT Work and Workers

In this section of the report, the American Institutes for Research (AIR) describes the job of the Airport Traffic Control Tower (ATCT) line controller as it is performed today. Although readers of this report are likely to be familiar with the Air Traffic Control Specialist (ATCS) job, this section describes how the Federal Aviation Administration (FAA) organizes information about the job (i.e., the job analysis data). For example, information about the current job is organized in a hierarchy of increasingly detailed job responsibilities for which ATCSs are held accountable. Job analysis data also capture the characteristics of workers, including the Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs) required to perform the job well and the Tools and Equipment they use on the job (see Appendix A for all job analytic data). Understanding this organizational structure is critical for interpreting the NextGen 2018 job description (see Section V), because the description is organized in a similar fashion.

Current ATCT Job Characteristics

As previously stated, ATCS work that is currently performed in the ATCT environment is captured in hierarchical fashion. *Tasks* capture the most detailed aspects of the job and are grouped into higher level categories called *Sub-Activities*, which are further grouped into higher level categories called *Activities*. The following description of the current job is organized according to the 11 job Activities of ATCT controllers:

- Activity 1. Establish Situation Awareness
- Activity 2. Manage Communications
- Activity 3. Manage Flight Plan Data
- Activity 4. Manage Air Traffic
- Activity 5. Resolve Conflicts
- Activity 6. Manage Departing and Arriving Traffic
- Activity 7. Transfer of Radar Identification
- Activity 8. Assess Impact of Weather
- Activity 9. Manage Airspace and Movement Areas
- Activity 10. Manage Resources
- Activity 11. Respond to Emergencies and Unusual Situations

Each of these is described below.

Current ATCT Activity 1: Establish Situation Awareness

Activity 1 for ATCT line controllers includes the responsibility to achieve and maintain optimal situation awareness about events that either are taking place or will take place in their assigned area(s) of responsibility. Situation awareness begins as controllers accept responsibility for the control position, is maintained throughout their position assignment, and ends when they transfer their situation awareness to the relieving controller.

As ATCT line controllers begin working their assigned positions, they must relieve other controllers who are responsible for positions. During this period, relieving controllers must become thoroughly familiar with the current status of the position for which they will be responsible. These controllers access current and predicted operational information by observing status and information areas (SIAs), information contained on the Automated Terminal Information Service (ATIS), flight strips, and the alphanumerical data blocks of the surface surveillance systems, such as Airport Surface Detection Equipment-Model X (ASDE-X), Automated Radar Terminal System (ARTS), Common Automated Radar Terminal System (CARTS), or Standard Terminal Automation Replacement System (STARS). Once initial assessments have been made, controllers follow position relief checklists and use sign-in logs to complete the transfer of control. After assuming the position, controllers adjust the displays, volumes, and configurations, if necessary, to ensure that all are satisfactory and usable.

During their work period, controllers scan and monitor airport surveillance radar systems, flight strips, weather data, aircraft and vehicle positions, and equipment status monitors (alarms) to establish overall awareness of the operation. ATCT line controllers use all informational sources to identify patterns and irregularities, not only within their area of responsibility but also in adjacent areas, on the airport, and within the National Airspace System (NAS) as a whole.

The final step of maintaining situation awareness occurs as controllers are relieved from their positional duties. At this time, they pass all previously gathered information to the next controller. This protocol ensures that the next controller can also establish and maintain situation awareness and provide uninterrupted service to users. Both controllers must review information for completeness and accuracy as they incorporate it into their position relief briefing using recorded lines and position checklists. An acceptable exchange is completed as they fill out and sign the position logs.

The purpose of establishing and maintaining situation awareness is to give ATCT line controllers the means to operate their position while still being able to consistently manage operations and communicate effectively with others. This communication is covered in the next Activity.

Current ATCT Activity 2: Manage Communications

Controllers working in the ATCT environment control the movement of aircraft and vehicles—and ensure their separation—primarily by communicating clearances and other instructions to others. Information vital to the operation of the NAS is contained in this constant flow and exchange of information.

More specifically, ATCT line controllers are responsible for establishing, maintaining, transferring, and terminating two-way communications with operators as well as with other controllers and facilities. Controllers use radio frequencies and landlines that are part of the Rapid Deployment Voice Switch (RDVS) or the Enhanced Terminal Voice Switch (ETVS). After initial contact is established, controllers formulate clearances, instructions, and other messages by following a specific protocol of initiating, receiving, and verifying information for accuracy. If updates or amendments are needed, controllers ensure communications integrity by completing them in a timely manner.

Communications provide the key link to air traffic control system functionality. Each component of this system must be relayed in a complete, timely, and accurate manner to ensure the smooth, safe flow of air traffic and to allow other important information to be relayed. Responsibilities regarding flight plan data are covered in the next section.

Current ATCT Activity 3: Manage Flight Plan Data

ATCT line controllers are required to manage flights according to planned or requested routes of flight. They review individual flight plans and route clearances according to the specifications of NAS system architecture.

Controllers access flight plan data via the Flight Data Input/Output system (FDIO), which produces paper flight strips, or by the Electronic Flight Strip Transfer System (EFSTS). Once controllers receive the flight plan, they verify it for accuracy, amend it if necessary, enter it into the NAS system, and coordinate with other controllers if necessary.

They "follow" the progress of the flight, using these data from one control position to the other. Flight strips are marked according to published procedures and sequenced for other controllers. In some instances, departure messages are forwarded to Air Route Traffic Control Center (ARTCC) and Terminal Radar Approach Control (TRACON) controllers. After flights and flight plans become inactive, line controllers file them appropriately and drop them from the system when they are no longer necessary.

The flow of flight plan information keeps the system operating seamlessly and is also an important link to overall system effectiveness. Flight plan data replace the need for the information relayed via voice on landlines, thereby reducing radio frequency congestion and allowing controllers to concentrate on air traffic management, which is described in the following Activity.

Current ATCT Activity 4: Manage Air Traffic

ATCT line controllers are responsible for the safe, orderly, and expeditious movement of air traffic in a system wide environment. Each aircraft or flight trajectory is actively managed or controlled by line controllers using radar or nonradar separation and the "first come first served" method of air traffic service delivery. Emergency and safety of flight are considered a first priority of duty, however, and medical, rescue, and security operations are given priority status over normal operations.

ATCT line controllers must first establish aircraft and vehicle identification and position via an Out-The-Window (OTW) view, radar surveillance tools (Digital Bright Radar Indicator Tower Equipment [D-BRITE]/Remote ARTS Color Display [RACD]), and/or radio communications (RDVS/ ETVS). Once identification and position have been established, controllers then provide separation services, which is the primary method of preventing aircraft or vehicular accidents. More specifically, as controllers receive requests (via FDIO, EFSTS), evaluate traffic conditions (via ASDE or ASDE-X), and formulate control instructions based on known conditions (via SIAs), they approve, deny, or modify clearances that accommodate those requests. Clearances for departures, arrivals, and airspace transitions are also handled using established procedures that are outlined in Letters of Agreement (LOAs), Standard Operating Procedures (SOPs), and other directives. If an aircraft or surface vehicle deviates from the restrictions issued, controllers restate control instructions to the aircraft/vehicle to achieve the desired operational integrity. When necessary, controllers use the Rapid Deployment Voice Switch (RDVS) or Enhanced Terminal Voice Switch (ETVS) to request assistance from other controllers or facilities regarding questionable operations.

In addition to actively controlling the aircraft and vehicles in their area of responsibility, controllers respond to requests for route and flight plan deviations and provide severe weather avoidance (using the Low Level Wind Shear Alert System [LLWAS]), fuel optimization planning, and noise abatement to achieve optimized flow scenarios. They may provide additional services on a workload-permitting, case-by-case basis; the provision of these services is subject to the controller's discretion. For example, controllers may perform visual flight rule (VFR) flight following Tasks and amend flight plans. In addition, other information is formulated and issued in the form of advisories, which can be either general or specific, such as turbulence or bird activity notifications.

ATCT line controllers must give equal consideration and balance individual operational needs with the needs of an entire system. To do this effectively, they must have access to near real-time and accurate information, which allows them to remain flexible and effective in maximizing operations. As controllers provide and manage separation, they are also responsible for resolving conflicts within the system.

Current ATCT Activity 5: Resolve Conflicts

ATCT line controllers strive to actively prevent or mitigate conflicts to give system users the ability to react in a timely manner. Their goal is to prevent such occurrences, or to reduce the likelihood of such occurrences, as they manage air traffic. However, conflicts can occur between two aircraft, between an aircraft and the ground, and between aircraft and airspace and can occur when vehicles or aircraft fail to conform to instructions. These occurrences can be the result of errors in judgment by any of the many participants in the NAS or as a result of unforeseen circumstances, including severe weather, emergencies, or other unusual circumstances.

After a potential or actual conflict is identified, controllers determine its validity by using several different methods. The method used depends partly on the facility's unique configuration and the availability of tools and equipment. First, controllers may use an OTW view to scan airport movement areas or nearby airspace to determine whether a conflict exists. Second, controllers may listen to and verify readback from pilots regarding a potential or actual conflict via the RDVS/ETVS. Third, if available, controllers may monitor radar displays (e.g., D-BRITE/RACD/Tower Display Workstation [TDW]) for minimum safe altitude warning (MSAW) alerts, converging course information, and traffic conflictions. Finally, if an ATCT facility has ASDE-X, controllers may scan its display for potential surface area incursions. These steps for determining the validity of a conflict are not mutually exclusive.

Once the validity of the conflict has been verified, then controllers issue alerts or advisories via the RDVS/ETVS with a specific description (e.g., traffic, severe weather, unsafe conditions) using radio or landlines. After issuing advisories or safety alerts, controllers continue to monitor the aircraft as it maneuvers through movement areas or nearby airspace using the OTW view if visibility permits or via radar or surface surveillance (e.g., ASDE-X) displays. Controllers monitor movements to ensure that operators comply with issued instructions and that the situation has been resolved.

Conflict mitigation is the ATCT line controller's primary responsibility. All available system procedures and resources are focused on the recognition and mitigation of conflicts. Although conflicts cannot be eliminated entirely in complex systems like the NAS, they can be resolved on a local level and then archived and examined to be incorporated in the future advancement of system safety.

Current ATCT Activity 6: Manage Departing and Arriving Traffic

ATCT line controllers are responsible for coordinating departing and arriving traffic in a manner that maximizes efficiency without compromising safety. Balancing these two competing goals requires substantive planning and evaluation by ATCSs as they manage ground departure traffic and departing and arriving traffic at the runway, including takeoff terminations, missed approaches, and airborne departures, which may occur simultaneously.

In managing ground departing traffic, ATCT line controllers receive the flight strip and a request from the pilot for a pushback or taxi clearance, at which time they evaluate the predicted sequence to achieve an optimal flow. After an optimal sequence has been achieved and forwarded, line controllers issue taxi instructions to the pilot and record flight times and additional information on the flight strip. They observe the aircraft during taxi to ensure conformance and issue a frequency change to the pilot. The receiving controller in the tower receives the flight strip, ensures data accuracy, and verifies the aircraft's position and intentions before beginning to coordinate the takeoff segment of departure. This controller determines a departure interval, and then a departure release is obtained from the TRACON departure controller. If any additional information is required at this time, ATCT line controllers make the necessary amendments and issue updated information to the aircraft prior to departure.

Controllers scan the airport surface area and associated airspace to detect and mitigate any potential conflicts. Line up and wait or takeoff instructions are issued, and once the aircraft is airborne, controllers ensure that all transfer data are correct and correlate with the aircraft's position before a frequency change is made. If a takeoff is terminated, or an aircraft executes a go-around/missed approach, controllers quickly determine the need for alternative action and coordinate with the pilots and other controllers to forward appropriate information.

Controllers manage arrival traffic by observing or receiving notice of aircraft movement, position, and intentions from flight strips, landlines, or data blocks. They determine an appropriate course of action and predict if any conflicts exist prior to issuing landing clearances. Flight data information is logged on flight strips as necessary. During traffic management flow constraint periods or when responding to traffic management initiatives, line controllers determine the cause for the delay and communicate with pilots, traffic managers, and supervisors if necessary to determine impacts on the local operation or on the operation of the NAS as a whole. Information is logged on flight strips or on facility logs as aircraft are guided to adhere to constraints. FDIO, RDVS/ETVS radios and landlines, alphanumeric information contained on radar and surface surveillance displays, SIAs, and ATIS information are all used by ATCT line controllers as they perform the duties listed above. Weather and wind instruments are used as real-time determinates of operations, as are printed material contained in LOAs, SOPs, aircraft performance, and aeronautical charts.

The effective management of air traffic sequences during arrival, departure, and taxi-out phases of flight increases the efficiency and maximizes traffic throughput; this is important at all times and in all ATCT facilities. However, operational efficiency is especially important during periods of high volume when airspace is congested and when slowdowns in flow will have a pronounced, negative ripple effect throughout the NAS. Many features of the current-day ATCT line controller job allow system users to transition seamlessly during these phases of flight and effectively decrease those bottlenecks. The next Activity, the transfer of radar identification, describes how these transitions can occur invisibly to the pilot and thereby help with overall system effectiveness.

Current ATCT Activity 7: Transfer of Radar Identification

As aircraft leave airspace controlled by one controller and enter another controller's airspace, the controller responsible for that aircraft must effect a positive transfer of control. This requirement ensures information integrity and makes sure that each aircraft is actively controlled by a single controller at any given time.

ATCT line controllers perform the function of radar identification transfer by initiating and receiving point outs and handoffs from other controllers by using the alphanumeric displays and data blocks (e.g., D-BRITE, RACD, TDW). This alphanumeric capability provides controllers with the ability to silently communicate with other controllers. Flight progress strips are also used to track and record information. They receive requests, initiate automated and manual handoffs, and coordinate restrictions as necessary to transfer aircraft identification, position, and flight information from one airspace jurisdiction to another.

Infrequently, ATCT line controllers initiate a radar "handoff" or "point out" to gain approval for using another controller's airspace. During such instances, the controller receives the request, determines the need for coordination, ensures that conflicts have been resolved, and gives extra instructions to facilitate the operation. Appropriate coordination is made and information is logged on flight strips or entered on the data block by the line controller. In the rare instance when such requests cannot be approved, controllers use alternative methods of routing, declaring radar contact to indicate that they now accept responsibility for the aircraft and suppressing automated tracking information accordingly.

Controllers complete the transfer of aircraft in transit in the manner above to provide system users with a seamless transition along their route of flight. ATCT controllers continue to update and modify this information in a manner that allows less frequency congestion, more situation awareness, and better overall system performance. These procedures allow aircraft to transition in a more positive control environment. Another very important job Activity for controllers concerns the impact of weather on their operation. It is one of the most dynamic and challenging aspects of the job.

Current ATCT Activity 8: Assess Impact of Weather

Controllers must constantly observe weather conditions and evaluate whether and how they will affect airport operations. Responding to changing weather conditions is critical because it gives aircraft operators the ability to avoid potentially unsafe conditions during ground movement and critical phases of flight.

To respond appropriately to often rapidly changing weather conditions, controllers actively monitor and record information (e.g., movement and intensity of winds or storms) that is gathered by weather sensors. These data are typically displayed on automated surface observing systems (ASOSs), LLWAS, and Runway Visual Range (RVR) indicators. If the ATCT has a traffic management unit (TMU) position, a Traffic Management Advisor (TMA) and Integrated Terminal Weather Service (ITWS) could provide information on a desktop computer located in the tower. ITWS provides controllers with vital information from weather products such as the Terminal Doppler Weather Radar, Next Generation Weather Radar, and Airport Surveillance Radar-Model 9. Other inputs are received from the National Lightning Detection Network, National Weather Service (NWS) Rapid Update Cycle data, and the Meteorological Data Collection and Reporting System. Controllers must also solicit Pilot Weather Reports (PIREPs) or flight condition reports from pilots using the radios or landline relays whenever certain weather phenomena exist in or are forecast for their airspace. Among these phenomena are low visibility conditions at or less than five miles, thunderstorms, lightening, turbulence, icing, wind shear, and volcanic ash clouds.

As ATCT line controllers process weather information, they observe and receive notices of changes in operations. To receive the timeliest information, line controllers request braking action reports, flight conditions, and any changes that will have an impact on flight conditions. As they receive these reports, they relay information to other facilities and record information as required.

Weather is the single most important variable in air traffic control (ATC) system performance. Severe weather poses a very dangerous and ever-changing threat to the safety of flight. Early detection and mitigation by ATCT line controllers can greatly enhance the overall performance of the system and can also allow operators to perform their duties safely. ATCT line controllers must manage weather and mitigate its impact to safely manage their assigned airspace and movement areas (as described in Activity 9 below).

Current ATCT Activity 9: Manage Airspace and Movement Areas

Controllers direct aircraft or vehicular ground movement to maintain an effective flow of traffic on airport movement areas, or within their assigned airspace, or both. This coordination of traffic is important to ensure safety and maximize throughput.

ATCT line controllers manage their areas effectively by a process during which they grant temporary releases of their airspace or movement areas to other controllers. They first receive a request, observe and evaluate what effect the release will have on their operation, and then approve or disapprove the request and coordinate accordingly. Controllers also respond to changes in operational status by using SIAs or to changes in runway or taxiway conditions by first receiving the notification of changes via radio or landline, reviewing the situation, coordinating changes, and using visual aids or memory joggers to remember what to do. Once they have determined the appropriate action to take, they issue appropriate instructions and ensure that information is logged as required and the status information areas are updated. If ATCT line controllers need to transfer a position or sector for reconfiguration, they first advise the receiving controller to prepare by adjusting displays, configuring the position accordingly, and receiving a briefing. The receiving controller is then ready to accept responsibility and assume control.

Effective airspace and movement area management translates into overall system effectiveness. In addition, as controllers use the proper information and resources and make decisions quickly and efficiently, they more effectively manage their resources. This is an important job responsibility and it is covered in the next Activity.

Current ATCT Activity 10: Manage Resources

ATCT line controllers are responsible for ensuring that the levels of performance at their positions are maintained to a consistently high standard. To do this, they must identify and respond to threats to their personal and position resources, such as overload situations.

First and foremost, ATCT line controllers must evaluate whether they are fit for duty. If not, they must notify their supervisor, even if they can continue to work in a limited capacity. After they are on position, controllers must remain in constant communication with other controllers and supervisors to recognize when traffic reaches overload or saturation levels. These conditions limit the effectiveness of the work environment as a whole. During these high workload periods, voice frequencies can become dangerously congested and important safety rules can be violated as a result. Traffic managers and supervisors work with line controllers to implement an effective reduction strategy. Identifying and implementing these strategies are key Tasks of the controller's job.

Controllers must work as members of a highly functioning team. It is critical for controllers to maintain an overall tower awareness to provide assistance to fellow controllers if necessary. To achieve this awareness, controllers monitor nearby positions. Controllers must also remain proficient at the job by performing recurrent training exercises and adhering to safety standards requirements.

Because the flow of traffic varies, it is important for ATCT line controllers to achieve and maintain balance in their workload and in their work environment. This is done to manage and mitigate the potential errors that could occur during periods of heavy or complex traffic when controllers are stretched to the limit of their performance capabilities.

Current ATCT Activity 11: Respond to Emergencies and Unusual Situations

Although redundancy is built into the systems in use by today's ATCT controllers, there is still the potential for unplanned outages and loss of functionality or service degradation. Because the consequences of these types of failures include the potential for loss of life, ATCT line controllers must be able to continue to provide control services to aircraft that are in their airspace at all times even if a problem or an unexpected situation occurs.

Controllers must be well trained and proficient at executing several different contingency scenarios. First, controllers must detect failures and respond to alarms. They must then forward the notice of failure to supervisors and maintenance technicians and immediately implement appropriate backup procedure(s). If a data input failure is detected, controllers must receive and forward data manually. If there is a display failure, controllers must receive notice of and verify all computer actions during the transition from automated to manual stages. For the Host computer system (i.e., Host and Oceanic Computers System Replacement or HOCSR) failures, controllers must revert to ARTS stand-alone mode and manual writing of flight progress strip information. Controllers must also revert to nonradar procedures for sensor or tracking failures. Finally, if a communication failure is detected, controllers must switch to a backup radio or frequency, revert to light gun signal communications, receive a new frequency assignment, or select alternate means of information transmission.

Controllers are also responsible for responding to security threats through various methods including the delegation of airspace to different control authorities. Lost or stolen aircraft procedures involve line controllers working very closely and in tandem with law enforcement, military, or search and rescue authorities. Specific protocols are followed to ensure that safety is not compromised during these emergency evolutions.

A defining characteristic of emergency and other unusual situations is their imminent nature. Control personnel must act accordingly to immediately find solutions to these occurrences. These situations can also be unique, leaving controllers to formulate original and creative solutions while still adhering to the rules of safety and the limitations of the operators.

CURRENT KSAOS

In addition to describing the characteristics of the work of ATCT controllers, a traditional job analysis identifies the characteristics required of workers to perform the job well. As previously stated, the characteristics required of ATCT controllers to perform the job are described in terms of KSAOs. A *Knowledge* is body of factual, technical, or procedural information individuals use to perform a job. A *Skill* is the capability, developed through training or practice, to perform job Tasks. An *Ability* is a general human trait individuals possess that gives them the capacity to carry out physical and mental acts required by a job's Tasks. An *Other Personal Characteristic* is an attitude, a preference, an opinion, or a personality trait that influences how well individuals can carry out job Tasks.

Information regarding the KSAOs required for a job can be used for many personnel-related purposes. More specifically, Knowledges and Skills must be taught before they can do the job. This training can take place either before individuals enter a job or as part of on-the-job training. Consequently, they are the foundation for training programs. Abilities and Other Personal Characteristics are characteristics that can be known about individuals before they are trained to perform a job and consequently can be the basis for pre-employment selection tests. The following KSAOs required to perform the current job of the ATCSs were recently updated by AIR, who worked closely with technical subject matter experts (SMEs).

Current Knowledges

The current knowledge requirements for ATCSs working in the ATCT environment are substantive. These requirements are captured in a two-level taxonomy consisting of 27 high-level Knowledge categories, which are further described in terms of many more specific Knowledge subcategories. Note that these are topics only; they are not designed to represent an actual training curriculum. The complete list of current Knowledge categories and subcategories can be found in Appendix A. As a convenience, the Knowledge categories are listed in Table 4.[4]

[4] Note that the Knowledge categories required for ATCSs are the same for all three FAA facility types (i.e., ATCT, TRACON, and ARTCC). However, the subcategories vary somewhat across facility type.

Table 4. Current ATCS Knowledge Categories

No.	Knowledge Category
K1	Knowledge of Federal Aviation Administration
K2	Knowledge of General Air Traffic Structure
K3	Knowledge of Professional ATCS Requirements
K4	Knowledge of Aviation Science
K5	Knowledge of Human Factors in Aviation
K6	Knowledge of Geography
K7	Knowledge of Navigation
K8	Knowledge of Basic Weather Concepts
K9	Knowledge of Surveillance Systems Architecture
K10	Knowledge of Communication Systems Architecture
K11	Knowledge of Aircraft Characteristics and Features
K12	Knowledge of Aircraft Operations
K13	Knowledge of General Airport Characteristics
K14	Knowledge of Aeronautical Publications and ATC Procedures and Directives
K15	Knowledge of Airspace
K16	Knowledge of Flight Plan Data
K17	Knowledge of Air Traffic Management Procedures
K18	Knowledge of Facility-Specific Characteristics
K19	Knowledge of Facility Tools and Equipment
K20	Knowledge of ATC Communication Processes
K21	Knowledge of the Concept of Separation
K22	Knowledge of Providing ATC Services
K23	Knowledge of Additional ATC Services
K24	Knowledge of Approach / Arrival Operations
K25	Knowledge of Departure Operations
K26	Knowledge of Special Operations
K27	Knowledge of Emergency and Unusual Situations

Current Skills

ATCT controllers must not only possess factual information about the work but also be skilled in doing the work. That is, it is not enough to simply know the rules of separation; it is critical that controllers also be skilled in applying the rules in the context of separating air craft. The 58 Skills required of ATCSs are captured in 12 categories, which are provided in Table 5. The list of Skills with their definitions can be found in Appendix A.[5]

[5] Note that the Skills required for ATCSs are the same for all three FAA facility types (i.e., ATCT, TRACON, and ARTCC).

Table 5. Current ATCS Skills

No.	Skill Category	Skill Label
Sk1	Communication	Oral Communication
Sk2	Communication	Written Communication
Sk3	Communication	Active Listening
Sk4	Time Sharing	Task Switching
Sk5	Time Sharing	Attention Switching
Sk6	Time Sharing	Interruption Recovery
Sk7	Information Management	Information Location
Sk8	Information Management	Decoding
Sk9	Information Management	Encoding
Sk10	Information Management	Reading Comprehension
Sk11	Information Management	Information Filtering
Sk12	Information Management	Rule Application
Sk13	Math and Science	Basic Math Operations
Sk14	Math and Science	Principle Application
Sk15	Task Management	High Workload Recognition
Sk16	Task Management	Performance Monitoring
Sk17	Task Management	Task Prioritization
Sk18	Task Management	Task Timing
Sk19	Task Management	Composure Maintenance
Sk20	Teamwork	Position Relief Briefings
Sk21	Teamwork	Shared Responsibility Position Teamwork
Sk22	Teamwork	Inter-position Teamwork
Sk23	Teamwork	Coordination
Sk24	Teamwork	Cue Recognition/Comprehension
Sk25	Situation Awareness	Strategic Scanning
Sk26	Situation Awareness	Operational Comprehension
Sk27	Situation Awareness	Object Projection
Sk28	Situation Awareness	Facility Monitoring
Sk29	Air Traffic Management	Flight Strip Utilization
Sk30	Air Traffic Management	Spatial Information Application
Sk31	Air Traffic Management	Object Identification and Position Establishment
Sk32	Air Traffic Management	Separation Strategy Development
Sk33	Air Traffic Management	Separation Strategy Selection
Sk34	Air Traffic Management	Separation Strategy Implementation
Sk35	Air Traffic Management	Sequencing Strategy Development
Sk36	Air Traffic Management	Sequencing Strategy Selection
Sk37	Air Traffic Management	Sequencing Strategy Implementation
Sk38	Air Traffic Management	Spacing Strategy Development
Sk39	Air Traffic Management	Spacing Strategy Selection
Sk40	Air Traffic Management	Spacing Strategy Implementation

No.	Skill Category	Skill Label
Sk41	Conflicts	Conflict Identification
Sk42	Conflicts	Conflict Resolution Strategy Development
Sk43	Conflicts	Conflict Resolution Strategy Selection
Sk44	Conflicts	Conflict Resolution Strategy Implementation
Sk45	Conflicts	Advisories/Alerts Utilization
Sk46	Weather	Weather Data Interpretation
Sk47	Weather	Current Weather Assessment
Sk48	Weather	Weather Projection
Sk49	Weather	Weather Strategy Development
Sk50	Weather	Weather Strategy Selection
Sk51	Weather	Weather Strategy Implementation
Sk52	Tools and Equipment	Tool & Equipment Operation
Sk53	Tools and Equipment	Tool & Equipment Status Recognition
Sk54	Tools and Equipment	Tool & Equipment Degradation/Failure Response
Sk55	Emergencies	Emergency Recognition
Sk56	Emergencies	Emergency Response Development
Sk57	Emergencies	Emergency Response Selection
Sk58	Emergencies	Emergency Response Implementation

Current Abilities

Although the Knowledges and Skills required of ATCT controllers must be taught, some required characteristics are more innate and more immutable. ATCSs must possess 36 Abilities to perform well in the current ATCT environment. These are provided in Table 6. The list of Abilities, and their definitions, can be found in Appendix A.[6]

Table 6. Current ATCS Abilities

No.	Ability Label
Ab1	Oral Expression
Ab2	Written Expression
Ab3	Written Comprehension
Ab4	Verbal Reasoning
Ab5	Oral Comprehension
Ab6	Hearing Sensitivity
Ab7	Auditory Attention
Ab8	Visual Color Discrimination
Ab9	Vision
Ab10	Movement Detection
Ab11	Perceptual Speed and Accuracy

[6] Note that the Abilities required for ATCSs are the same for all three FAA facility types (i.e., ATCT, TRACON, and ARTCC).

No.	Ability Label
Ab12	Number Facility
Ab13	Mathematical Reasoning
Ab14	Working Memory
Ab15	Long-Term Memory
Ab16	Fluency Of Ideas
Ab17	Problem Sensitivity
Ab18	Deductive Reasoning
Ab19	Inductive Reasoning
Ab20	Creativity
Ab21	Sustained Attention
Ab22	Concentration
Ab23	Attention To Detail
Ab24	Flexibility
Ab25	Composure
Ab26	Chunking
Ab27	Mechanical Reasoning
Ab28	Learning
Ab29	Visuospatial Reasoning
Ab30	Visualization
Ab31	Two-Dimensional Mental Rotation
Ab32	Three-Dimensional Mental Rotation
Ab33	Recall From Interruption
Ab34	Time Sharing
Ab35	Wrist/Finger Speed
Ab36	Control Precision

Current Other Personal Characteristics

Finally, Other Personal Characteristics of controllers also contribute to their performance of the current job. Table 7 lists the 14 Other Personal Characteristics required in the current ATCT environment. The list of Other Personal Characteristics, and their definitions, can be found in Appendix A.[7]

Table 7. Current ATCS Other Personal Characteristics

No.	Other Personal Characteristics Label
O1	Professionalism
O2	Motivation
O3	Career Orientation
O4	Conscientiousness
O5	Integrity

[7] Note that the Other Personal Characteristics required for all ATCS are the same for all three FAA facility types (i.e., ATCT, TRACON, and ARTCC).

O6	Cooperativeness
O7	Interpersonal Tolerance
O8	Self-Confidence
O9	Taking Charge
O10	Self-Awareness
O11	Interest in High Intensity Work Situations
O12	Risk Tolerance
O13	Realistic Orientation
O14	Internal Locus of Control

Section IV. Drivers of the NextGen ATCT Work Environment

INTRODUCTION

By 2018, new technology, automation, and procedures will change the environment in which Airport Traffic Control Tower (ATCT) controllers perform their job. Some of these Drivers represent the introduction of new concepts. Others represent an expansion of currently available technology, upgrades to current systems, or new ways of doing things. Some stand alone and are not dependent on others; some are subsets of—or otherwise overlap with—others. In this section, AIR identifies and describes the Next Generation Air Transportation System (NextGen) technologies, automation, and procedures presumed to be in place by 2018 that will most directly influence the job of ATCT line controllers. These Drivers inform and support the job and worker changes identified in Section V of this report.

It should be noted that although the importance of these concepts in the mid-term environment was substantiated by the multiple sources of information gathered for this research, in some cases, little information exists regarding specifically what part of the technology, automation, or procedure will be implemented by 2018 or at what facilities. In other cases, the information that is available lacks detail or is conflicting. In these situations, AIR took all available information into account and endeavored to make the best decision possible regarding what Drivers will be in place by 2018. AIR was compelled—*by necessity*—to make such a decision so that the impact on the job of the Air Traffic Control Specialist (ATCS) could be determined and described in this report.

For example, research conducted early in the project by AIR suggested that Staffed NextGen Towers (SNTs) may have an important influence on the NextGen mid-term work environment for ATCT line controllers. However, later analyses indicated that SNTs will likely not be operational in a meaningful way by 2018; consequently, the concept was eliminated from this report. Further, AIR initially identified Integrated Departure/Arrival Capability (IDAC) as an automation system in ATCT that might affect the ATCT line controller job in the mid-term. However, currently little information exists on IDAC that warrants discussion as part of the ATCT list of Drivers.

Although AIR had enough information about these eight Drivers to consider their impact on the job, in some situations, there was so little information that AIR opted not to include the technology, automation, or procedure as a Driver. For example, research conducted early in the project suggested that SWIM may have an important influence on the NextGen mid-term work environment for the ATCT line controller. However, subsequent research did not result in enough evidence that SWIM would be operational by 2018 to warrant its inclusion as a primary NextGen Driver for ATCT. Similarly, it seems likely that Unmanned Aircraft Systems (UASs) will be an important part of the landscape for at least some controllers by 2018, but it is too early to estimate the impact on the job.

Satellites as Foundational Technology

After considering all the available data, AIR identified eight specific NextGen Drivers that are presumed to influence the job of the ATCT controller by 2018. For simplicity and convenience, the Drivers shown in Table 8 in are presented in alphabetical order:

Table 8. Drivers Influencing the NextGen Mid-Term ATCT Work Environment

No.	ATCT NextGen Driver
1	4-Dimensional Weather Data Cube
2	Airport Surface Detection Equipment-Model X
3	Automatic Dependent Surveillance-Broadcast
4	Data Communications
5	Integrated Arrival, Departure, and Surface
6	Terminal Automation Modernization and Replacement
7	Tower Flight Data Manager
8	Wake Turbulence Mitigation for Departures

However, before a discussion regarding these eight Drivers, it must be stated that NextGen—and consequently many of these Drivers—are only possible due to the foundational nature of satellite technology and related components that enhance those data. More specifically, satellite-based positioning, navigation, and timing services provide aviation industry stakeholders with highly accurate information regarding the location of aircraft and other objects, such as aids to navigation and ground vehicles in four-dimensional space. Although widely available to the public, the availability, accuracy, and integrity of the Global Positioning System (GPS) data are further enhanced in aviation through the use of supplemental systems such as the Wide Area Augmentation System (WAAS) and the Ground Based Augmentation System (GBAS).

The increases in accuracy, reliability, and integrity of these data, when compared with traditional radar surveillance and ground-based navigation services, have a profound impact on what is possible in the National Airspace System (NAS). For example, GPS technology is not influenced by weather in the same way that ground-based technologies are. Thus, operations can continue in weather that once would have grounded aircraft, which improves efficiency and throughput. Properly equipped aircraft are no longer required to fly from one ground-based navigation aid to the other. Aircraft can now navigate between predefined points in space. This allows more direct and flexible routes to be flown, thus increasing efficiency in the NAS and savings for the user. Having highly accurate data regarding aircraft allows the Federal Aviation Administration (FAA) to build—and for aircraft to fly—highly prescribed performance-based routes that improve efficiency and reduce fuel burn. Finally, knowledge of accurate aircraft location improves situation awareness for controllers, thus reducing uncertainty. These reductions in uncertainty could theoretically—and may ultimately—result in reductions in separation minima between aircraft, which will help NextGen achieve the ultimate goal of increased capacity and efficiency in the NAS. Note that aircraft in the terminal environment are already close together and commercial aircraft are limited in their ability to maneuver. Consequently, any reduction is likely to be small.

In sum, satellite-based surveillance and navigation support and enable many specific technologies, automation, and procedures and will in turn assist the ATCS to work more efficiently in the NextGen mid-term. More specifically, this technology supports and enables the eight NextGen Drivers identified above, which are most likely to affect the ATCT work environment by NextGen 2018 and are of particular interest for the purpose of building a description of the 2018 ATCT job.

DRIVER 1: 4-DIMENSIONAL WEATHER DATA CUBE

The 4-Dimensional Weather Data Cube (4-D Wx Data Cube) is a representation of "all unclassified weather information used directly and indirectly for making aviation decisions." Although the exact sources of information available in 4-D Wx Data Cube are still unknown, they are projected to include human-generated observations, ground-based and aircraft sensors, models, climatological data, algorithms, and human-produced forecasts from public and private sources. Four dimensions will be used to describe and present weather information: altitude, latitude, longitude, and time.

4-D Wx Data Cube will merge weather data and provide NAS users with an FAA-authorized common weather picture to support effective and coordinated air traffic management decisions. More specifically, 4-D Wx Data Cube will organize the cataloged weather observations and perform any necessary unit conversions. It will then select observations to be included in the common weather picture and perform quality processing by evaluating observations for reasonability. Finally, it will calculate certain values from direct observations, such as 2-minute wind speeds and 10-minute average runway visual range. Users will have the option to view all the underlying raw weather data or to view a synthesis of all weather data in the form of a common weather picture on the Single Authoritative Source (4-D Wx SAS) system.

These data will be accessible in the form of text, graphic, or machine-readable products by modifying the information from 4-D Wx SAS that will be available in a virtual database. Note that 4-D Wx Data Cube will contain weather information from a number of sources that vary in availability, statistical reliability, consistency, refresh rates, and resolution. Necessarily then, the rate at which 4-D Wx SAS information is refreshed will depend on the type of weather information and the Air Traffic Control (ATC) facility where 4-D Wx SAS will be housed. For example, updates on convective weather forecasts will be quicker than those for space weather. It is currently unknown on which automation platform in ATCT this 4-D Wx SAS information will exist.

Weather alerts, advisories, and warnings will be created by decision support tools (DSTs) outside the 4-D Wx SAS that will determine whether its forecast exceeds the user-determined thresholds. These DSTs are still in the planning phase while research is being conducted to determine which tasks should be allocated to Air Navigation Service Providers (ANSPs), flight operators, and automation. DSTs are expected to be part of the final phase of implementation and therefore are not likely to be part of the mid-term.

The benefits of 4-D Wx Data Cube and the 4-D Wx SAS are that they will provide line controllers and other NAS users with access to the same weather information provided by a common weather picture. This common weather picture will enhance the situation awareness of line controllers by providing them with the necessary information to facilitate decision making and reduce the negative impact of weather on the safety, capacity, and efficiency of air traffic. Other general benefits of 4-D Wx Data Cube include providing information for other DSTs for agencies and entities beyond FAA, providing a way for controllers to access critical National Weather Service (NWS) products beyond aviation, and linking current National Oceanic and Atmospheric Administration (NOAA) systems with 4-D Wx Data Cube.

The 4-D Wx Data Cube implementation is proposed to be completed in three phases: Initial Operating Capability (IOC), Intermediate Capability (IC), and Full Operational Capability (FOC). IOC is projected to provide information on parameters relevant to air traffic management, including turbulence, icing, convection, ceiling, visibility, and wake vortex displacement. Four-dimensional gridded data are already available for all these parameters except wake vortex. IOC is scheduled to be complete by 2012. Next, IC is projected to be implemented by 2016 and will enable higher resolution and more accurate weather information that is compatible with other NextGen infrastructures. Finally, FOC will include decision-making functionalities such as statistical reliability of weather data and probabilistic forecasts, which are projected to be available in mid-term on a limited basis but fully operational by 2020. Based on this information, it is anticipated that IOC and IC will be implemented by 2018 and will influence the job of mid-term ATCT line controllers. However, given that the completion date for FOC is 2020 and given that the integration of weather information into DSTs (i.e., finding the best fit between weather information and the DST to host that information) will be an iterative process and may take longer than expected, AIR is assuming that FOC will not significantly influence the job of controllers in 2018.

Driver 2: Airport Surface Detection Equipment-Model X

Airport Surface Detection Equipment-Model X (ASDE-X) is a surveillance system that integrates data from multiple sources, including surface surveillance radar located at the ATCT and at remote stations, multilateration sensors, Automatic Dependent Surveillance-Broadcast (ADS-B) sensors, the terminal automation system, and aircraft transponders. Synthesis of these data sources allows aircraft and vehicle positions to be shown on a color display superimposed over a map of the airport runways, taxiways, and approach corridors. The system includes collision safety logic processing, which detects and alerts controllers to potential collision situations on the runways.

ASDE-X provides several benefits to ATCT controllers, especially during night, bad weather, and low visibility conditions. These benefits include, but are not limited to the following:

- There will be fuller coverage of aircraft and vehicles on runways and taxiways. Being able to locate aircraft and vehicles equipped with an ADS-B transponder on or near the airport surface movement areas will enhance controllers' situation awareness.
- Safety will be increased by providing visual and audio alerts to controllers regarding potential runway conflicts.

By 2018, all Core 30 airports (see Appendix D) will be equipped with ASDE-X. It is not anticipated that a significant number of additional non-Core 30 airports will be equipped with

ASDE-X by 2018 because the system is costly and brings the most benefit to the larger, more complex airports.[8]

Driver 3: Automatic Dependent Surveillance-Broadcast

Automatic Dependent Surveillance Broadcast is a surveillance technology on board aircraft that transmits the aircraft's GPS-identified position to ground stations, which in turn broadcast the information to controller screens and cockpit displays. ADS-B consists of two components: ADS-B In and ADS-B Out. ADS-B In consists of equipage and services that allow aircraft to receive traffic and weather broadcast services information in the cockpit and is expected to help improve situation awareness. ADS-B Out refers to the broadcast of aircraft location information via ADS-B transmissions from equipment on board the aircraft to ADS-B ground stations and to other aircraft if they are appropriately equipped. It is projected to provide more up-to-date and more precise information regarding aircraft position (and theoretically could provide many other parameters) to controllers than is currently available through traditional radar. This increase in data accuracy will allow a reduction in separation minima and radar like separation in areas with no, little, or unreliable radar coverage. Consequently, this supports increases in the capacity of the NAS.

Controllers are expected to realize important benefits from ADS-B In, including shared situation awareness and the ability to assign self-separation to specific pairs of aircraft. Controllers will also realize benefits from ADS-B Out.

- ADS-B Out will provide controllers with more up-to-date and precise information regarding an aircraft's position, thus reducing uncertainty.
- ADS-B Out will provide enhanced visibility of aircraft located in remote or nonradar areas (e.g., Gulf of Mexico, parts of Alaska) to line controllers, thus allowing radar like separation of equipped aircraft.
- ADS-B Out is projected to be more reliable compared to radar systems.

Currently, the implementation timeline for ADS-B In is unknown. An Aviation Rulemaking Committee has been established but has not yet made a formal decision regarding an implementation deadline for aircraft equipage. The FAA's Operational Improvements (OIs) refer to ADS-B but not to the specific components of ADS-B-In and ADS-B Out. Given the dearth of available information, AIR assumes that ADS-B In will not have a substantial impact on the work performed by ATCT line controllers in 2018. Although ADS-B In has not been mandated, federal regulations require that ADS-B Out be installed on aircraft flying in the busiest airspace by 2020. Approximately 60% of commercial aircraft will be equipped with ADS-B Out by 2018 because the cost and technology challenges, such as changing equipage standards, will prevent a portion of certificate holders from adopting ADS-B early.

[8] By 2018, many additional ATCTs will have displays with data tags of properly equipped aircraft and vehicles. However, these displays will be populated with data from ADS-B Out and as such will not include the same functionalities as displays populated with ASDE-X data.

DRIVER 4: DATA COMMUNICATIONS

Data Communications (Data Comm) refers to a digital communication system that will provide controllers with the capability to communicate with pilots using a computer-based data entry system—assuming that aircraft are properly equipped and the message meets certain operational constraints. Data Comm is a large system comprising multiple ground and airborne subsystems that interact with each other to exchange messages between controllers and pilots.

Data Comm will result in a number of benefits. First, Data Comm will reduce the number of radio transmissions, which will reduce the congestion on radio frequencies that is so prevalent near high-density airports. Evidence that this benefit will be realized is supported by human-in-the-loop (HITL) experiments conducted at the William J. Hughes Technical Center, which showed that dissemination of taxi-out instructions via Data Comm reduced voice frequency use on the ground control frequency by 12% when 75% of the departure aircraft were equipped with Data Comm. Second, Data Comm will allow controllers to work more efficiently. For example, controllers will be able to send a single message to multiple aircraft simultaneously if the aircraft are properly equipped. Data Comm can be used to transmit longer, more complex messages than could be adequately communicated in a voice communication. Third, Data Comm will reduce hearback/readback errors. Finally, Data Comm supports shared situation awareness. That is, Data Comm messages are typed into the system, which will allow control instructions to be reflected in air traffic management systems.

Latency challenges are associated with Data Comm messaging, and the length of the latency is variable. Although the exact delay in Data Comm messages is unknown, for Data Comm to meet requirements to be implemented in Segment One, it must meet a 95th percentile latency requirement of 8 seconds or less for time-critical clearance messages and of 30 seconds or less for all other data messages. In addition, delays will likely be associated with controllers and pilots recognizing the receipt of Data Comm messages and crafting and sending a response. Due to these latency challenges, it is anticipated that radio transmissions will continue to be used for time-sensitive messages and that Data Comm messaging will be reserved for issues that are less time sensitive. Despite this challenge, which will persist into 2018, the benefits of data communications are significant.

Data Comm is proposed to be implemented in three phases: Segment One, 2012 through 2017; Segment Two, 2017 through 2022; and Segment Three, 2022 and beyond. Consequently, the ATCT line controllers' job in the mid-term will be affected primarily by Segment One and marginally by Segment Two. These two segments are presented in detail below:

- *Segment One (2012–2017)*: Segment One functionalities will enable ATCT line controllers to meet many of their data communications requirements. For example, in Segment One, Data Comm will allow controllers to compose messages, will provide predefined messages for controllers, and will allow these messages to be transmitted. In this segment, the FAA will add the ability to broadcast messages in mass format. Further, in terms of ATCT-specific requirements, Data Comm will be used for transmitting Automated Terminal Information Service (ATIS) messages and other functions. For example, Data Comm will process requests for current ATIS and enable NAS users to manage the contents of the ATIS.

- *Segment Two (2017–2022)*: Segment Two will extend the use of Data Comm to other types of messages, such as aircraft-generated information necessary for conformance management of future trajectories and hazardous weather information sent to aircraft. It may further support the expansion of NextGen Trajectory Based Operations (TBOs) into other portions of the airspace. To accomplish this, Data Comm will acquire aircraft-generated trajectory information from ADS-B equipped aircraft and disseminate aircraft-generated contract data to NAS users.

Given the time frames specified for each segment and what is known to date about Data Comm research, AIR anticipates that Segment One will be operational by 2018 and thus will influence the ATCS job in the mid-term. However, the expectation is that Segment Two will not influence the job of 2018 controllers for two reasons. First, it is unlikely that Segment Two will be initiated by 2017. This is keeping with the more general notion that NextGen is—for a number of reasons—not likely to proceed according to schedule. Finally, even if Segment Two is initiated in 2017, it is unlikely that all the stages of the lifecycle management process (i.e., mission analysis, investment analysis, testing, and implementation) for Segment Two functionalities will be complete by 2018.

Driver 5: Integrated Arrival, Departure, and Surface

Integrated Arrival, Departure, and Surface (IADS) is a concept that supports improved integration of arrivals, departures, and surface operations through the improvement of interactions among the systems, services, and personnel responsible for these traffic flows. This integration is achieved by electronic sharing of all critical information among all NAS users and through the integration of arrival, departures, and taxiway scheduling. More specifically, IADS will enable ATCT line controllers to better plan for and execute departures in congested terminal environments by taking advantage of many of the NextGen enhancements planned for communications, navigation, surveillance, automation, weather, and procedures. It will integrate information on predicted demand, current capacity, and current and future conditions, including weather and runway configurations, route of flight, and user preferences, to allow more efficient movement of aircraft from the movement area spot to the Top of Ascent (TOA). Further, IADS will provide ATCSs with suggestions for routing and taxi routing from automation (e.g., Collaborative Departure Queue Management, CDQM DST). Because this concept is still evolving, the actual DSTs have not been designated but are likely to be part of other NextGen tools and equipment such as the Tower Flight Data Manager (TFDM), which is described in a later section of this report.

The major outcomes of the IADS concept are shared situation awareness and increased collaboration among line controllers, traffic flow management, and other NAS users. As a result, IADS is projected to present several key benefits as reported in the IADS Concept of Operations document:

- *Increased efficiency*: IADS may lead to improved departure planning resulting in more efficient trade and fill slots in overhead traffic streams. IADS may also increase throughput at the Core 30 airports (see Appendix D) and improve airport configuration planning.

- *Increased predictability*: IADS may help achieve improved surface sequencing, better on-time performance from airlines, and more up-to-date departure and arrival (predicted and actual) times.
- *Increased capacity:* IADS will allow more efficient use of all arrival, departure, and surface areas.
- *Enhanced safety*: The IADS operations are also likely to result in fewer distractions for controllers and pilots because of reductions in arrival vectoring. Surface conformance monitoring tools (e.g., ASDE-X) will provide deviation alerts to controllers.

The IADS concept is currently in the early stages of development. The IADS Concept of Operations was released in August 2010 in draft form. Although the concept is proposed to be operational by 2018, the specifics of how it will be implemented are not yet available. For example, it is unknown what DSTs exist or will be developed to support the IADS concept. However, certain tools that will enable the IADS concept, such as ASDE-X, CDQM, Data Comm, 4-D Wx SAS, and Area Navigation/Required Navigation Performance (RNAV/RNP), will be in place by 2018 at medium- to high-density airports. Consequently, it is presumed that the IADS concept will also be operational by 2018 at medium- to high-density airports.

Driver 6: Terminal Automation Modernization and Replacement, Phase 3

Terminal Automation Modernization and Replacement (TAMR) is a program to modernize the primary radar systems that controllers use at Terminal Radar Approach Control (TRACON) and associated ATCT facilities. The purpose of the TAMR program is to replace the aging systems that currently exist in the nation’s ATCTs and TRACONs and make them compatible with NextGen technology. The TAMR program is evolutionary and is being implemented in three phases. In TAMR Phase 1, Standard Terminal Automation Replacement System (STARS) was deployed to TRACON sites and associated ATCTs and was operational at 43 facilities by 2006. In TAMR Phase 2, STARS is projected to replace automation systems (specifically, Automated Radar Terminal System or ARTS IIE) at five additional TRACONs and modernize ARTS IIE at four large TRACONs. In TAMR Phase 3 (or TAMR 3), automation systems at the remaining 106 sites will be either replaced or upgraded to include a mix of replacement and upgrade of the old Common Automated Radar Terminal System (CARTS).

The major goal of TAMR 3 is to build a system that is compatible with other NextGen systems (e.g., ADS-B, ASDE-X, weather products) and that can be easily upgraded or used to replace older systems. In addition, TAMR 3 will incorporate some of the functionalities of TFDM and add other functionalities (e.g., weather products) without drastically changing the original platform. Specifically, TAMR 3 may incorporate Data Comm systems and the Electronic Flight Strip Transfer System (EFSTS) that transmits flight information between the ATCT and the TRACON. The consolidation of various functionalities will reduce the amount of time controllers spend seeking information, which should assist them in processing more traffic in a shorter period of time. The benefits of TAMR 3 can further be understood through functionalities of TFDM (described in the next section).

Currently, little information exists regarding the TAMR 3 completion timeline. However, the FAA's current automation road map shows that TAMR 3 will be initiated in mid-2013 and will be completed by the end of 2019. In addition, the FAA has traditionally rolled out innovations to facilities by most pressing need, depending on variables such as air traffic volume, current automation status, and resources available. Consequently, for purposes of building the ATCT job description, AIR assumes that TAMR 3 modernization will be complete in at least 50% of the busiest TRACONs and their associated ATCTs by 2018.

DRIVER 7: TOWER FLIGHT DATA MANAGER

Tower Flight Data Manager is a new terminal automation platform that consolidates information from multiple ATCT systems and subsystems and presents information to controllers on a new workstation display(s). Currently, the FAA is prototyping four TFDM functionalities or modules: Tower Information Display System (TIDS—surveillance display with data feed from ASDE-X); Flight Data Manager (FDM—electronic flight strip organizer); Weather; and DSTs. These modules will be built into either a single large display or several separate displays.

Six main DSTs are part of the DST module of the TFDM platform. The DSTs and their benefits are shown below:

- *Taxi route generation:* This TFDM DST will generate taxi routes and present them to controllers as options. The routes generated by the DSTs will provide efficient route options based on airport information, arrival/departure fixes, advanced surveillance information, and other airport information that will help controllers with coordination of taxi routes. As a result, this functionality (i.e., taxi route generation) will prevent gridlock, reduce taxi time, and reduce fuel burn. Additionally, this tool is projected to monitor conformance to taxi routing, which will assist controllers in resolving potential runway incursions.
- *Sequencing and scheduling*: This DST will provide better management of pushback and takeoff times, optimize sequencing of aircraft weight classes based on aircraft readiness (i.e., capability of aircraft to make it to the runway for departure), and provide options to controllers to modify the sequence if needed.
- *Runway assignment*: Instead of controllers selecting the runway, this DST will select runways based on airport and flight information and provide options to controllers to assign aircraft to runways and balance taxi time and departure queue length. Efficient arrival/departure balancing will in turn maximize throughput.
- *Departure routing*: This DST will aid controllers in proactively ensuring that the route is clear of traffic and weather constraints during departure as well as developing and coordinating reroutes as needed.
- *Airport configuration*: This DST will help controllers facilitate changes to airport configuration and proactively anticipate the need to reroute traffic. More specifically, this DST will facilitate better prediction of traffic and provide controllers with a much longer planning time to make necessary changes, such as modifying flight plans and rerouting ground traffic.
- *Data exchange*: This DST will enhance operational efficiency for ATCT controllers by supporting the exchange of information among air carriers, ATCT, TRACON, and Air Route Traffic Control Center (ARTCC) facilities. Currently, data exchange is

being built on the System Wide Information Management (SWIM) network. Note that data exchange is a capability that supports DSTs, but is not a DST in itself.

CDQM is a critical concept that will enable many of the aforementioned functionalities. Specifically, CDQM will enable taxi route generation, sequencing and scheduling, runway assignment, and departure routing by meeting departure demands to runway capacity. CDQM will restrict departure delays to the gate rather than allow aircraft to push back into taxi delays. Reducing taxi delays will further reduce fuel burn, emissions, operating costs, and traffic congestion on the airport movement area. Sharing of CDQM data among controllers, air traffic management (ATM) personnel, and flight operators is also predicted to increase common situation awareness. Specifically, for ATCT line controllers, CDQM data will provide flexibility in the rearrangement of initial allocations of flights in the departure queue.

TFDM will exist in a meaningful way in 2018. The FAA's current automation road map shows that TFDM Phases 1 and 2 will be completed by mid-term 2018. In TFDM Phase 1, some functionalities (e.g., taxi route generation, sequencing and scheduling) and DSTs (e.g., CDQM) will be complete; in Phase 2, TFDM will include the remaining functionalities with some advanced DSTs. The FAA has not yet determined what TFDM modules will be implemented at which ATCT facilities by mid-term 2018. The TFDM deployment schedule will depend on the ATCT facility needs, available positions, costs, contractors, and time frame, among others. However, for building the description for how the ATCT controller's job will change in 2018, AIR is required to project a timeline for TFDM implementation. Based on the current progress of TFDM, AIR believes that except for the Data Exchange DST, the other five DSTs will be in existence on the TFDM platform by 2018.

Driver 8: Wake Turbulence Mitigation for Departures

Wake Turbulence Mitigation for Departures (WTMD) is a set of procedures that will allow controllers to safely reduce spacing restrictions for aircraft departing on closely spaced parallel runways (CSPRs). WTMD will use an algorithm to process information from automated surface observing system (ASOS) wind sensors on the airport surface and winds aloft forecasts to determine when crosswinds will mitigate the presence of wake turbulence vortexes during parallel runway operations.

This algorithm will be attached to a DST that will alert supervisors and ATCT line controllers when conditions are favorable to allow reducing separation minima for departing aircraft on CSPRs. The alarm will be on both supervisor and controller displays. In ATCT facilities, however, supervisors will determine when air traffic controllers can reduce departure spacing. Once controllers receive the decision from supervisors, they can implement the appropriate wake turbulence separations. The WTMD DST will also provide alarms to supervisors and controllers for when favorable crosswind conditions no longer exist.

WTMD's primary benefit is increased throughput at airports with CSPRs. That is, controllers do not currently have access to information regarding when conditions (i.e., wind) are acting to dissipate wake turbulence. Consequently, standard wake turbulence separation criteria are imposed to mitigate this risk. While conservative, these separation standards ensure safety.

WTMD will allow controllers to apply reduced spacing between aircraft departing on CSPRs, thus increasing the departure throughput during favorable crosswinds.

WTMD is restricted to airports with CSPRs and cross-wind availability, so it is currently planned to be implemented in nine of the 30 core airports and the Lambert-St. Louis International Airport (STL). Although the FAA must first determine whether the costs associated with WTMD warrant implementation in the mid-term, WTMD is in the testing phase and close to being ready for implementation. For the purposes of this report, AIR assumes that WTMD will be available by 2018 in the 10 major airports targeted.

Section V. Characteristics of NextGen ATCT Work and Workers

Now that the notion of job Tasks and Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs) have been introduced and defined for today's Airport Traffic Control Tower (ATCT) line controller, and the ATCT Next Generation Air Transportation System (NextGen) Drivers described, the American Institutes for Research (AIR) describes in this section the job of the ATCT line controller and the characteristics required to perform it—as they are proposed to exist in 2018.

This description is organized by the eight ATCT NextGen Drivers that were described in Section IV: 4-Dimensional Weather Data Cube (4-D Wx Data Cube); Airport Surface Detection Equipment-Model X (ASDE-X); Automatic Dependent Surveillance-Broadcast (ADS-B Out); Data Communications (Data Comm); Integrated Arrival, Departure, and Surface (IADS); Terminal Automation Modernization and Replacement (TAMR 3); Tower Flight Data Manager (TFDM); and Wake Turbulence Mitigation for Departures (WTMDs). As stated previously, this approach reduces redundancy and thus makes the descriptions easier to read than if they were presented by Activity. When reviewing this section, readers should be reminded that the Drivers have a variable effect on the job, with some Drivers having an impact on only a few facilities (and thus only a few controllers) and others having a broader impact (see Section IV for more details).

Following a short summary of each Driver, an overview of the impact of the Driver on the job of the Air Traffic Control Specialist (ATCS), the job Activities that are proposed to be affected *most directly* by that Driver are listed and changes to the specific Tasks are described. Then, the KSAOs that are proposed to be affected most directly are listed and the changes are described. For each impact, the number of the specific Task or KSAO being affected is listed in italic font in parentheses. For example, Task 235 from the current ATCT Task list is listed as (*T235*). Note that identified changes are specific to the implementation of the Driver being described; the changes may not result in a concomitant change to the job overall. Finally, potential threats to safety and efficiency are presented, followed by a summary of the Driver's impact. This structure can be represented as follows:

- Identification and Summary of the Driver
- Presentation of a table that visually summarizes the changes resulting from the implementation of the Driver
- Identification of Changes to ATCT job Tasks
  - Explanation of changes to the Current Task list
  - Explanation of changes to how Tasks are performed
- Identification of Changes to the Characteristics Required of ATCT Controllers
  - Explanation of changes to the Current KSAO list
  - Explanation of changes to curriculum required to teach Knowledges
  - Explanation of changes to properties of Knowledges
  - Explanation of changes to curriculum required to teach Skills
  - Explanation of changes to the properties of Skills
  - Explanation of changes to properties of Abilities
  - Explanation of changes to properties of Other Personal Characteristics

- Identification of Potential Threats to Safety and Efficiency
- Summary of the Driver's Impact

Note that the impacts described in any given section are the proposed result of the implementation of the individual NextGen Driver being described in that section, and not an indication of the overall impact on the job. For example, a Driver may reduce how often a controller will perform a particular Task or need a particular Skill, but this does not necessarily represent the net effect of NextGen on the job overall. Readers are encouraged to consult the Executive Summary and the Conclusions sections of this report for AIR's high-level summary of the net effect of the Drivers on the job.

Also, note that several ATCT NextGen Drivers will affect the clearances, instructions, and other messages that are issued by controllers. However, recall that Activity 2 (*A2-Manage Communications*) captures Tasks associated with the basic communication process, not the issuing of a specific communication. Consequently, the impacts of Drivers on specific communications are identified in the Activity where that communication occurs.

Finally, recall that this Job Description is based on information available as of January 2011.[9] It is fully anticipated that the vision of the job of the NextGen 2018 line controller will change as the NextGen concept matures and as specific platforms, systems, policies, and procedures are developed and implemented to support it.

Driver 1—4-Dimensional Weather Data Cube

4-D Wx Data Cube is a framework for grouping all unclassified weather information used directly and indirectly for making aviation decisions by four characteristics: latitude, longitude, altitude, and time. This grouping of weather information will affect the job by giving controllers more timely, accurate, and comprehensive weather information from a single authoritative source (i.e., the 4-D Wx SAS) available at controllers' workstations. Moreover, 4-D Wx Data Cube information will be available to other users of the National Airspace System (NAS) and will provide subscribers with a common weather picture. Definitive information is not yet available regarding where 4-D Wx Data Cube will be installed. Based on available information, it will likely be implemented as part of TFDM. It is assumed that the precipitation overlay that currently exists on the radar display would continue to be available and could be selected at the controller's discretion.

Overview of Changes From Implementing 4-D Wx Data Cube

The following table provides a visual summary of the changes that will occur as a result of implementing 4-D Wx Data Cube. Additional details regarding these changes can be found in the sections that follow.

[9] An exception is that the Operational Improvements referenced in this report are from November 2010.

Table 9. Overview of the Impact of 4-D Wx Data Cube

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO lists:			Add: • ATC Automation (*New K*) • Interoperability (*New K*)			Add: • Technology Acceptance (*New O*)	Add: • 4-D Wx Data Cube (*New TE*)
Driver otherwise affects existing Task or KSAO:	T3 T7 T8 T12 T16 T17 T25 T45 T49 T80 T83 T84 T89 T90 T94 T101 T114 T115 T127 T132 T140 T145 T151 T154 T155 T171 T172 T175 T180 T185 T193 T206 T227 T228 T229 T236 T242 T247	T262 T267 T271 T280 T286 T288 T290 T291 T292 T293 T295 T297 T298 T299 T303 T305 T313 T319 T320 T322 T328 T332 T358 T359 T364 T365 T366 T370 T372 T376 T377 T379	K8.2 K8.6 K8.9 K8.10 K8.11 K19.1 K19.2 K19.3 K19.4 K19.5 K19.6 K19.7 K19.8 K22.3 K22.10	Sk1 Sk3 Sk8 Sk11 Sk20 Sk23 Sk25 Sk26 Sk46 Sk47 Sk48 Sk49 Sk52 Sk53 Sk54	Ab1 Ab4 Ab5 Ab8 Ab11 Ab19 Ab24 Ab26 Ab28 Ab34	O14	

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how*

Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List
None.

Changes to How Tasks Are Performed
4-D Wx Data Cube and the associated 4-D Wx SAS will affect *how* ATCT line controllers perform many of those job Tasks. The implementation will affect many Tasks because weather information is a part of so many controller decisions. AIR opted to provide information about the impact of the implementation of 4-D Wx Data Cube on all Tasks, even if the impact is relatively indirect (i.e., through the utilization of more accurate weather information) as opposed to direct (i.e., through changes in how controllers use information or how they perform a Task). This is to ensure that the substantive nature of the impact of improving access to and accuracy of weather data is not minimized. AIR proposes that the 4-D Wx Data Cube will most directly affect the following nine of the 11 ATCT job Activities:

- Activity 1. Establish Situation Awareness
- Activity 3. Manage Flight Plan Data
- Activity 4. Manage Air Traffic
- Activity 5. Resolve Conflicts
- Activity 6. Manage Departing and Arriving Traffic
- Activity 7. Transfer of Radar Identification
- Activity 8. Assess Impact of Weather
- Activity 9. Manage Airspace
- Activity 11. Respond to Emergencies and Unusual Situations

Activity 1: Establish Situation Awareness
It is not yet known on which ATCT automation platform 4-D Wx Data Cube will exist. However, based on the information synthesized to date, AIR believes it is most likely that the data will be part of TFDM. 4-D Wx Data Cube, then, represents a new tool or equipment (*New TE*) for the ATCT controller. Hence, controllers will scan a different piece of equipment or system to access weather information (*T12*). Scan time is likely to be reduced because this new single display will replace the multiple sources of weather information used by ATCT controllers today.

To the extent that 4-D Wx Data Cube displays are more customizable current sources of weather information, then its implementation adds another piece of equipment to be adjusted (*T7*) and to scan for configuration (*T8*), which will increase overall time required for system configuration. Although controllers will have another piece of equipment to adjust when assuming position responsibility (*T7*), the implementation of 4-D Wx Data Cube should allow controllers to scan more efficiently.

Because 4-D Wx Data Cube will provide a synthesis of different and highly accurate sources of information via 4-D Wx SAS, controllers will spend less time conducting and participating in position relief briefings (*T3*, *T25*). Controllers will not have to explain the content of multiple weather sources, but instead can focus on the content of the synthesized data in the 4-D Wx SAS. The increases in accuracy and higher resolution of weather information available from 4-D Wx Data Cube will mean that controllers will spend less effort interpreting data to identify patterns or irregularities (*T16*). This will also likely help controllers project the current weather situation into the future because they will be starting from more accurate information regarding the location (e.g., perimeter, altitude) of weather systems (*T17*).

Activity 3. Manage Flight Plan Data

Controllers use weather information today when evaluating flight plan requests (*T45*) and when determining the need for flight plan amendments (*T49*). However, the implementation of 4-D Wx Data Cube will provide controllers with more weather information and more accurate weather information. Consequently, the quality of the decisions made during these two Tasks will improve because controllers will know with greater certainty whether a proposed flight plan is feasible or not. This means controllers will be less likely to change a flight trajectory due to weather when such a change is not required.

Activity 4. Manage Air Traffic

While performing radar and nonradar separation of aircraft, ATCT controllers must identify potential conflicts (*T80, T89*), which requires projecting mentally an aircraft's current position into the future. Because projections are affected by the presence of weather, having a greater amount of and more accurate weather information via 4-D Wx Data Cube will enable controllers to make better decisions regarding the presence of potential conflicts. When performing radar and nonradar separation of aircraft, controllers must also determine the appropriate control actions (*T83, T90*). 4-D Wx Data Cube will provide controllers with information that allows them to know with greater certainty the location of severe weather. This will allow controllers to develop more user appropriate and therefore more realistic and efficient control actions. 4-D Wx Data Cube-provided weather information will also influence the prioritization of control actions (*T84, T90*). Having more accurate weather information will help controllers determine which control action is the safest and most efficient, thus improving reliability.

The improved weather information provided by 4-D Wx Data Cube will help ATCT controllers when determining an appropriate plan of action in response to special operations (*T94*). Knowing with greater certainty the location (e.g., perimeters, altitudes, and times) of severe weather will allow them to create flight plans or flight trajectories that safely avoid severe weather but will not unnecessarily restrict the movement of aircraft. These plans will be more tailored, realistic, and efficient. The same will be true when evaluating conditions for providing VFR flight following (*T101*). Because VFR flight following is not a required service but rather one that controllers can provide if workload and other conditions permit, controllers must evaluate their workload when determining whether to provide this service. Knowing with greater certainty the location of severe weather will allow controllers to better evaluate if weather is—or will become—a factor.

The implementation of 4-D Wx Data Cube will assist controllers as they evaluate pilot requests for deviation. If a request for deviation is approved but restrictions are required, controllers will have to generate an alternative clearance. Again, the evaluation of the pilot's request and the determination of an appropriate clearance are influenced by weather (*T114*, *T115*). Having improved weather information will allow controllers to develop more tailored (i.e., appropriate to the user), realistic, viable, and efficient control actions.

Activity 5. Resolve Conflicts
Conflicts can occur between aircraft, between an aircraft and the ground, and between an aircraft and airspace boundaries. Each of these processes will be influenced by the implementation of 4-D Wx Data Cube. The first step in performing aircraft conflict resolutions is for controllers to identify potential losses of separation by projecting mentally the future position of aircraft. Because this process is affected by the presence of weather, having improved weather information will help controllers make more accurate decisions (*T127, T140, T151*). The improvements in 4-D Wx Data Cube-provided weather information will also help controllers determine which control action being considered to resolve the conflict is the safest and most efficient (*T132, T145, T155*). In addition, more accurate weather information will allow controllers to more precisely determine whether an airspace violation occurred as a result of weather (*T154*). This is important because controllers must ascertain facts and details regarding potential airspace violations.

Controllers will be able to utilize 4-D Wx Data Cube information to more accurately determine the need for advisories or alerts (*T171*) due to weather. Greater accuracy in these decisions will prevent controllers from issuing advisories/alerts unnecessarily or from issuing advisories/alerts with inaccurate information. Improved weather information may reduce the need for blanket broadcasts; and controllers will generate more situation specific advisories/alerts (*T172*). Finally, controllers will be better able to determine if and when the weather has returned to normal, and thus will be more likely to cancel the advisory or alert at a more appropriate time (*T175*), reducing uncertainty in flight planning.

Activity 6: Manage Departing and Arriving Traffic
Having access to more weather information and more accurate weather information will allow controllers to more accurately evaluate the control environment when determining the optimal traffic flow (T180). Knowing with greater accuracy the location of weather will allow controllers to better predict where airport chokepoints are likely to occur. This allows for more "real time" adjustments to sequences. It will allow them to project ground traffic to determine the most appropriate departure sequences (*T185, T236*).

When managing departure traffic, 4-D Wx Data Cube provided information, which is more accurate than the information available today, will help controllers make better decisions when determining the appropriate departure interval (*T193*) and when determining whether to cancel a takeoff clearance (*T206*). When managing arrival traffic, 4-D Wx Data Cube provided information will assist controllers in making better decisions regarding the safety of airfield and traffic conditions (*T227*). Increased accuracy in the data will also assist them in determining appropriate landing sequences (*T228*), and increased standardization of weather information across facility types will assist them in coordinating landing sequences with TRACON controllers (*T229*).

4-D Wx Data Cube will provide ATCT line controllers with weather information that looks more similar to the weather information that traffic management unit (TMU) already has available. Consequently, this will make the discussion of traffic management initiatives (TMIs) (*T242*) and the coordination with TMU (*T247*) much easier for controllers. Furthermore, if the Federal Aviation Administration (FAA) elects to give TMUs access to 4-D Wx Data Cube, it will make decision-making and coordination between controllers and TMU even easier, because they will be looking at the exact same weather information (*T242, T247*). The availability of shared information is likely to improve the quality and timeliness of decisions.

Activity 7. Transfer of Radar Identification

Coordination between controllers, including coordination required for initiating and accepting handoffs, will be more standardized and more productive because both controllers will have access to the same weather information (*T262, T267*). In addition, having more accurate weather information will allow controllers to make better decisions regarding the need for changes in flight trajectories, and subsequently in determining the need or conditions for pointouts (*T271*). For example, controllers would not identify the need for a change in trajectory when one did not really exist, and, conversely, they would not fail to identify the need for a change in trajectory when one was required, thus reducing inefficiency in the NAS. Finally, having more accurate weather information will allow controllers to have more appropriate responses to pointout requests (i.e., controllers will know whether a restriction is necessary and consequently will not unnecessarily restrict aircraft) (*T280*).

Activity 8: Assess the Impact of Weather

Controllers will observe changes in weather conditions on the new 4-D Wx Data Cube display (*T286*). Controllers will request weather reports from other controllers less often (*T288*) because controllers will be entering weather information into the 4-D Wx Data Cube system, which will then be shared. Conversely, controllers will receive fewer requests from other facilities for weather information (*T292*).

Because 4-D Wx Data Cube provided information is more accurate, the decision making of controllers when determining whether airport conditions have changed and when determining whether conditions are IFR or VFR will be improved (*T290, T291*). Note that controllers will still have to forward changed airport condition information to pilots and dispatchers but, assuming that this information is on 4-D Wx Data Cube, they will not have to forward to other controllers (*T295*) because they will already have access to those data.

There will be changes in how weather data are recorded (*T293*). First, the data that are recorded will be different (e.g., will be in 4-D or 4-D compatible format). Second, the actual entry of weather information will be made into the 4-D Wx Data Cube system instead of the existing Tools and Equipment.

Controllers' response to severe weather will change as a result of the implementation of 4-D Wx Data Cube. Controllers will receive information regarding severe weather intensity and trend from a new display that provides information of higher quality and timeliness (*T297*). In order for the information contained in 4-D Wx Data Cube to be truly 4-dimensional, severe weather data will have to be formatted and communicated in four dimensions. This will mean that pilots will have to provide the information in four dimensions and controllers will have to request it in that format (*T298*). This information will be shared and displayed in the same manner to all subscribers in a 4-D Wx SAS. Thus, requesting information from and disseminating it to other controllers will occur less often because subscribers will see the same weather depiction (*T298, T303*), thus reducing the coordination. The increase in accuracy in weather data will improve controllers' decision making with regard to evaluating the potential impact of severe weather (*T299*). It may also reduce the frequency of this Task because more weather data will have been mined and synthesized before being presented.

Activity 9. Manage Airspace

ATCT controllers identify the need for use of another controller's airspace based partly on the presence of weather. Improvements in information regarding the location of severe weather will allow controllers to make better decisions regarding the need for different flight trajectories and hence the need for changes in airspace (*T305*). For example, controllers would not identify the need for a change in trajectory when one did not exist. Conversely, they would not fail to identify a change in trajectory when one was required. This could reduce the workload associated with shifting an aircraft to another radio frequency unnecessarily.

Having more accurate weather information will allow controllers to better evaluate the feasibility of—and options for—the temporary release of airspace to another controller (*T313*). The coordination required for temporary release of airspace, once approved, will be eased and more productive because both controllers will have access to the same weather information (*T320*).

When airspace status changes, such as during the combining and decombining of control positions, controllers have to coordinate the change and any associated restrictions with others. Because controllers will have access to the same weather information as a result of the implementation of 4-D Wx Data Cube, coordination (*T319*, *T320*) will be standardized and more productive; less explanation will be required regarding the change and any associated restrictions. Furthermore, to the extent that controllers must take weather into account when developing appropriate control actions to ensure that aircraft are separated from the newly restricted airspace, 4-D Wx Data Cube provided information will help controllers to refine control actions so that they are more operationally appropriate, preventing them from generating "one size fits all options" (*T322*).

Processes associated with responding to runway or taxiway usage or conditions will change. Controllers will receive notices of changes via 4-D Wx Data Cube (*T328*). When determining the control actions required to accommodate changes, controllers will take 4-D Wx Data Cube information into account. Because these data are superior in accuracy, this will improve their decision making (*T332*).

Activity 11. Respond to Emergencies and Unusual Situations

Both evaluation and reevaluation of emergency or unusual situations require that controllers take into account the impact of weather. Having improved weather information will allow controllers to make decisions that are more operationally appropriate (*T358*, *T365*, *T370*, *T376*). Similarly, determining an appropriate plan of action and revising the plan both require that controllers take into account the impact of weather. Having more accurate weather will allow controllers to develop plans that are both viable and represent the best case scenario (*T359*, *T366*, *T372*, *T377*) without over- or under-controlling. Finally, coordination with others who also have access to 4-

D Wx Data Cube information during emergency or other unusual situations will ease discussions and be more productive (*T364, T379*).

Changes to Characteristics Required of ATCT Controllers

When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics or KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List

The introduction of 4-D Wx Data Cube into the ATCT environment does not require deleting or modifying the language of currently required Knowledges, Skills, Abilities, or Other Personal Characteristics. However, it does require the addition of two new Knowledges. First, a new Knowledge that captures concepts important for understanding and using automation will need to be added (*New K-ATC Automation*). This new knowledge will be a sub-category under an existing Knowledge category K5, which captures general aviation human factors information (i.e., not system specific) that controllers must know. Second, a knowledge that captures information related to how the new tool or equipment works in conjunction with other facility tools and equipment (*New K-Interoperability*) will also need to be added. This Knowledge will be part of the existing Tools and Equipment Knowledge category (*K19-Knowledge of Facility Tools and Equipment)*.

The implementation of 4-D Wx Data Cube also requires the addition of a new Other Personal Characteristic—the need for controllers to have positive attitudes towards, perceive the usefulness of, and to perceive ease of use of technology (*New O-Technology Acceptance*). In order for controllers to use 4-D Wx Data Cube and 4-D Wx SAS to perform their jobs efficiently, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges

The introduction of 4-D Wx Data Cube will require that ATCT line controllers learn new training material to support both existing and new knowledge topics. Training content relevant for the new Knowledge related to ATC automation (New *K-ATC automation*) includes the evolution of ATC automation; risks associated with automation (e.g., improper reliance on automation); benefits of automation (e.g., freeing of cognitive resources for use on other tasks); automation design considerations, including appropriate allocation of Tasks to people and to machines; and concepts associated with decision support tools (DSTs), including the decision support tool–decision-making tool continuum, evaluation strategies, and the concept of automation-based algorithms and importance of understanding them.

4-D Wx Data Cube may change PIREP solicitation requirements (*K8.9-Pilot Report [PIREP] solicitation requirements*); in order for the information to be 4-dimensional, controllers will have to know how to solicit the information from pilots in four dimensions.

ATCT controllers will also have to learn new curriculum associated with the use of the tool (*K19-Knowledge of Facility Tools and Equipment*) including content for all the existing Knowledge subcategories (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators; K19.7-Minor troubleshooting; K19.8-Backup systems).* For example, if 4-D Wx Data Cube adds new sensors that do not exist today, then controllers will need to be taught about the location, capabilities, and limitation of the new sensors, and how to interpret the information they provide. In addition, controllers will need to be taught curriculum for the new Knowledge regarding how the new set of tools and equipment work in conjunction with the other facility Tools and Equipment *(New K-Interoperability).* In the case of 4-D Wx Data Cube, curriculum would include information regarding how the 4-D Wx Data will be depicted on the radar display, how the system as a whole interacts with the existing radar, and whether 4-D Wx Data Cube information will be displayed on other systems that currently display weather such as Information Display System (IDS).

4-D Wx Data Cube will also require that controllers learn new scanning strategies (*K22.3-Scanning strategies*) that incorporate the 4-D Wx Data Cube information. Specifically, they will need to learn how to scan the tool to get the information out of it that is needed at any given moment. They will also need to learn how to integrate this tool into their scanning of all tools available in the ATCT environment. Although Knowledge of scanning strategies is important, it is unclear whether/how controllers are currently taught this Skill. Based on AIR's research, it appears to be taught by only some trainers.

Finally, 4-D Wx Data Cube will provide controllers with a greater amount of and more accurate information that will affect their severe weather avoidance strategies. Controllers may need to attend to different information that was not previously available, and consequently will need to learn new severe weather avoidance strategies (*K22.10-Strategies for severe weather avoidance*).

Changes to Properties of Knowledges

Because 4-D Wx Data Cube consolidates weather information into a single authoritative source, controllers may no longer need to know where and how to get weather information from each individual source or how to synthesize weather from different sources. Consequently, while controllers will still need to know the sources of weather information (*K8.2-Sources of weather information*), they may need to know about the sources in less detail and they may need to know less about weather interpretation (*K8.6-Weather data interpretation*).

Since more NAS users will have access to the same weather picture, the Knowledges associated with the recording and dissemination of weather information will be needed less often. For example, assuming that 4-D Wx Data Cube will have automated terminal information service (ATIS) information that is normally transmitted to the Tower from the other facilities via a landline or flight data input/output (FDIO), there will be a reduction in the amount of weather information recording that ATCT line controllers will have to perform because it will be displayed on 4-D Wx Data Cube. Consequently this knowledge will be used less often (*K8.10-Weather information recording*). Similarly, since controllers in all facilities are viewing the same weather information, ATCT controllers will disseminate this information less often to other controllers and hence will use this knowledge less often *(K8.11-Weather information dissemination requirements*). Note that controllers will likely still have to disseminate weather information to pilots in 2018 because aircraft will not be appropriately equipped to receive this weather information in the cockpit by that time.

Changes to Curriculum Required to Teach Skills
If 4-D Wx Data Cube brings with it new symbols, acronyms, abbreviations, or other truncated data—which seems logical given 4-D Wx SAS has to collapse so many sources of raw data into a single display—then ATCT line controllers will need to learn Skills in interpreting these truncated data (*Sk8-Decoding*). Also, to the extent that 4-D Wx Data Cube provides greater and more accurate information about weather, and because it is a new piece of equipment, controllers will need to learn what information to include about 4-D Wx Data Cube in the position relief briefing and to practice relaying it (*Sk20-Position Relief Briefings*).

Since 4-D Wx Data Cube is a new tool, controllers may need to be taught new scanning Skills to help them quickly and accurately search the tool (*Sk25-Strategic Scanning*). In addition, to the degree that 4-D Wx Data Cube provides new information or information that is chunked differently, controllers will need new Skills at combining the elements identified in the scan to develop an understanding of the operational context (*Sk26-Operational Comprehension*) that can be used as the basis for making operational decisions.

Insofar that 4-D Wx Data Cube provides controllers with new and/or more strategic information than they have today, controllers will need new Skills at decision-making about the impact of weather on operations (*Sk47-Current Weather Assessment*). Controllers will also need to be taught new Skills in projecting this new information and its impact on operations (*Sk48-Weather Projection*). Moreover, controllers will need to be taught new Skills in using this new information to develop viable weather mitigation strategies (*Sk49-Weather Strategy Development*).

Lastly, controllers will need to be taught new Skills associated with effectively using the tool and its input devices (*Sk52- Tool and Equipment Operation*), recognizing equipment degradation/failure (*Sk53- Tool and Equipment Status Recognition*), and responding to equipment degradation/failure using minor troubleshooting and backup procedures (*Sk54-Tool and Equipment Degradation/Failure Response*).

Changes to Properties of Skills
If other parties besides ATCT line controllers (e.g., TMU, TRACON controllers) also get a complete 4-D Wx Data Cube that includes weather observations and PIREPs, then less information will have to be shared verbally. For that reason, line controllers will spend less time using their Skill at verbally communicating information (*Sk1-Oral Communication*), Skill at attending to what others are saying and asking questions if needed (*Sk3-Active Listening*), and working with others to accomplish air traffic Tasks (*Sk23-Coordination*).
Given that 4-D Wx Data Cube provides controllers with the option of viewing all underlying raw data or a synthesized 4-D Wx SAS version of the data, it will have differing effects on the Skill required to identify the information needed from all the air traffic information available (*Sk11-Information Filtering*). If controllers are using the underlying raw data, their proficiency at information filtering becomes more important. Conversely, if controllers are using 4-D Wx SAS, which synthesizes weather data, their proficiency at information filtering becomes less important.

4-D Wx Data Cube will also have differing effects on Skills associated with interpreting weather data (*Sk46-Weather Data Interpretation*). To the extent that controllers use the system's underlying raw data, it will increase the Skills required for weather interpretation because they will be receiving more raw data to process. However, to the extent that controllers prefer to use 4-D Wx SAS, then it will reduce the Skills required for weather interpretation because these controllers will have to do less cross-referencing and synthesizing from various non-connected sources and thus less evaluation of data.

Changes to Properties of Abilities
4-D Wx Data Cube may decrease the use of several Abilities. If other NAS users besides ATCT line controllers (e.g., TRACON controllers, TMU personnel) also get 4-D Wx Data Cube, it will reduce the amount of time ATCT line controllers will spend using Abilities associated with communicating information and ideas verbally (*Ab1-Oral Expression*), understanding principles governing the use of verbal concepts (*Ab4-Verbal Reasoning*), and understanding information that is presented verbally (*Ab5-Oral Comprehension*). Less information will be shared verbally and fewer discussions will take place regarding the impact of weather because that information will be on 4-D Wx SAS.

If 4-D Wx Data Cube replaces the other sources of weather information currently in use in the ATCT, this change could decrease the importance of being able to shift between two or more sources of information (*Ab34-Time Sharing*) because controllers will not have to monitor the status of as many pieces of equipment for different types of weather information. Similarly, controllers using 4-D Wx SAS may further reduce the need for the ability to shift between multiple sources of information (*Ab34-Time Sharing*) because different sources of weather information will be consolidated into one place.

4-D Wx Data Cube will also increase the use of several Abilities. To the extent that controllers are utilizing raw data on the 4-D Wx Data Cube, then processing large volumes of data will be required and Abilities, including perceiving information quickly and accurately, performing simple processing Tasks (*Ab11-Perceptual Speed and Accuracy*), and quickly and accurately organizing information into meaningful groups (*Ab26-Chunking*), may become more important. Controllers need these Abilities today to process weather information, but the addition of more available weather information makes these data reduction and summarization Abilities more important.

Since 4-D Wx Data Cube will provide new and more timely information to controllers, the Ability to combine pieces of information to form general conclusions and to find relationships among events (*Ab19-Inductive Reasoning*) will be more important and required at a higher level. The weather information provided will be more dynamic and will have more parameters. ATCT controllers will need to be able to adapt to having 4-D Wx Data Cube at their workstations (*Ab24-Flexibility*). If 4-D Wx Data Cube display increases the use of color for coding information, which seems likely given the substantive synthesis required for 4-D Wx SAS, then the Ability to detect differences between colors (*Ab8*) will be required more often. Finally, controllers will also need to be able to learn the Knowledge and Skills associated with 4-D Wx Data Cube and to apply lessons learned from experience using this new tool (*Ab28-*

Learning). These Abilities are already required in the present job but they will be increasingly required in NextGen for all Drivers.

Changes to Properties of Other Personal Characteristics
In addition to the new Other Personal Characteristic (*New O-Technology Acceptance*) that was described above, the addition of technologies increases the importance of having the belief that individuals have influence over the outcome of an event and taking responsibility of outcomes (*O14-Internal Locus of Control*). Controllers need to understand 4-D Wx Data Cube thoroughly, so that they perceive it as a tool to help them complete work Tasks, as opposed to simply letting the automation inappropriately control their decision-making processes.

Potential Driver-Induced Risks to Safety and Efficiency
The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 15 risks associated with ATCT NextGen Drivers is presented in Appendix B. Seven potential risks with regard to the implementation of 4-D Wx Data Cube are:

- *Degradation or Failure of Equipment or Systems*: The introduction of 4-D Wx Data Cube will provide controllers with more weather information and more accurate weather/flight condition information in a single source. If 4-D Wx Data Cube fails or the information being provided is degraded in some way, then controllers will have to return to gathering weather/flight condition information from multiple sources, which may not be as accurate. This may increase time and decrease accuracy. The negative impacts on decision-making may decrease safety and efficiency.
- *Improper Reliance on Automation or Procedures*: If controllers over-rely on 4-D Wx Data Cube, this may result in decreases to safety and efficiency. For example, controllers may stop soliciting or disseminating critical weather/flight condition information from pilots. In contrast, if controllers do not input the required data (e.g., icing conditions) into 4-D Wx Data Cube in a timely manner, then these data will be requested by others, thus decreasing safety and efficiency.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities of 4-D Wx Data Cube and any of its limitations may result in poor controller performance, which could increase the possibility for error and reduce safety and efficiency.
- *Mixed ATC Tools, Equipment, or Procedures*: If 4-D Wx Data Cube is not implemented in other ATC facilities, or if it is implemented on a significantly different schedule, then the resulting differences in availability of weather/flight condition information or format of said information poses several risks, including the inability to disseminate information to other controllers and difficulty in communicating about weather with other controllers.
- *Poor Computer-Human Interface Design*: If the display that provides the line controller with synthesized information (in the 4-D Wx SAS) is not designed in a way that presents the information in a meaningful way (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), this could increase the possibility for error, thus reducing efficiency and safety.

- *Skill Decay*: 4-D Wx Data Cube will reduce the need for line controllers to coordinate with others, including pilots and weather information providers to gather weather/flight condition information and, consequently, these skills could decay. This impact is likely to occur as a result of degradation or failure of 4-D Wx Data Cube.
- *Technology Development and Maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is highly unlikely that 4-D Wx Data Cube will be released into the NAS with known deficiencies, the full impact of using it in an operational context may not be realized until the system goes "live." For example, the system may not have reliable interoperability with other systems. In addition, it is not until technologies are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, then they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

4-D Wx Data Cube will have a significant impact on air traffic control operations. This impact is primarily due to the increases in the quality of ATCSs' decision-making, which is the result of controllers having more weather information and more accurate weather information that is readily available. Improved decision-making could in turn increase safety and efficiency. Uncertainty regarding weather will be reduced. Controllers will not have to take the most conservative approach, but instead can issue more tailored instructions that maintain safe separation from weather but minimize impact on the aircraft's desired route. Mitigation of severe weather should occur sooner.

Although the basic job Tasks required of controllers will remain the same, the impact of 4-D Wx Data Cube is on the information used to perform the Tasks. This impact is relevant for nearly every Activity because nearly every Activity requires assessing the impact of weather or communicating weather information. 4-D Wx Data Cube is likely to affect ATCT controllers more than TRACON and ARTCC controllers because ATCT controllers are the observers and recorders of weather. The detailed information captured above regarding the impact of 4-D Wx Data Cube on the job of ATCT line controllers was presented in an effort to illuminate this substantive impact of 4-D Wx Data Cube on the job overall.

4-D Wx Data Cube may also reduce communications with others by making the same information available to all subscribers. This standardization will reduce workload and conserve resources for controllers.

4-D Wx Data Cube will impact the training content for ATCT line controllers because it is a new tool. 4-D Wx Data Cube will make the job easier for ATCT line controllers because it synthesizes weather information that currently is housed in multiple places into one single authoritative source and shares that common picture with all NAS subscribers. However, while 4-D Wx Data Cube adds functionality and reduces burdens associated with gathering information from multiple places, automation generally increases the need for basic technical/computing Knowledges and Skills required of controllers (e.g., controllers need to understand what information the automation has access to and the algorithms it is using to use it safely). They need to know which components are critical and which are not in cases of degradation or outages. In sum, the addition of automation does not result in the need for lower skilled employees, but rather the opposite.

Finally, until 4-D Wx Data Cube is fully implemented, training on both the old weather systems as well as 4-D Wx Data Cube will likely continue to be required. Thus, the introduction of 4-D Wx Data Cube results in an additional training burden without substantially reducing existing training, at least in the short run.

DRIVER 2: AIRPORT SURFACE DETECTION EQUIPMENT—MODEL X

Airport Surface Detection Equipment—Model X (ASDE-X) is a surface surveillance system that will affect the job Activities of ATCT line controllers more than the other Drivers. As described in Section IV, ASDE-X will affect the job by giving controllers better visual coverage of aircraft and vehicles on the surface and, in the immediate, surrounding runway areas while also adding conflict detection and alerting capabilities. Although ASDE-X has already been deployed to some airports, it will have a greater impact on the NAS overall in terms of safety and efficiency when it is deployed to all of the Core 30 airports (see Appendix D) by the mid-term.

Overview of Changes From Implementing ASDE-X

The following table provides a visual summary of the changes that will occur as a result of implementing 4-D Wx Data Cube. Additional details regarding these changes can be found in the sections that follow.

Table 10. Overview of the Impact of ASDE-X

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:		Add: • ATC Automation (*New K*) • Interoperability (*New K*)			Add: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T3 T185 T11 T189 T15 T192 T17 T193 T20 T200 T21 T206 T25 T208 T72 T210 T73 T212 T75 T214 T77 T218 T78 T227 T80 T230 T86 T237 T91 T239	K9.1 K9.2 K9.3 K9.4 K9.5 K11.6 K19.1 K19.2 K19.3 K19.4 K19.5 K19.6 K19.7 K19.8 K21.3	Sk1 Sk3 Sk4 Sk5 Sk6 Sk8 Sk14 Sk23 Sk25 Sk26 Sk27 Sk30 Sk41 Sk52 Sk53	Ab1 Ab4 Ab5 Ab6 Ab7 Ab8 Ab24 Ab28 Ab33 Ab34 Ab35 Ab36	O2 O7 O12 O14	

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	T118 T243 T125 T244 T127 T305 T130 T309 T131 T313 T134 T322 T159 T329 T160 T332 T162 T358 T165 T359 T180 T370 T181 T372 T184	K22.3	Sk54			

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how* Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List

None.

Changes to how Tasks Are Performed

Although the implementation of ASDE-X will not require adding to, deleting from, or modifying any of the current job Tasks, it will affect *how* some of the Tasks are performed and thus influence various outcomes. AIR proposes that this assumption will most directly affect the following job Activities of the ATCT controller:

- Activity 1: Establish Situation Awareness
- Activity 4: Manage Air Traffic
- Activity 5: Resolve Conflicts
- Activity 6: Manage Departing and Arriving Traffic
- Activity 9: Manage Airspace and Movement Areas
- Activity 11: Responding to Emergencies and Unusual Situations

Activity 1: Establish Situation Awareness

ASDE-X will affect this Activity by providing ATCT line controllers with a new tool in facilities where ASDE-X currently does not exist and provide an accurate and comprehensive picture on a display of the location and identity of aircraft and vehicles on the ground, which is not available today. ASDE-X will allow controllers to establish situation awareness by scanning a radar/traffic display instead of relying primarily on an OTW view (*T11*). Switching between looking out the window and down at a display will increase the time required to complete the scan. It will also increase the effectiveness of the scan by providing information about aircraft and vehicles that are outside their visual range or during low visibility conditions. Controllers will have to request pilot position reports much less often because their identification and position will be displayed (*T15*). ASDE-X will use safety logic processing to project the future position of aircraft and vehicles. If a potential or actual conflict exists, the system will alert controllers. Consequently, ASDE-X will change how controllers project current operations into the future (*T17*).

ASDE-X is a new tool to the ATCT environment, which means that controllers will have another piece of equipment to monitor for status (*T20*) and from which they will receive information (*T21*), which could increase the time required for both. The presence of an additional tool and more information regarding the operational context could increase the time required to receive a position briefing (*T3*) as well as to conduct the briefing (*T25*).

Activity 4: Manage Air Traffic
ASDE-X will affect this Activity by providing ATCT line controllers with a new source of information about the identification and position of aircraft and vehicles on the ground, which will assist them when observing or verifying movement into or out of the airspace and movement areas (*T72*, *T77*, *T78*, *T86*, *T91*). ASDE-X will provide controllers with another tool for performing position correlation procedures (*T73*) and ultimately for confirming radar identification (*T75*), especially in low visibility conditions.

ASDE-X will also assist controllers in providing radar separation of aircraft and vehicles on the ground. In particular, it will help controllers identify potential or actual conflicts (*T80*) by providing coverage of movement areas that controllers did not have visual access to previously and by providing alerts of potential or actual conflicts. Similarly, ASDE-X will help controllers identify non-conformance in ground operations, especially during low visibility conditions and in places that are not easily seen from an OTW view (*T118*) and in verifying compliance with instructions to correct the nonconformance (*T125*). This will allow controllers to maintain throughput during these situations, which will even out the flow of traffic.

Activity 5: Resolve Conflicts
As with Activity 1, ASDE-X will affect this job Activity through the use of its collision safety logic processing that will help ATCT line controllers to identify potential or actual aircraft or vehicle conflicts (*T127*, *T159*) by presenting an additional alert (*T130*, *T160*). Controllers will be able to use both their current OTW view and lighting systems, and an ASDE-X-provided view of the runway to help them determine the validity of aircraft and vehicle conflicts (*T131*, *T162*). This ensures that controllers will have information about a larger area of the airport surface. In addition, it may help controllers process the validity of conflicts on the ground more quickly because the conflict probe may provide more accurate calculations of space and time than the human can produce and may also provide this information more quickly. Finally, ASDE-X-provided information will provide another means for controllers to verify aircraft and vehicle conformance to instructions (*T134*, *T165*), especially in low visibility conditions or in locations not easily seen from the tower window.

Activity 6: Manage Departing and Arriving Traffic
ASDE-X will play a major role in this Activity by providing more comprehensive coverage of the airport surface area, especially in bad weather and on movement areas that are hidden from view or out of the range of the OTW view. When managing ground departure traffic, controllers will use ASDE-X-provided information regarding the identification and position of aircraft to evaluate the environment (*T180*) and determine the appropriate sequence of aircraft to optimize flow (*T181*) and to observe the sequence even in low visibility conditions or on areas of the airport that are not easily visible via an OTA view. ASDE-X will allow controllers better sequencing of aircraft because the aircraft location and flight information will be together on one screen, instead of controllers having to sort, order, and mark paper flight progress strips that have the flight information. This will reduce the burden on controllers to match aircraft location with flight information because it will already be matched on the ASDE-X screen in the form of data tags located next to each aircraft. Having access to the same information regarding ground traffic may allow controllers working within ATCT facilities to better coordinate with one another regarding sequencing (*T184*). Projecting the future position of ground traffic will be aided by the ASDE-X conflict probe (*T185*). Finally, controllers will be able to identify whether aircraft have departed the gate and are in conformance with taxi instructions (*T189*).

Controllers will also use ASDE-X-provided information to assist them in managing both takeoffs and takeoff terminations. First, they will be better able to verify that aircraft are ready for takeoff (*T192*) and that runway conditions are acceptable for takeoffs and landings (*T200*). A scan of the ASDE-X information will provide a more comprehensive view of the operational context, which will assist controllers in determining the appropriate interval for departure (*T193*). ASDE-X-provided information will help controllers determine whether a takeoff clearance needs to be canceled (*T206*). They will be able to observe the aborted takeoff (*T208*) more easily and can more quickly coordinate the termination with others (*T210*).

In addition to helping controllers prepare for departures, ASDE-X information will help controllers manage both departures and arrivals more efficiently. First, it will allow controllers to verify the exact position of departures or arrivals, especially in low visibility conditions or in cases where the runway end is not visible from the tower cab, thus enabling them to forward notification of departures and recognize arrivals in a more timely manner (*T212*, *T218*). It may also allow controllers to be aware of missed approaches in a more timely manner (*T214*). Preparing for arrivals will be aided by ASDE-X, as controllers will have access to more information about the airfield and traffic conditions (*T227*). Clearances will be more efficient because controllers will have more information regarding the appropriate runway exit points (*T230*).

Finally, ASDE-X-provided information will assist controllers in responding to flow constraints and the traffic management initiatives implemented to alleviate them. It will assist controllers in developing taxi instructions that ensure proper sequencing of aircraft (*T237*) and in determining whether aircraft are ready for departure (*T239*). When responding to traffic management initiatives, controllers can use ASDE-X-provided information to help evaluate traffic flow (*T243*) and to develop options for sequencing and resequencing aircraft to conform to TMIs (*T244*).

Activity 9: Manage Airspace and Movement Areas
ASDE-X will affect this Activity by providing an additional source of information regarding movement areas, especially in low visibility conditions and on areas that are obscured from an OTW view. This will help controllers better determine whether and when movement areas need to be released or returned (*T305*, *T309*) Controllers will also be able to use ASDE-X information to better respond to requests for release of movement area (*T313*) and to make better informed decisions about optimizing traffic movement in response to changes to movement areas, runways, or taxiways (*T322*). When runway or taxiway usage changes, controllers can review the traffic situation to optimize the flow of traffic (*T329*) and to determine the appropriate control actions required in response to those changes (*T332*).

Activity 11: Responding to Emergencies and Unusual Situations
ASDE-X will affect controllers' responses to emergencies and unusual situations by providing them with improved visibility of surface areas, even in low visibility conditions and on movement areas out of the range of the OTW view. Controllers will have a more accurate picture of where emergency and surrounding aircraft and vehicles are located on the ground. As a result, ASDE-X will allow controllers to more accurately evaluate the situation (*T358*, *T370*) and determine the appropriate plan of action (*T359*, *T372*). This will result in controllers providing better services, while reducing the need for voice exchanges regarding identification and position when in radar range from aircraft and emergency vehicles.

Changes to Characteristics Required of ATCT Controllers
When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics or KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List
The introduction of ASDE-X to the ATCT work environment does not require adding new Skills or Abilities, nor does it require deleting or modifying the language of these worker requirements. However, its introduction to the ATCT environment will require the addition of two new Knowledges: Knowledge of ATC automation (*New K-ATC automation*) and interoperability among ATC tools and equipment (*New K-Interoperability*). It will also require the addition of a new Other Personal Characteristic. More specifically, it adds the need for positive attitudes towards, perceived usefulness of, and perceived ease of use of technology (*New O-Technology Acceptance*).

Changes to Curriculum Required to Teach Knowledges
Some ATCT facilities have already installed ASDE-X, and controllers in those facilities have been trained. However, controllers who have not yet been trained will need to learn new course curriculum content. Content for the topic area of *ATC automation* would include evolution of ATC automation, risks of automation (e.g., improper reliance on automation), benefits of automation (e.g., freeing up of cognitive resources so controllers can focus on more complex

Tasks), automation design considerations (e.g., appropriate allocation of Tasks to people and to machines). It would also cover content on DSTs, including the decision support–decision-making continuum, evaluation strategies if it is a DST and not a decision-making tool (DMT), and the concept of algorithms and the importance of understanding them.

Controllers will need to learn new information regarding this new type of surveillance system architecture (*K9-Knowledge of Surveillance Systems Architecture*), including all the subcategories associated with this knowledge category (*K9.1-Types of surveillance systems; K9.2-Fundamentals; K9.3-Components; K9.4-Utility; K9.5-Limitations*).

In addition, controllers will also need to learn this new piece of equipment—ASDE-X (*K19-Knowledge of Facility Tools and Equipment*)—including all the sub-categories associated with this knowledge category (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators; K19.7-Minor troubleshooting; K19.8-Backup systems*). Controllers will also need to be taught content for the new Knowledge topic *Interoperability*, which would include how the tool/equipment interacts with the other Tools and Equipment of the ATCT line controllers. In the case of ASDE-X, this would include information regarding the coverage provided on the existing radar display and that provided by ASDE-X.

Controllers will also need to learn new conflict resolution strategies and procedures (*K21.3-Conflict resolution strategies*) because ASDE-X has sensors that will identify potential and actual conflicts on the runway and alert controllers as necessary.

Finally, controllers will need to be taught new scanning strategies to help them learn how to scan the ASDE-X efficiently, to help them allocate scanning time between the ASDE-X and other tools/equipment located in the tower, and between an OTW and a "heads down" view (*K22.3-Scanning strategies*). Currently, it is unclear whether and how the knowledge of scanning strategies is being taught to controllers.

Changes to Properties of Knowledges
With the addition of ASDE-X to the ATCT environment, knowledge of the equipment onboard aircraft that enable and support ASDE-X (*K11.6-Avionics*) will become more important.

Changes to Curriculum Required to Teach Skills
Controllers need to include training to become skilled at using ASDE-X, including alarm recognition and differentiation. This includes Skill at operating ASDE-X (*Sk52-Tool and Equipment Operation*), Skill at recognizing that the system is performing unreliably or not at all (*Sk53-Tool and Equipment Status Recognition*), and Skill in responding under these circumstances (*Sk54-Tool and Equipment Degradation/Failure Response*).

Changes to Properties of Skills
There are several skills related to time sharing that will increase in importance with the introduction of ASDE-X. Skill at quickly shifting between tasks (*Sk4-Task Switching*) and shifting quickly between auditory and visual sources to obtain information needed (*Sk5-Attention Switching*) will become more important. Skill at maintaining situation awareness and returning

quickly to job Tasks after being interrupted (*Sk6-Interruption Recovery*) will be needed more often because of the alerts/alarms associated with ASDE-X and the brief interruptions it presents to controllers.

The introduction of a new radar display in the tower will increase proficiency required with several other skills, including how often controllers will use skill at interpreting air-traffic-related symbols, acronyms, abbreviations, and other truncated data such as data blocks (*Sk8-Decoding*), as controllers did not have data blocks for ground traffic before ASDE-X. In addition, Skill at applying scanning strategies to quickly and accurately search for ATC-relevant information (*Sk25-Strategic Scanning*) will become more important as controllers' time becomes more and more divided among multiple sources of information. Finally, ASDE-X will increase how often controllers are required to use a dynamic four-dimensional mental picture generated from two-dimensional information for managing air traffic (*Sk30-Spatial Information Application*), because the ASDE-X view is 2-D, not OTW. Controllers will need greater proficiency at combining the elements identified during the operational scan to develop a meaningful mental picture of the operational context (*Sk26-Operational Comprehension*) because controllers are combining more pieces of information.

There are several skills that will decrease in importance or that controllers may not use as often. First, because ASDE-X has conflict detection sensors, its introduction reduces how often controllers need Skill at quickly and accurately identifying potential or actual conflicts on runways (*Sk41-Conflict Identification*). Controllers will need Skill at applying math and science principles (*Sk14-Principle Application*) less often because ASDE-X will be doing many calculations for controllers that were once managed mentally.

Second, controllers will still need coordination skills but may utilize them less often with ASDE-X because controllers will be able to see and collect information via ASDE-X display. Similarly, controllers will still need Skill at verbally communicating clearances and instructions (*Sk1-Oral Communication*), Skill at attending to what others are saying and asking questions if needed (*Sk3-Active Listening*), and Skill at working with others to accomplish air traffic Tasks (*Sk23-Coordination*), but may utilize them less often with regard to ground operations because they will not need to request pilot/vehicle position reports. Controllers will be able to see aircraft and vehicles on the display even in low or no visibility conditions. Finally, controllers may need Skill at mentally projecting an object's future position to identify conflicts (*Sk27-Object Projection*) less often, at least for runway-bound aircraft and vehicles, because ASDE-X will identify conflicts on the runway automatically and will alert controllers.

Finally, because ASDE-X has a QWERTY keyboard for manipulation and data entry requirements, Skill at effectively using input devices and peripherals and optimizing their usage will become more important (*Sk52-Tool and Equipment Operation*).

Changes to Properties of Abilities

Several abilities will increase in importance or be required more often as a result of adding ASDE-X, especially as a result of the introduction of new conflict alarms/alerts. First, ASDE-X adds an aural conflict alert, and its introduction into the tower environment may increase the importance of being able to detect or tell the difference between sounds (*Ab6-Hearing Sensitivity*). Second, because on the additional alerts associated with ASDE-X, its introduction may increase how often controllers need to hear a single source of sound in the presence of other distracting sounds (*Ab7-Auditory Attention*). Third, if the ASDE-X display is a color display, then it increases how often controllers need to be able to match or detect differences between colors (*Ab8-Visual Color Discrimination*). Finally, ASDE-X may increase how often controllers need the ability to return to a task after being interrupted (*Ab33-Recall from Interruption*), as the runway conflict alerts/alarms will sound at various intervals that are not pre-defined.

The introduction of ASDE-X will increase the need for controllers to be able to shift quickly between two or more tasks or sources of information (*Ab34-Time Sharing*), because what was once gathered by looking out the window may now be gathered from two separate sources. ASDE-X increases the need for basic computing. This will increase how often and how accurately controllers will need to be able to make fast, simple, repeated movements with their hands—such as those required when typing on a keyboard and using other data entry devices (*Ab35-Wrist/Finger Speed*), as well as adjusting the controls of a machine to an exact position (*Ab36-Control Precision*).

Three abilities controllers will likely utilize less often are verbal communication (*Ab1-Oral Expression*), perceiving and understanding principles governing the use of verbal concepts (*Ab4-Verbal Reasoning*), and listening to and understanding information presented in words (*Ab5-Oral Comprehension*). Controllers will not have to call as often for position reports and will communicate less with other controllers because of shared situation awareness.

Finally, the introduction of ASDE-X—as with other technologies, automation, and procedures—will increase the need for controllers to be able to adjust or adapt to changing situations (*Ab24-Flexibility*). Similarly, controllers will need to be able to apply lessons learned from experience quickly and efficiently (*Ab28-Learning*).

Changes to Properties of Other Personal Characteristics

Controllers who are motivated to learn through challenges on the job and to progress to a higher level of skill (*O2-Motivation*) may do better as new tools/equipment are added because they will be willing to learn the new equipment and apply its capabilities more quickly.

The introduction of ASDE-X into the ATCT environment may alter the balance between safety and efficiency. More specifically, because ASDE-X has runway conflict alarms that will immediately be known to all; this may encourage controllers to maximize safety at the expense of efficiency. That is, controllers may be more inclined to maintain maximum rather than minimum separation standards. Offsetting this tendency may increase the need for controllers to be willing to balance these two sometimes competing goals (*O12-Risk Tolerance*). Second, ASDE-X alerts will draw attention to errors committed by controllers that were perhaps less visible before. As a result, controllers will be working under the additional stress of potentially being publicly criticized or embarrassed among their colleagues for committing errors. Hence, the need for controllers to be willing to accommodate or deal with differences in personalities, criticisms, and interpersonal conflicts in the work environment (*O7-Interpersonal Tolerance*) may increase. Finally, the belief that ATCT controllers have influence over outcomes of an event (*O14-Internal Locus of Control*) will become more important as a result of implementing ASDE-X because controllers need to perceive that they have control over the technology and the situation, not simply responding to technology.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 15 risks associated with ATCT NextGen Drivers is presented in Appendix B. Six potential risks with regard to the implementation of ASDE-X are:

- *Degradation or Failure of Equipment or Systems*: The implementation of ASDE-X is dependent upon many other systems, including ground-based, aircraft-based, and space-based equipment and systems. If there is degradation or failure in any of these, controllers will have to revert to backup procedures, many of which rely on older and inferior technologies and systems that are less efficient. In addition, controllers may be inefficient in their use, which has the potential to cause delays or increase errors.
- *Improper Reliance on Automation or Procedures*: If ASDE-X is perceived as untrustworthy it will be under-utilized. Over-reliance on ASDE-X could also create risks if controllers rely too heavily on the conflict alerts. Both can reduce efficiency and increase the possibility for error.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities of ASDE-X and any of its limitations may result in poor controller decision-making, especially as it relates to conflict alerts. For example, controllers need to understand the algorithms behind safety logic processing that will detect and alert controllers to potential or actual runway collisions.
- *More Dynamic Work Environment*: ASDE-X introduces a verbal alert (the runway incursion alert) to the ATCT environment. While an important safety feature, the introduction of another alert into an environment that already contains alerts could pose challenges for controllers. First, the alert is verbal and could interfere with controllers' ability to hear other critical information. If the volume on the alert is decreased, then the opposite could occur: the controller would not hear it. Finally, if ASDE-X algorithms are designed in such a way as to prompt many false alerts, then controllers' cognitive workload and reaction times could be increased.
- *Poor Computer-Human Interface Design*: If the display for ASDE-X that provides controllers with vehicle and aircraft position is not designed in a way that presents the information in a meaningful way (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), this could increase the possibility for error, thus reducing efficiency and safety.
- *Technology Development and Maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is highly unlikely that ASDE-X will be released into the NAS with known deficiencies, the full impact of using it in an operational context may be not realized until the system goes "live." For example, the system may not have reliable interoperability with other systems. In addition, it is not until technologies are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, then they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

Overall, the introduction of ASDE-X to the ATCT work environment increases safety by reducing runway incursions and increasing visibility of aircraft and vehicles on the surface. Consequently, this means controllers can continue to takeoff/land planes even in low visibility conditions. Moreover, maintaining throughput should mean less fluctuation in traffic flow from hour to hour and a more even distribution of workload among controllers. ASDE-X also allows conflicts to be detected earlier, due to increased and shared situation awareness, and with greater accuracy. As a result, ASDE-X increases both safety and efficiency because it allows continuous traffic flow and prevents bottlenecks.

Reductions in voice communications due to more comprehensive information via ASDE-X also result in better system efficiency for the NAS users. As a result of more and more accurate information presented via ASDE-X, this Driver makes the line controllers' job an increasingly automated job and a decreasingly OTW job. This marks another step along the automation continuum toward full automation.

Driver 3—Automatic Dependent Surveillance-Broadcast Out

ADS-B Out is a satellite-based system that is deployed on aircraft, and which transmits the aircraft's GPS-identified position to ground stations, which in turn broadcasts the information to controller screens and cockpit displays. In the mid-term, it is anticipated that approximately 60% of commercial aircraft will be equipped with ADS-B Out.

Overview of Changes From Implementing ADS-B Out

The following table provides a visual summary of the changes that will occur as a result of implementing ADS-B Out. ADS-B Out does not affect the Tools and Equipment that ATCT controllers use because ADS-B Out is aircraft equipage. Additional details regarding these changes can be found in the sections that follow.

Table 11. Overview of the Impact of ADS-B Out

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:	Modify:[10] • T76 • T253 • T254 • T283		Add: • Service Orientation (*New Sk*)		Add: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or	T11 T15 T17 T45 T72	K7.1 K14.3 K7.2 K14.4 K7.3 K14.5 K7.4 K14.6 K7.6 K16.2	Sk17	Ab24 Ab28	O12 O14	

[10] Because the modifications required to these Tasks are minor (i.e., removal of the word "radar") and because of the number of Tasks, AIR did not list the modified Tasks here. However, Tasks to be modified are listed in full in other Drivers.

	Tasks (T)	Knowledges (K)		Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
KSAO:	T74 T78 T79 T80 T81 T82 T83 T84 T85 T86 T87 T88 T89 T90 T91 T283 T320 T345 T346 T347 T358 T383 T384 T385	K7.7 K7.8 K9.1 K9.2 K9.3 K9.4 K9.5 K11.6 K12.3 K12.4 K14.1 K14.2	K16.4 K17.7 K18.7 K18.18 K18.19 K18.21 K19.4 K19.8 K21.2 K21.3 K22.6 K22.7 K27.4				

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how* Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List

The implementation of ADS-B Out will require modifications to the wording of Tasks in the following job Activities:

- Activity 4. Manage Air Traffic
- Activity 7. Transfer of Radar Identification

Activity 4. Manage Air Traffic

The Tasks associated with transfer or radar identification (*T76*) will be modified by replacing the term “radar” with “aircraft” because with the existence of ADS-B Out as aircraft equipage, controllers will not technically be using radar. However, transfer of aircraft identification procedures will look the same but will use different ATCT equipment.

Activity 7. Transfer of Radar Control

Similarly, the title of this Activity 7 (*A7-Transfer of Radar Control*) and some of the Tasks within it will need to be modified to replace the term "radar" with "aircraft." More specifically, controllers will receive requests for transfer of aircraft identification, instead of requests for transfer of radar identification (*T253*). Also, controllers will determine the need for transfer of aircraft identification as opposed to radar identification (*T254*). Lastly, controllers will still declare aircraft contact (*T283*). However, this contact will not be based on their radar-identified position, but rather on their ADS-B Out-based position.

Changes to How Tasks Are Performed

To the extent that ADS-B Out provides controllers with more accurate information, it will most directly impact how the core job Activities associated with controlling traffic and, to a lesser extent, how Activities involved in responding to emergencies and other unusual situations are performed. Note that although numerous Activities are proposed to be affected, the proposed impact on these Activities is narrow and is constrained to impacts associated with increases in the accuracy of positional data. Note that ADS-B Out has a significant impact on ground operations. This impact is described in detail in the section above on ASDE-X. To reduce repetition, this section focuses only on the impact of ADS-B Out on airborne operations. AIR proposes that ADS-B Out will most directly affect the following four of the 11 ATCT job Activities:

- Activity 1. Establish Situation Awareness
- Activity 3. Manage Flight Plan Data
- Activity 4. Manage Air Traffic
- Activity 11. Respond to Emergencies and Unusual Situations

Activity 1. Establish Situation Awareness

Controllers' scan of their control environment will provide more meaningful data as a result of the installation of ADS-B Out onboard aircraft. In other words, ADS-B Out will show more aircraft than could be seen previously in airspace with no, little, or unreliable radar coverage. ADS-B Out will also provide more accurate and more-up-to-date information about the position of aircraft (*T11*). Assuming that equipage information is encoded in some way into the data block, controllers will also require more time scanning to gather information about whether aircraft are ADS-B Out equipped (*T11*).

Furthermore, controllers will request fewer position reports because aircraft in no, little, or unreliable radar coverage areas will now be present on their current radar/traffic display (*T15*). Finally, to the extent that positional information from ADS-B Out shows aircraft that were not visible before, the projection of aircraft into the future (*T17*) will be easier as all aircraft will be tracked on a single display.

Activity 3. Manage Flight Plan Data

The information about aircraft equipage is a new piece of information that controllers need to take into consideration when evaluating the flight plan (*T45*).

Activity 4. Manage Air Traffic
Knowing with greater certainty where aircraft are located in time and space affects several controller job responsibilities associated with performing radar separation of aircraft. More specifically, in areas that have currently have no, little, or unreliable radar coverage, the implementation of ADS-B Out will mean that controllers will observe aircraft entering airspace on the radar/traffic display (*T72*) more often, and will perform radar-based position correlation procedures more often (*T74*). Controllers will perform Tasks associated with radar separation (*T78-T86*) more often. Conversely, because ADS-B Out will provide controllers access to more positional data (i.e., from aircraft not previously covered by radar), controllers will perform all the Tasks associated with nonradar separation (*T87-T91*) less often. Note that this impact will be limited as ATCT controllers are rarely required to perform nonradar separation.

Activity 11. Respond to Emergencies and Unusual Situations
ADS-B Out will enhance emergency alerting for ATCT controllers: even if primary or secondary radar feeds become dysfunctional, controllers will still be able to quickly locate distressed or downed aircraft through information provided by ADS-B Out (*T358*) and shown on the radar/traffic display. To the extent that aircraft are ADS-B Out-equipped, controllers will initiate backup systems (*T383*), implement backup procedures (*T384*), and initiate nonradar separation procedures (*T385*) less often because these aircraft will still show up on controllers' radar/traffic display. In sum, ADS-B Out reduces the negative impact of radar equipment failure/degradation. However, controllers will still have to perform all the Tasks associated with responding to emergencies for other non-ADS-B Out equipped aircraft.

Changes to Characteristics Required of ATCT Controllers
When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics or KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List
The installation of ADS-B Out onboard aircraft does not require adding to, deleting from, or modifying the language in the existing list of Knowledges or Abilities. However, the implementation of ADS-B Out onboard aircraft will add a new Other Personal Characteristic to capture the necessity for ATCT controllers to adopt positive attitudes toward and be willing to work with aircraft that are ADS-B Out-equipped (*New O-Technology Acceptance*). ADS-B Out will also require the addition of a new Skill that will support controllers in being responsive and helpful when working with an increasing number of aircraft with varying levels of equipage and capability (*New Sk-Service Orientation).*

Changes to Curriculum Required to Teach Knowledges
The accuracy of ADS-B Out data will have a positive effect on the design and usage of the airspace. The introduction of ADS-B Out will change air route structure and airspace systems architecture to reflect new system accuracy (e.g., add new ADS-B Out-enabled routes).

Controllers will need to be taught these new routes and architecture (*K7.1-Air route structure*). However, ATCT controllers currently use this knowledge very seldom and, consequently, the impact will be minimal.

Furthermore, controllers need to be trained in the relative importance of NAVAIDs, usage of NAVAIDS by aircraft with different equipage (*K7.2-Types of NAVAIDs*), and a new type of satellite-based navigation that is possible a s result of ADS-B Out technology (*K7.3-Types of navigation*).

As a result of new air route structures, aeronautical charts will look different and will need to be included in the new training curriculum (*K7.4-Aeronautical charts*). ADS-B Out will decrease the constraints associated with terrain clearance restrictions and make better use of ADS-B Out's capabilities (*K7.8-Terrain features*). Consequently, aircraft will be able to come closer to terrain features (e.g., mountains) because ADS-B Out provides more accurate location of aircraft.

If ADS-B Out is not currently being taught, it will need to be taught as an additional component of the surveillance systems architecture (*K9-Knowledge of Surveillance Systems Architecture*), including all the associated Knowledge subcategories (*K9.1-Types of surveillance systems; K9.2-Fundamentals; K9.3-Components; K9.4-Utility; K9.5-Limitations).* Furthermore, if ADS-B Out has not already been added to the training curriculum, new curriculum will have to be added to teach controllers about specific onboard avionics capabilities that enable ADS-B Out (*K11.6-Avionics*). Additionally, the avionics that enable ADS-B Out and the process whereby aircrafts' time and position data are disseminated via satellite also needs to be added to the curriculum.

The addition of ADS-B Out to various aircraft could change operating and flight rule requirements as described in federal aviation regulations (*K12.3-Flight rules*). Any new aeronautical publications and ATC procedures that need to be implemented as a result of ADS-B Out will need to be taught (*K14-Knowledge of Aeronautical Publications and ATC Procedures and Directives*) along with all the Knowledge sub-categories (*K14.1-Types of aeronautical publications and ATC procedures and directives; K14.2-Purpose; K14.3-Authoritative source of information; K14.4-Location and format of current version; K14.5-Subject areas contained in each ATC publication; K14.6-Types of sensitive documents*) to ATCT controllers. Controllers need to be taught Knowledge of individual aircraft characteristics that represent unique equipage. More specifically, controllers will need to be taught the required components (*K16.2-Required Components*) of flight plan data and how to evaluate the impact of ADS-B equipage on providing ATC services (*K16.4-Evaluation Strategies*). This information is contained in the data block, and recognizing/understanding this information must be taught as part of Knowledge interpretation (*K19.4-Interpretation of information provided*).

To the extent that facilities gain new aircraft positional awareness as a result of ADS-B Out, the number of positively controlled aircraft being managed would increase, thus influencing flows. Controllers will need to be taught the new flows (*K18.18-Facility traffic flows*) and traffic patterns (*K18.19-Local traffic patterns*). New facility-specific directives and procedures, especially in areas that had little, no, or unreliable radar coverage before, will need to be taught to controllers (*K18.21-Facility specific directives and procedures*).

Increases in accuracy regarding the position of aircraft made possible by ADS-B Out could support the reduction of separation minima (*K21.2-Separation minima*), requiring controllers to learn the new separation minima. Controllers will also need to be taught new conflict resolution/separation strategies (*K21.3-Conflict resolution strategies*). For example, positive positional information available because of ADS-B Out will reduce the amount of airspace that is unused because controllers will no longer be required to obtain Instrument Flight Rules (IFR) cancellation notices. Consequently, controllers can begin using that unused airspace without having to wait for IFR cancellation notices from pilots or control facilities. Controllers will no longer be required to wait to release subsequent IFR departures, when previously they would have waited until the first aircraft was in an area of radar coverage. Instead, controllers will have accurate positional information from ADS-B Out, which they can substitute for radar coverage that will allow them to release the next aircraft. Finally, controllers will need to be taught new information to take into consideration when assuming the responsibility for aiding search and rescue operations (i.e., enhanced ability to locate ADS-B Out-equipped aircraft, *K27.4-Search and rescue*).

Changes to Properties of Knowledge

ADS-B Out will utilize latitude and longitude for geo-referencing. In addition, 4-dimensional way points (i.e., latitude, longitude, altitude, time) will be used much more often instead of identifying locations based on ground-based NAVAIDS or radar-identified positions. Consequently controllers will apply knowledge of geo-referencing more often (*K7.6-Geo-referencing*). Compulsory position reporting will be needed less often (*K7.7-Compulsory position reporting*) because controllers will know where the aircraft are even in areas with little, no, or unreliable radar coverage. ADS-B Out will decrease the frequency with which controllers apply Knowledge of altimeter setting (*K12.4-Altimeter setting criteria*), especially at higher altitudes, because these data are available to controllers via the satellite-based navigation system.

ADS-B Out reduces the aircraft's navigational reliance on ground-based NAVAIDs because positional data are available to them via a satellite-based navigation system. Consequently, knowledge of NAVAIDs will be used less often (*K18.7-Local navigation aids*). This is a substantive benefit because NAVAIDs are prone to outages due to malfunction, loss of power, and to atmospheric conditions such as weather. In addition, their reception is limited by terrain. Satellite-based technology like ADS-B Out will reduce the need for knowledge of backup systems (*K19.8-Backup systems*) during NAVAID outages. However, this Knowledge will still be needed during GPS outages or interferences. Finally, Knowledge of nonradar procedures (*K22.7-Nonradar procedures*) will be needed less often and Knowledge of radar separation services (*K22.6-Radar services procedures*) will be needed more often because ADS-B Out will provide the location of properly equipped aircraft on the radar/traffic display even in areas that previously had no, little, or unreliable radar coverage.

Changes to Curriculum Required to Teach Skills

Today's line controllers must be responsive and helpful to NAS customers during the course of their daily jobs (e.g., when responding to pilot requests for deviation). However, the implementation of ADS-B Out will increase the need for controllers to be skilled in providing service to properly equipped air carriers (*New Sk-Service Orientation*). They will need to provide the option of flying different types of routes (i.e., optimized routes) to ADS-B Out-equipped aircraft.

In addition, because ADS-B Out represents a shift from "first come, first served" to "best equipped, best served", controllers will need to be taught and to practice Skills in identifying the appropriate order of work Tasks under best equipped, best served circumstances (*Sk17-Task Prioritization*).

Changes to Properties of Skills
None.

Changes to Properties of Abilities
Once aircraft are equipped with ADS-B Out, their position will be displayed on controllers' radar/traffic display with other radar identified and ADS-B equipped aircraft. ATCT controllers must be able to adapt to the display that now has new information (*Ab24-Flexibility*). In addition, controllers will need to be able to profit from their own and others' experience (*Ab28-Learning*) regarding ADS-B Out.

Changes to Properties of Other Personal Characteristics
Accepting the risks associated with the job while still embracing its challenges (*O12-Risk Tolerance*) is an important Other Personal Characteristic currently for ATCT controllers. However, risk tolerance will increase in importance because of the potential reduction in aircraft-to-terrain and aircraft-to-aircraft separation standards. Also, controllers' belief that they have control over the outcome of events (*O14-Internal Locus of Control*) will increase in importance because it is vital for controllers to believe that maintaining separation is under their control instead of shifting responsibility to the pilot or to the automation.

Potential Driver-Induced Risks to Safety and Efficiency
The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 15 risks associated with ATCT NextGen Drivers is presented in Appendix B. Ten potential risks with regard to the implementation of ADS-B Out are:

- *Best Equipped, Best Served*: Not all aircraft will be ADS-B Out-equipped in the mid-term. Although ADS-B Out-equipped aircraft will be allowed to perform new operations as a result of this equipage, the risks associated with these operations are discussed in the context of specific Drivers and are described in other parts of this Section of the report.
- *Coordination of Multiple Stakeholders*: NextGen is affecting—and will continue to affect—numerous diverse stakeholders, including government entities, air carriers, operators, airport ground and ramp personnel, airport authority personnel, and the flying public. Significant intra- and inter-team coordination will be required to build and implement the ADS-B Out system and the accompanying policies and procedures that will govern its use. If this coordination is not handled effectively, it could result in inconsistencies and lack of standardization in the ADS-B Out system.
- *Deficiencies in Technology*: While ADS-B Out technology remedies some of the vulnerabilities in existing technologies, to the extent that ADS-B Out relies on

satellites, they are vulnerable to system interruptions from a variety of sources, including space weather and acts of terrorism. System interruptions are more likely to affect large service areas with potentially large numbers of controllers working across many facility boundaries being affected, as opposed to radar or NAVAID malfunctions that are likely to be more localized. In this case, it will be difficult for controllers to revert easily to backup procedures due to the wide outage area and the substantive amount of time that could potentially pass before the system is restored. Both of these risks could pose threats to safety and efficiency.

- *Degradation or Failure of Equipment or Systems*: System malfunctions may occur as a result of failure at the ground stations or global positioning satellites that enable transmission of ADS-B Out data to controllers' displays. In situations where the aircraft is flying in an area that is not covered by radar, this could result in aircraft dropping off the radar/traffic display.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities of ADS-B Out and any of its limitations may result in poor controller performance, which could increase the possibility of error and reduce safety and efficiency.
- *Mixed Aircraft Equipage*: ADS-B Out will not be installed on all aircraft. If controllers do not have access to current information about aircraft equipage, this could increase cognitive workload and decrease efficiency.
- *Poor Computer-Human Interface Design*: If the display that provides the line controller with information about aircraft equipage is not designed to present the information in a meaningful way (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), this could increase the possibility of error, thus reducing efficiency and safety.
- *Reduced Separation Minima*: The implementation of ADS-B Out theoretically supports a reduction in separation minima as a result of increases in certainty regarding aircraft position. As a result, controllers will need to remediate conflicts more quickly, which may require more precise and timely judgments. If conflicts are not remediated in time, loss of life or property may result.
- *Skill Decay*: Implementation of ADS-B Out as aircraft equipage has the potential for decay of the Skills required for managing traffic using nonradar procedures. The result is lack of preparedness by line controllers and reduction in safety during unusual situations, when the automation is either not functioning (e.g., system outages) at all or is providing inaccurate information.
- *Technology Development and Maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is highly unlikely that the components of the ADS-B Out system will be released into the NAS with known deficiencies, the full impact of using it in an operational context may not realized until the system goes "live." For example, the system may not have reliable interoperability with other systems. In addition, it is not until technologies are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

Note that ADS-B Out provides accurate information to controllers, but unless data are fed into the radar display, ADS-B Out has little direct impact on controllers' job Activities and/or KSAOs. Furthermore, increases in the accuracy of surveillance data is generally expected to increase safety and efficiency. More specifically, knowing with greater certainty where aircraft are increases controllers' situation awareness and hence their confidence in data. This may allow controllers to work more quickly and efficiently, as it will be less important to spend substantive amounts of time verifying and re-verifying positional data for accuracy, especially in areas that previously had little, no, or unreliable radar coverage. Increased accuracy and confidence in data also improves decision-making for line controllers.

The impact of ADS-B Out will be felt primarily by controllers who currently manage airspace with no, little, or unreliable radar coverage. Finally, controllers can be flexible in routing these aircraft through airspace with little, no, or unreliable radar coverage and will be less dependent on existing ground-based radar stations or NAVAIDs.

Driver 4—Data Communication

Data Comm is a digital communication system that controllers will use to communicate with pilots flying aircraft that have been equipped with Data Comm capabilities. The Data Comm system consists of multiple ground and airborne sub-systems that will aid controllers in sending data messages to pilots, thus reducing the volume of and reliance on voice communications via radio. Data Comm will provide a multitude of benefits to controllers at the nation's busiest airports. For example, Data Comm will reduce the congestion of radio frequencies that is prevalent at the Core 30 airports (see Appendix D). Data Comm is also projected to reduce hear back/read back errors, thereby maintaining efficient communication between pilots and controllers, and also lessening system errors.

Overview of Changes From Implementing Data Communications

The following table provides a visual summary of the changes that will occur as a result of implementing the Data Comm system. Additional details regarding these changes can be found in the sections that follow.

Table 12. Overview of the Impact of Data Comm

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:	Add: • Evaluate the situation to determine if and when to use data communication (*New T)* • Establish data communications with pilots (*New T)* • Verify accuracy of data communication messages (*New T)* • Evaluate the status of data messages in the queue (*New T)* • Prioritize data messages (*New T)* • Verify the communication loop is complete (*New T)* • Manage the interaction between radio and Data Comm systems (*New T)* • Override a message if necessary (*New T)*	Add: • ATC automation (*New K*) • Interoperability (*New K*)	Add: • Service Orientation (*New Sk*) Modify Definition: • Sk10		Add: • Technology Acceptance (*New O*)	Add: • Data Comm (*New TE*)
Driver otherwise affects existing Task or KSAO:	T3 T157 T7 T173 T8 T179 T10 T182 T11 T195 T20 T199 T21 T201 T25 T202 T29 T203 T32 T221	K5.1 K5.2 K10.1 K10.2 K10.3 K10.4 K10.5 K11.6 K16.2 K16.4	Sk1 Sk3 Sk4 Sk6 Sk10 Sk17 Sk18 Sk20 Sk24 Sk26	Ab1 Ab2 Ab3 Ab4 Ab5 Ab11 Ab14 Ab23 Ab24 Ab28	O4 O14	

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	T33	T223	K18.17	Sk52	Ab33		
	T34	T225	K19.1	Sk53	Ab34		
	T35	T226	K19.2	Sk54	Ab35		
	T36	T233	K19.3				
	T37	T234	K19.4				
	T38	T235	K19.5				
	T39	T237	K19.6				
	T40	T248	K19.7				
	T41	T252	K19.8				
	T42	T263	K20.1				
	T43	T264	K20.2				
	T45	T276	K20.3				
	T48	T294	K20.4				
	T85	T298	K20.5				
	T90	T303	K22.3				
	T98	T308	K22.4				
	T116	T315	K22.10				
	T136	T323	K22.11				
	T148	T360	K22.12				
		T362	K27.5				
		T364					
		T366					
		T373					
		T375					
		T378					
		T379					

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how* Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List

The implementation of Data Comm does require changes to Tasks in one of the 11 job Activities:

- Activity 2. Manage Communications

Activity 2. Manage Communications

Because not every pilot-controller communication will be achieved via Data Comm in 2018, establishing and terminating radio communications and all of the Tasks associated with it will still have to be performed for every aircraft. However, additional Tasks associated with the Data Comm process and issuing the Data Comm messages will also have to be performed. These new tasks will need to be added to Activity 2 (*A2-Manage Communications*). More specifically, these include new Tasks associated with evaluating the situation to determine whether and when to use data communications (*New T*) and establishing data communications with pilots (*New T*). Controllers will need to perform Tasks for verifying the accuracy of Data Comm messages before transmission (*New T*), evaluating the status of Data Comm messages as they are listed in a queue (New *T*) that will be created for delivery, prioritizing these messages (*New T*), sending, and then verifying the receipt of the messages in order to complete the communications loop before "closing out" the Task (*New T*). Finally, controllers will need Tasks to manage the interaction between radio and Data Comm systems (*New T*) in order to override and intercept Data Comm messages with radio messages and vice versa (*New T*).

Changes to How Tasks Are Performed

In addition to requiring an expansion of the list of Tasks, the implementation of Data Comm is projected to also affect *how* controllers perform the following 10 job Activities. Note that an impact on Activity 2 (*A2-Manage Communications*) is described for this Driver because the basic communication process will be changed. This is in contrast to other Drivers that only have an impact on specific communications and that do not identify this Activity as being affected. AIR proposes that Data Comm will most directly affect ten of the 11 ATCT job Activities:

- Activity 1: Establish Situation Awareness
- Activity 2: Manage Communications
- Activity 3: Manage Flight Plan Data
- Activity 4: Manage Air Traffic
- Activity 5: Resolve Conflicts
- Activity 6: Manage Departing and Arriving Traffic
- Activity 7: Transfer of Radar Identification
- Activity 8: Assess the Impact of Weather
- Activity 9: Manage Airspace and Movement Areas
- Activity 11: Respond to Emergencies and Unusual Situations

Activity 1: Establish Situation Awareness

Assuming that the Data Comm system allows line ATCT controllers to input personal preferences, such as the use of color or the order of messages in a queue, Data Comm will increase the time required for controllers to adjust the workstation (*T7*) and to check the workstation's configuration (*T8*). In addition, assuming that equipage information is encoded in some way into the datablock, controllers will require more time scanning to gather information about whether aircraft are Data Comm-equipped (*T11*).

ATIS information will be sent out via Data Comm when possible. Consequently, controllers will have to update the ATIS broadcast in the Data Comm system (*T10*). Controllers will have to monitor the Data Comm system for system status (*T20*) and they may also receive equipment and automation status information (*T21*) about Data Comm. This availability of extra information will result in additional time required to receive (*T3*) or to give a position relief briefing (*T25*).

Activity 2: Manage Communications
There is the potential for the total number of clearances, instructions, or other messages to be composed and sent will be reduced because controllers can now compose a message one time and send it to multiple aircraft simultaneously. Consequently, the Tasks associated with issuing clearances, instructions or other messages will be performed less often (*T32-T43*). The clearances, instructions, or other messages that are required could be sent either via radio communications as they are today, or via data communications, or by a combination of both of these methods. Data Comm will reduce how often controllers have to perform hearback/readback Tasks (*T37, T38, T40, T41*) and the number of corrections (i.e., restating clearance, instruction, or message if required) that have to be made (*T39*) due to hearback/readback errors. However, Data Comm will create the need to correct errors that occur due to the improper entry of messages (*New T*).

In addition, when controllers are issuing the most current ATIS information, they will be doing so via Data Comm whenever possible (*T29*).

Activity 3: Manage Flight Plan Data
Because not all aircraft will be equipped with Data Comm, controllers will have to consider this when evaluating flight plans (*T45*). For example, to the extent that airspace is restricted only to aircraft that are equipped with Data Comm, controllers would need to know this to determine whether a particular route or usage of airspace is possible. Controllers will also be able to issue flightplan clearances via Data Comm to appropriately equipped aircraft (*T48*).

Activity 4: Manage Air Traffic
Depending on time constraints, the nature of the control instructions, and aircraft equipage, controllers could issue control instructions for visual and radar separation of aircraft (*T85*) or nonradar separation of aircraft (*T90*), and respond to pilot requests for flight path deviations (*T116*) via data communications, radio communications, or both. Controllers may use Data Comm when coordinating special operations (*T98*). For example, they can issue a single message to multiple aircraft or communicate with a single aircraft more discretely.

Activity 5: Resolve Conflicts
Controllers will be able to issue messages simultaneously to multiple aircraft if they are Data Comm-equipped. This capability may help when resolving conflicts between aircraft, as controllers will be able to issue advisories or alerts simultaneously to all other aircraft that are not involved in conflicts (*T136*). They can thereby focus only on aircraft that need immediate assistance. Additionally, controllers will be able to issue advisories while performing unsafe altitude (*T148*), airspace violation (*T157*), and unsafe condition (*T173*) resolutions via data communication messages simultaneously to multiple aircraft. Data Comm messages are not likely to be used during communication with aircraft involved in a potential or actual conflict due to the latency associated with the delivery and receipt of Data Comm messages.

Activity 6: Manage Departing and Arriving Traffic
If aircraft are appropriately equipped and the messages are not time critical, then instead of issuing clearances and revisions via voice communications, controllers may be able to issue these messages via Data Comm. Consequently, controllers may receive requests for taxi instructions via Data Comm (*T179*). In addition, when issuing taxi instructions to sequence departures to

optimize flow (*T182*), controllers may send Data Comm messages instead of using voice communications. Controllers may also issue current departure information (*T199*) via Data Comm. Finally, although it is unlikely that these messages would be sent only via Data Comm, control instructions issued prior to takeoff (*T201),* departure instructions (*T202*), or the actual takeoff or amended takeoff clearance *(T195, T203*) may be issued via Data Comm to augment the voice message.

Data Comm may also be used to assist controllers with arrivals. Controllers may receive requests for arrival instructions from pilots (*T221*), may verify that pilots have the appropriate arrival information (*T223*), and may issue appropriate traffic information (*T225*) via Data Comm. Although it is unlikely that controllers will issue arrival instructions (*T226*) solely via Data Comm, they may issue these messages via Data Comm to augment voice communication.

Finally, Data Comm may be used to assist controllers with flow constraints. They may inform pilots of estimated departure clearance times (*T233*), issue instructions for gate holds (*T234*), advise pilots of ground delays (*T235*), or issue taxi instructions to achieve the desired sequence (*T237*). To the extent that the cancellation of a Traffic Management Initiative requires communication with aircraft, it will also affect how controllers issue instructions to comply with TMIs (*T248*) and coordinate cancellations of TMIs with others (*T252*).

Activity 7: Transfer of Radar Identification

Although the actual transfer of radar identification occurs between two controllers, controllers may have to issue control instructions to aircraft as a result of the timing or terms of transfer. Data Comm could be used to issue these control instructions to pilots. If aircraft are appropriately equipped and the required messages are not time critical, controllers can issue messages associated with a manual handoff (*T263*), a redirect from airspace (*T264*), and as the result of a rejected pointout (*T276*) via Data Comm.

Activity 8: Assess the Impact of Weather

ATIS messages may be updated by data input (*T294*) and disseminated (*T303*) via Data Comm to appropriately equipped aircraft. If aircraft are appropriately equipped and the required messages are not time critical, controllers can solicit (*T298*) and disseminate PIREPs and other severe weather information (*T303*) via Data Comm.

Activity 9: Manage Airspace and Movement Areas

Lastly, when managing airspace and movement areas, if aircraft are appropriately equipped and messages are not time critical, controllers can issue messages regarding temporary release of airspace or movement areas (*T308*, *T315*) via Data Comm. In addition, instructions concerning changes in airspace and movement area status (*T323*) may be issued via data communications rather than voice communications.

Activity 11: Respond to Emergencies and Unusual Situations

Controllers will be able to use Data Comm to communicate during emergencies or unusual situations. Although controllers will not communicate with aircraft experiencing a time critical emergency or during a time critical unusual situation, they will be able to send messages to multiple aircraft simultaneously regarding the situation, to communicate discretely with a single aircraft, or to communicate with a "no radio" (NORDO) aircraft via Data Comm (*T360*, *T364*, *T366, T375, T378, T379*). Although an actual emergency would not likely be declared via Data Comm, this method could be used to provide supplemental information that is repetitive in nature (*T362*), thus saving time and allowing the controller to focus on the emergency aircraft. Similarly, it is unlikely that security notifications would be sent out solely via Data Comm, but controllers may issue them via Data Comm to supplement voice transmission (*T373*).

Changes to Characteristics Required of ATCT Controllers

When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing lists of KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List

There will be a few additions to the list of Knowledges, Skills, and Other Personal Characteristics. First, there will be a new Knowledge sub-category that captures general information about air traffic control automation (*New K-ATC automation*). This new Knowledge sub-category will be part of the high-level category for aviation human factors. Data Comm will also require the addition of another new Knowledge (*New K-Interoperability*) that will capture information regarding how the facility Tools and Equipment will work together once Data Comm is implemented.

Second, the implementation of Data Comm will require modifying the definition of reading comprehension Skill (*Sk10-Reading Comprehension*) from its current focus on static documents such as regulations and operating procedures to include dynamic text-based air traffic information. Finally, implementation of the Data Comm system will require the addition of a new Other Personal Characteristic to capture the requirement for ATCT controllers to have positive attitudes toward and be willing to use Data Comm technology (*New O-Technology Acceptance*) to take advantage of its positive benefits. In order for controllers to use Data Comm to perform their jobs efficiently, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges

The implementation of Data Comm will require new course curriculum to teach controllers about the new Knowledge topic regarding ATC automation. Relevant content for this topic area would include evolution of ATC automation, risks (e.g., improper reliance on automation) and benefits (e.g., freeing up cognitive resources that are taken up by performing repetitive Tasks). Also, automation design considerations including appropriate allocation of Tasks to people and to machines, importance of the DST vs. decision-making tool DMT continuum, need for evaluation strategies based on whether the tool is DST vs. DMT, and the concept of what algorithms are and how they apply to operations would be added to the category.

Controllers will also need to be taught about the architecture of this new communication system (*K10-Knowledge of Communication Systems Architecture*), including all the sub-categories associated with this Knowledge (*K10.1-Types of communication systems; K10.2-Fundamentals; K10.3-Components; K10.4-Utility; K10.5-Limitations*). Controllers will also need to learn about the specific types of both data communication system and subsystem capabilities that may be installed on aircraft (*K11.6-Avionics*). This is important because there may be different types of data communication systems with different operating capabilities. Controllers will need to understand these differences to interact with them effectively.

In addition to understanding the possible different types and capabilities of onboard Data Comm systems that represent unique equipage, controllers would be taught about Data Comm as a required component of flight plans (*K16.2-Required components*). Controllers would also need to be taught strategies for taking aircraft equipage into consideration when evaluating flight plans (*K16.4-Evaluation strategies*). The data block itself would be taught as part of Knowledge about the information provided by the tool/equipment (*K19.4-Interpretation of information provided*).

Furthermore, controllers will need to be taught facility specific directives and procedures (*K18.17-Facility specific directives and procedures*) such as Letters of Agreement (LOAs), Memoranda of Understanding (MOUs), and other directives associated with the use of Data Comm. Controllers will need new training curriculum regarding how to operate Data Comm equipment (*K19-Knowledge of Facility Tools and Equipment*). In particular, controllers will need to learn all of the sub-categories (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators; K19.7-Minor troubleshooting; K19.8-Backup systems*) associated with the Knowledge of facility Tools and Equipment. In addition to learning new content regarding the existing Knowledge subcategories, controllers will also need to be taught new curriculum for the new Knowledge sub-category regarding how Data Comm will work in conjunction with other existing facility Tools and Equipment (*New K-Interoperability*). In the case of Data Comm, this would include information regarding when to use the Data Comm system and when to use radio communications, as well as procedures for when and how to override previously sent messages.

Along with learning how to use the Data Comm system, controllers will also need to be taught Data Comm processes. This includes all the sub-categories under the Knowledge category for ATC communication processes (*K20.1-Types of ATC communications; K20.2-Components of each type of communication; K20.3-Proper phraseology; K20.4-Roles and responsibilities of communicators; K20.5-Communication procedures*). For example, new phraseology may have to be taught to controllers for situations that do not exist today (i.e., when overriding a previously sent Data Comm message with a voice communication or vice versa). Depending on whether and how the capability for data communication messages to be tracked is developed (e.g., the capability could be a list), controllers may need to be taught new scanning strategies (*K22.3-Scanning strategies*), such as what information to look for, where, and how often to scan.

Controllers will also need to be taught new Knowledges associated with providing ATC services, including composing clearances and control instructions (*22.4- Procedures for composing clearances and control instructions*), as well as new strategies for severe weather avoidance (*K22.10-Strategies for severe weather avoidance*), such as using data communications to send a weather-related messages to all aircraft in the area. However, Data Comm messages will not likely be sent to the aircraft being diverted because these would likely be time-critical messages. Controllers may also need to learn new requirements for transferring control of aircraft (*K22.11-*

Transfer of control requirements) and for transferring communication of aircraft (*K22.12-Transfer of communication requirements*), as they are no longer restricted to voice communications for issuing the change of frequencies.

Moreover, controllers may need to be trained on how to most effectively use Data Comm during emergency situations (*K27.5-Emergency assistance techniques*). For instance, controllers could use Data Comm to communicate information quickly to other aircraft not in distress by sending the same message to multiple aircraft simultaneously. Controllers could also use Data Comm to communicate with aircraft who are “no radio” (NORDO) or to selectively communicate with only one aircraft without requiring the pilot to make numerous radio frequency changes.

Changes to Properties of Knowledges
Because of latency in the delivery and receipt of Data Comm messages and the resulting Task fragmentation, Knowledge of human cognition (*K5.1-Human cognitive performance limitations*) will be important. For example, data communication will push the limits of working memory as Data Comm messages do not “complete” the communication loop right away as voice messages do; hence, these limitations become more important. Similarly, to the extent that controllers will have to input data/type free text messages, Knowledge of the physical limits as they apply to typing/data input (*K5.2-Human physical performance limitations*) will also become more important.

Implementation of Data Comm will increase the importance of understanding onboard avionics and their capabilities (*K11.6-Avionics*) as well as increase the importance of knowing which specific aircraft are Data Comm-equipped, which is contained in the flight plan (*K16.4-Evaluation strategies*) and is also likely in the data block (*K19.4-Interpretation of information provided*).

Changes to Curriculum Required to Teach Skills
Today’s line controllers must be responsive and helpful to NAS customers during the course of their daily jobs (e.g., when responding to pilot requests for deviation). However, the implementation of Data Comm will increase the need for controllers to be skilled in providing service to properly equipped air carriers (*New Sk-Service Orientation*). For example, Data Comm-equipped aircraft may be enabled to fly certain routes that were previously restricted due to radio navigation and voice communication limitations.

In order to minimize the effects of Data Comm message latency, controllers will need to be trained and will have to practice how to prioritize Tasks in terms of importance, time sensitivity, and best equipped, best served (*Sk17-Task Prioritization*). Controllers will also need to gain Skill at performing tasks at the appropriate time (*Sk18-Task Timing*), as it relates to the most efficient use of Data Comm systems. More specifically, controllers need to be trained in the Skill of timing when to send data communications so as to reduce the effects of message latency. Controllers will need to be taught Skill at conducting thorough and timely position relief briefings that contain Data Comm system and message information (*Sk20-Position Relief Briefings*).

Additionally, because Data Comm is a new tool, controllers will need to be taught Skills associated with effectively using the Data Comm (*Sk52-Tool and Equipment Operation*), including its input devices, Skill at recognizing when the tool is not performing reliably or at all (*Sk53-Tool and Equipment Status Recognition*), and Skill at responding by conducting minor troubleshooting or engaging in backup procedures if the equipment fails or is functioning in a degraded manner (*Sk54-Tool and Equipment Degradation/Failure Response*).

Changes to Properties of Skills
Data Comm will increase the frequency and hence the importance of several Skills needed to deal with message latency. Skill at switching between Tasks (*Sk4-Task Switching*) will be more important because while controllers are waiting for Data Comm messages to be transmitted, acknowledged, and read, they will likely need to move on to other Tasks. Similarly, it is likely that while controllers are performing other Tasks, they will be interrupted by receiving delayed message acknowledgements and other replies. Consequently, Skill at handling interruptions (*Sk6-Interruption Recovery*) will be needed more frequently.

The implementation of Data Comm will increase the frequency and hence importance of several Skills needed to send and receive messages. Skill at reading and understanding air traffic information (*Sk10-Reading Comprehension*) will become more important because controllers will be reading more information, as opposed to simply hearing and responding to verbally transmitted information. Skill at combining various elements identified during the operational scan to form a meaningful picture (*Sk26-Operational Comprehension*) will increase in frequency because of the addition of data messages that must be scanned. Skill at inputting data (via keyboard or other data entry device), which is part of tool and equipment operation (*Sk52-Tool and Equipment Operation*), will become more important because controllers will have to input messages much more often.

Conversely, Data Comm will likely decrease the frequency of several Skills. Because Data Comm will require using verbal control instructions less frequently, it will decrease how often controllers verbally communicate instructions (*Sk1-Oral Communication*) and how often they must attend to what others are saying during air traffic communications (*Sk3-Active Listening*). Skill at picking up on subtle verbal cues (*Sk24-Cue Recognition/Comprehension*) will not likely be used as often with Data Comm, as controllers will not be able to hear the sender's voice when using Data Comm.

Changes to Properties of Abilities
Data Comm will increase the importance of several Abilities. The Ability to communicate information and ideas in writing (*Ab2-Written Expression*) as well as read and comprehend information in writing (*Ab3-Written Comprehension*) will increase in importance because so much more air traffic information will be communicated through text instead of verbally. Data Comm will require controllers to process more information visually and, hence, will increase controllers' Ability to perceive visual information quickly and accurately and to perform simple processing Tasks (*Ab11-Perceptual Speed and Accuracy*).

The effect of Data Comm on working memory (*Ab14-Working Memory*) is mixed. More specifically, demands on working memory will become more significant because the communication process is fragmented and the cues that exist in radio communications (i.e., characteristics of pilot's voice) that serve as a memory aid for the communication or aircraft it was associated with will not be available in Data Comm. This puts additional burden on controllers' memory. However, demands on working memory will decrease to the extent that controllers will not have to remember what data communication messages were sent to what aircraft, as there will be a virtual record of it in Data Comm.

Abilities associated with shifting rapidly between Tasks and the source of information (*Ab34-Time Sharing*), and returning to work quickly after being interrupted (*Ab33-Recall from Interruption*) will become more important because the communication process is fragmented by the Data Comm message latency. There will be increased importance for controllers to identify and correct errors in Data Comm messages (*Ab23-Attention to Detail*) before they are sent. Additionally, the Ability of controllers to use their hands and fingers to type or use data input devices (*Ab35-Wrist/Finger Speed*) will increase in importance because Data Comm messages will require some data input.

While the Ability to adapt to changing circumstances (*Ab24-Flexibility*) and the Ability to profit from experience by applying lessons learned on the job (*Ab28-Learning*) are required for all Drivers, they are especially true for Data Comm in the ATCT environment. Controllers will have to be willing to learn the Knowledge and Skills associated with Data Comm. Similarly, they will need to be flexible and willing to use this new tool in their work Tasks. Controllers who do not possess these Abilities may take longer to fully embrace Data Comm.

Finally, the implementation of Data Comm will reduce the usage of certain Abilities. More specifically, because Data Comm systems will increase the usage of written communication, it will decrease how often controllers use their Ability to communicate (*Ab1-Oral Expression*), perceive (*Ab4-Verbal Reasoning*), and listen to and understand (*Ab5-Oral Comprehension*) key ideas verbally.

Changes to Properties of Other Personal Characteristics

Data Comm will require that controllers carefully check over text messages for mistakes before transmission, hence increasing the importance of being conscientious as an Other Personal Characteristic in all Tasks associated with sending data communication messages (*O4-Conscientiousness*). Data Comm will also increase the importance of internal locus of control (*O14-Internal Locus of Control*) because controllers need to see themselves as being in control of the technology and, hence responsible for outcomes instead of simply responding to the technology or situational outcome.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 15 risks associated with ATCT NextGen Drivers is presented in Appendix B. Although Data Comm supports many benefits, it also creates 12 potential risks. These risks are presented below:

- *Best Equipped, Best Served Strategy*: The best equipped, best served (BEBS) strategy is proposed to require controllers to give preference to appropriately equipped aircraft in certain situations. However, the requirement for controllers to consider BEBS in addition to the more critical considerations of safety and efficiency when engaging ATC Tasks may lead to increased cognitive workload and thus could increase the possibility for error.

- *Change in Culture*: Incumbent and incoming line controllers will need to demonstrate willingness to learn to use Data Comm for communicating with aircraft under certain circumstances. A lack of interest in learning and using Data Comm may lead to underutilization and also the creation of very different classes of controllers within a facility (i.e. early adopters versus late or non-adopters) which may reduce efficiency and could increase the possibility of making an error.
- *Coordination of Multiple Stakeholders*: NextGen is affecting—and will continue to affect—numerous diverse stakeholders. Significant intra- and inter-team coordination will be required to build and implement the Data Comm system and accompanying policies and procedures that will govern its use. If this coordination is not handled effectively, it could result in lack of standardization in the design, implementation, or use of Data Comm system. This decreases predictability, which poses a threat to safety and could reduce efficiency as controllers work to adapt to the inconsistencies.
- *Deficiencies in Technology*: Latency or delay in Data Comm message transmission and response will shift controllers away from a synchronous type of communication (e.g., instant messaging) and toward an asynchronous type of communication (e.g., email). The asynchronous type of communication will fragment controllers' flow of work Tasks and will introduce work interruptions, which may reduce efficiency and increase the possibility for error. In addition, it may increase the possibility of miscommunication or communication interruptions resulting from delayed messages and could reduce safe and effective operations.
- *Degradation or Failure of Equipment or Systems*: If the Data Comm system fails or degrades, controllers will have to revert to radio communications. This shift to pass information previously sent over Data Comm that is now required to be sent over radio will be more time-consuming and create a new interruption to the work flow, which will reduce efficiency and increase the possibility for error.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities of the Data Comm and any of its limitations may result in poor controller performance in communication management, and thus reduce efficiency and increase the possibility of error.
- *Loss of Party Line Information*: A loss of party line information—information that is available to multiple pilots via the radio when a single controller is interacting with a pilot—is expected as a result of the use of Data Comm. This loss of shared situation awareness could result in controllers having to communicate separately with many pilots. This could also have a negative impact on safety, as some information may be omitted altogether.
- *Mixed Aircraft Equipage*: Data Comm will not be installed on all aircraft. If controllers do not have easy access to near real-time and current information on their displays regarding aircraft equipage, this could increase cognitive workload and decrease efficiency. Additionally, controllers will have to differentiate which is the most appropriate method of issuing instructions based on aircraft equipage. This could potentially further increase cognitive workload and further decrease efficiency.
- *Mixed ATC Tools, Equipment, or Procedures*: If Data Comm is not implemented in all ATCTs, or if it is implemented on a significantly different schedule, then the resulting differences in communication capability poses several risks, including the

inability to communicate across data systems, and difficulty in transferring aircraft across airspace boundaries. This could reduce efficiency and increase the possibility for error.

- *Poor Computer-Human Interface Design*: If the Computer-Human Interface (CHI) that provides line controllers with Data Comm messages is not designed to present the information in a meaningful way or is not well integrated into existing systems (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), this could increase the possibility for error, thus reducing efficiency and safety.
- *Skill Decay*: Data Comm will decrease the use of skills associated with creating and issuing clearances and instructions via radio, including skill at picking up subtle verbal cues from others. The removal of subtle but rich verbal cues may result in controllers being less adept at situation assessment and could lead to communication errors (e.g., when gathering information from pilots), both of which have a negative impact on safety and efficiency.
- *Technology Development and Maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is highly unlikely that Data Comm will be released into the NAS with known deficiencies, the full impact of using it in an operational context may be not realized until the system goes "live." For example, the system may not have reliable interoperability with other systems. In addition, it is not until technologies are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, then they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

Data Comm is projected to have a significant impact on the method by which ATCT controllers provide air traffic services. As long as the message is not time critical, any Activity that involves receiving information from pilots, issuing clearances or instructions, providing general information, or issuing advisories could be performed via Data Comm. Data Comm affords controllers the capability to issue longer, more complex messages because they do not rely on pilot or controller memory for readback or recall purposes.

There are situations when issuing instructions via Data Comm may not be appropriate. First, line controllers will still have the capability to issue longer, complicated, or nonstandard verbal messages via multiple radio transmissions instead of the Data Comm system. Controllers may prefer this because longer, complicated messages are work-intensive and prone to error. Second, latency in the delivery of a message makes Data Comm an inappropriate system for relaying certain time critical information. For example, during emergencies, conflicts, or situations of nonconformance to controller instructions, controllers will be unable to relay messages to pilots via Data Comm.

Data Comm adds new Tasks but does not delete any. Thus, its introduction results in an additional training requirement as well as an increase in mental workload of controllers who will be responsible for working with two forms of communication instead of one. Data input is more work-intensive than voice communications in terms of formulating, entering, verifying, and correcting mistakes. However, the implementation of Data Comm will result in reduced congestion on radio frequencies, which will lead to freeing up of communication channels for more important messages. Although the Data Comm system will reduce certain errors such as hearback/readback, it will simultaneously increase controller workload—and hence the possibility of error—through task fragmentation and task switching.

Data Comm is a substantively different and new technology that does not lower KSAO requirements but rather increases them. The mixed aircraft equipage and the usage of both data communications and radio communications are going to create special challenges for controllers. Data Comm will move controllers away from a synchronous type of communication (e.g., instant messaging) and toward an asynchronous type of communication (e.g., email). This shift towards asynchronous communications will mean a fragmentation in controllers' flow of job Tasks and an increase in the possibility for error. This means that Data Comm may initially make the job harder, but this negative impact should lessen over time as controllers become more knowledgeable and skilled at using the tools and at working with both modes of communication together. Furthermore, the work environment may become less diverse and more tedious because the variation present in voice communications will be lacking.

To the extent that the Data Comm system in mid-term 2018 is going to be confined to short, simple, routine messages that are less prone to error and that are not time-critical, the overall impact of Data Comm is likely to be positive in terms of reducing workload and error. In addition, because intent data will now be part of the system, Data Comm will increase standardization and predictability for system operators.

DRIVER 5: INTEGRATED ARRIVALS, DEPARTURES, AND SEQUENCES

IADS is an information sharing concept that provides terminal controllers with integrated arrival, departure, and taxiway scheduling to help establish shared situation awareness and to help ATCT line controllers better plan for and execute arrival Activities. Note that IADS is supported by DSTs that are likely to be a part of TFDM. The impact of those DSTs is described in the section below on TFDM.

Overview of Changes From Implementing IADS

The following table provides a visual summary of the changes that will occur as a result of implementing IADS. Additional details regarding these changes can be found in the sections that follow.

Table 13. Overview of the Impact of IADS

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:						
Driver otherwise affects existing	T3 T11	K18.5 K19.4	Sk1 Sk3	Ab1 Ab4		

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Task or KSAO:	T12 T13 T14 T16 T25 T180 T181 T193 T215 T229 T236 T243 T245 T305 T313 T319	K22.3 K22.13 K24.5 K24.10 K25.5	Sk22 Sk23 Sk35 Sk36 Sk37 Sk38 Sk39 Sk40	Ab5 Ab24 Ab28		

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how* Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List

None.

Changes to How Tasks Are Performed

Although IADS is not proposed to require adding to, deleting from, or modifying the language in the existing Task list, it will likely change, however, *how* controllers perform certain Tasks. AIR proposes that IADS will most directly affect the following three of the 11 ATCT job Activities:

- Activity 1: Establish Situation Awareness
- Activity 6: Manage Departing and Arriving Traffic
- Activity 9: Manage Airspace and Movement Areas

Activity 1: Establish Situation Awareness

IADS will provide ATCT line controllers with new integrated information about arrivals that is not currently available. It adds another source of information to be scanned and tracked by controllers to gain situation awareness, which could increase the time required to perform this Activity (*T11-T14*). Further, this will add another element to the control environment, increasing the number of items that are included in and, consequently, the time spent on, receiving (*T3*) or conducting a position relief briefing (*T25*).

On the other hand, many previously disparate pieces of information will be integrated and combined, which should reduce the amount of time required to gather and interpret information from different sources (*T11*, *T16*). The integrated information may increase the efficiency of controllers by reducing information redundancy.

Activity 6: Manage Departing and Arriving Traffic
The primary effect IADS will have on managing departing and arriving traffic is the new shared situation awareness between terminal controllers of the interaction between arrivals, departures, and surface operations. ATCT controllers will use the more up-to-date predicted and actual departure and arrival times when evaluating the control environment to determine optimal flow of departure traffic (*T180*). This information will also augment the process of determining sequences (*T181)* and spacing (*T193*). This will enable controllers to fill in more slots in the flow, which will reduce delays and conserve NAS resources.

ATCT controllers will have to coordinate less frequently with other controllers both within and between facilities (*T229*) to coordinate the landing sequence, resulting in a reduced workload for controllers and a conservation of controller resources. For instance, go arounds/missed approaches that have to be reentered into the TRACON's flow will be part of the shared information. ATCT controllers will still have to coordinate go arounds/missed approaches with TRACON controllers. However, TRACON controllers may have access to information about the event when it occurs (*T215*).

When responding to flow constraints, IADS-provided information regarding predicted arrival times will help controllers to determine the departure sequence (*T236*). Similarly, having this information will also help controllers evaluate the impact of TMIs on traffic flow (*T243*) and to determine the appropriate action to bring aircraft into conformance with it (*T245*). For example, predicted information about departures and arrivals would assist the controller in determining which aircraft should be given priority to taxi or depart.

Activity 9: Manage Airspace and Movement Areas
Information regarding predicted departure and arrival times will aid controllers in determining the need for temporary release of movement areas (*T305*) and for evaluating the feasibility of releasing movement areas (*T313*). It will also help coordinate changes in movement area status or restrictions with others (*T319*).

Changes to Characteristics Required of ATCT Controllers

When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics or KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List
None.

Changes to Curriculum Required to Teach Knowledges
Although IADS will not require adding to, deleting from, or modifying the language in the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics required for ATCT line controllers, it will have an impact on training. First, ATCT controllers will need training in understanding how to use the data that IADS provides (*K19.4-Interpretation of information provided*) because these data are in many cases new to ATCT controllers. This knowledge will be taught as part of the facility Tools and Equipment Knowledge category, which is K19. Controllers will also need to be taught new scanning strategies (*K22.3-Scanning strategies*), both within the tool and as it relates to cross-tool scanning.

IADS may change what needs to be taught about providing ATC services. Because IADS will result in new information becoming available to controllers, such as runway configuration and taxi routing, controllers will need to be taught how to use this new information to enhance the provision of approach control services (*K22.13-Approach control service*) and for arrival sequencing (*K24.10- Arrival sequence*).

Changes to Properties of Knowledges
IADS will increase the importance of several Knowledges, including the airport diagram (*K18.5-Airport diagram*). IADS will provide ATCT line controllers with information about aircraft movement on surface areas depicted on the diagram (e.g., taxiways and runways) and controllers will be able to make better decisions if they have more accurate situation awareness. Knowledges about performance-based types of arrival routes (*K24.5-Area navigation [RNAV-enabled] arrival routes*) and departure routes (*K25.5-Area navigation [RNAV-enabled] departure routes*) will also increase in importance because these routes enable and support the IADS concept.

Changes to Curriculum Required to Teach Skills
Controllers currently retrieve information about each individual flight's initial Standard Instrument Departure (SID), route, fixes, and other information from paper or electronic flight strips. The implementation of IADS will allow departure optimization by the ground controller and the local controller at the runway (e.g., alternating SIDs) by providing them with more comprehensive information about all the flights in the departure sequence in a single source. New training curriculum will be required to teach controllers how to use this new IADS-provided information to develop, select, and implement sequencing strategies (*Sk35-Sequencing Strategy Development*, *Sk36-Sequencing Strategy Selection; Sk37-Sequencing Strategy Implementation*). They will also need to be taught how to use this information to develop, select, and implement spacing strategies (*Sk38-Spacing Strategy Development; Sk39-Spacing Strategy Selection; Sk40-Spacing Strategy Implementation*).

Changes to Properties of Skills
In addition to requiring changes in curriculum to teach Skills, the implementation of IADS will reduce how often controllers use several Skills. More specifically, the shared situation awareness produced by IADS will reduce the number of communications needed to gain information; more terminal controllers will have access to this information with IADS.

Consequently, controllers will need skill at communicating information verbally (*Sk1-Oral Communication*), between themselves and pilots and between themselves and other controllers, less often. Similarly, controllers will need skill at attending to what others are saying and taking time to understand the information (*Sk3-Active Listening*) less often because of the reduced number of communications. Skill at working collaboratively with other controllers will be used less often (*Sk22-Inter-position Teamwork*). Finally, IADS will also reduce how often skills associated with working together with other controllers to accomplish air traffic job tasks (*Sk23-Coordination*) are used. Again, controllers will need these skills less often because IADS will provide them with shared information and shared situation awareness.

Changes to Properties of Abilities

IADS will decrease the number of verbal communications as a result of electronic sharing of information. Consequently, IADS will reduce how often controllers need to be able to communicate information and ideas verbally (*Ab1-Oral Expression*), to perceive and understand principles governing the use of verbal concepts (*Ab4-Verbal Reasoning*), and to listen to and understand information and ideas presented verbally (*Ab5-Oral Comprehension*).

Controllers will need to be able to adjust and adapt to having IADS information at their workstations (*Ab24-Flexibility*). Controllers will also need to be able to learn the knowledge and skills associated with IADS and to apply lessons learned from experience using this new concept (*Ab28-Learning*). These abilities are already required in the present job, but they will be increasingly required in NextGen for all Drivers.

Changes to Properties of Other Personal Characteristics

None.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 15 risks associated with ATCT NextGen Drivers is presented in Appendix B. Six potential risks with regard to the implementation of IADS are:

- *Degradation or Failure of Equipment or Systems*: If there is degradation or failure in the IADS system, then controllers will have to revert to sequencing without the advantages of the additional information brought by IADS. The implementation of backup procedures will be less efficient and will increase the possibility of error, especially during the transition.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the procedures and information resulting from the implementation of IADS and of its limitations could result in poor controller decision-making with sequencing and prioritization, and underutilization of the tool's capabilities.
- *Mixed ATC Tools, Equipment, or Procedures*: If IADS is not implemented in the ATCT and its associated TRACON, or if it is implemented in different ways or on different schedules in the two facilities, then the benefits of shared situation awareness will not be realized.
- *Poor Computer-Human Interface Design*: IADS brings substantively more information regarding taxiway, departure, and arrival scheduling to the ATCT

controller. If the Computer-Human Interface (CHI) does not present the information in a meaningful way or is not well integrated into existing systems, this could result in delays and increase the possibility for error, thus reducing efficiency and safety. Because IADS provides a large volume of data, information presented to the controller via the CHI must be layered properly so it can be retrieved quickly and intuitively, and be easily distinguishable from other related information; and should be customizable via preference settings.

- *Skill Decay*: The implementation of IADS has the potential for the decay of the Skills required for sequencing traffic without the assistance of automation-provided information, including Skills associated with coordinating departure sequences with pilots and other controllers. The resulting lack of preparedness by line controllers could make them less efficient and error-prone when sequencing without the automation.
- *Technology Development and Maturation*: Although safety risk management analyses are required on new automation before implementation, new tools are often developed and tested as stand-alone systems. Although it is highly unlikely that IADS will be released into the NAS with known deficiencies, the full impact of using it in an operational context may not be realized until the system goes "live." For example, IADS may not have reliable interoperability with other air traffic concepts. In addition, it is not until IADS is fielded and is being used by controllers that it can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, then they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

Overall, IADS will improve efficiency of departures and arrivals, which increases throughput and conserves controllers' cognitive resources. It accomplishes this by providing ATCT line controllers with shared access to information, increasing their shared situation awareness with TRACON controllers, and introducing standardization of information between ATCT and TRACON line controllers.

IADS is still in the conceptual stage. As a result, AIR has estimated the impact of the concept on the KSAOs based on what is currently known. While the impact at the moment appears to be relatively small, it could increase once specific DSTs and equipment are developed to support it.

Driver 6: Terminal Automation Modernization and Replacement Program, Phase 3

TAMR 3 is an FAA initiative to replace or upgrade the primary radar display at TRACONs and associated ATCT facilities to STARS automation. Enhancements include addressing capacity limitations and creating an improved Computer-Human Interface. Additionally, the new display and processor will be compatible with NextGen technologies. More specifically, TAMR 3 will be capable of—and is anticipated to—incorporate Data Comm and the Electronic Flight Strip Transfer System (EFSTS). However, there is an overlap between TAMR 3 and TFDM; both platforms provide many of the same capabilities, including Data Comm and EFSTS. Consequently, these two platforms are unlikely to co-exist in the same facility due to redundancy in functionalities. For purposes of this report, AIR describes TAMR 3 functionalities and their impact on the job of the ATCT line controller in other sections of this report. Detail regarding Data Comm can be found in the section on Driver 4: Data Comm. The impact of EFSTS on the job of the ATCT line controller will be discussed in the TFDM section below.

Driver 7: Tower Flight Data Manager

Tower Flight Data Manager (TFDM) is a new automation platform. As described in Section IV, several current ATCT systems and sub-systems will be consolidated on this platform. In addition, new functionalities will be added, including Data Comm, EFSTS, and DSTs. The result is that a great deal of information will be available to controllers in one location. Controllers will be able to view many types of information on TFDM's multiple displays, including ground and airborne radar/traffic display, weather display, electronic flight strips, and DST displays. Once completed, TFDM will be the primary automation system at the line ATCT controllers' workstation. The consolidation of multiple independent systems into a single platform represents a significant change. TFDM is thus projected to transform how controllers manage and communicate air traffic information to FAA and non-FAA personnel. Recall that for purposes of this report, AIR describes the impact of data communications on the job of the ATCT line controller in detail in the section on Data Communications. Similarly, the impact of 4-D Wx Data Cube information and ASDE-X are described in their respective sections. Finally, ATCT controllers already have access to radar/traffic display information. Consequently, the text in this section is confined to the impact of EFSTS and the five proposed DSTs that will be available by 2018 on the job of the controller.

Overview of Changes From Implementing Tower Flight Data Manager

The following table provides a visual summary of the changes that will occur as a result of implementing TFDM. Additional details regarding these changes can be found in the sections that follow.

Table 14. Overview of the Impact of TFDM

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:			Add: • ATC Automation (*New K*) • Interoperability (*New K*)			Add: • Technology Acceptance (*New O*)	Add: • TFDM (New TE)
Driver otherwise affects existing Task or KSAO:	T3 T7 T8 T11 T13 T14 T20 T21 T25 T44	T181 T182 T184 T185 T186 T190 T191 T193 T200 T210	K16.3 K16.5 K16.6 K18.12 K19.1 K19.2 K19.3 K19.4 K19.5 K19.6	Sk1 Sk3 Sk5 Sk23 Sk25 Sk35 Sk36 Sk38 Sk39 Sk52	Ab1 Ab4 Ab5 Ab8 Ab16 Ab24 Ab28 Ab34	O14	

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	T45 T46 T47 T50 T51 T52 T53 T55 T56 T58 T59 T62 T63 T65 T66 T119 T134 T180	T227 T236 T237 T242 T249 T300 T305 T313 T319 T320 T329 T330 T332 T359 T363 T372	K19.7 K19.8 K22.3 K22.8 K24.1 K25.1 K25.2 K25.3	Sk53 Sk54			

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how* Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List

None.

Changes to How Tasks Are Performed

Although TFDM, as with several of the other Drivers described thus far, will not change the Tasks that are performed by ATCT controllers, it will change *how* the Tasks in the following six of the 11 ATCT job Activities are performed:

- Activity 1: Establish Situation Awareness
- Activity 3: Manage Flight Plan Data
- Activity 4: Manage Air Traffic
- Activity 6: Manage Departing and Arriving Traffic
- Activity 9: Manage Airspace and Movement Areas
- Activity 11: Respond to Emergencies and Unusual Situations

Activity 1: Establish Situation Awareness
TFDM is projected to increase the time controllers take to receive and give position relief briefings because the new functionalities will include new and additional information that must be relayed (*T3*, *T25*). In addition, because TFDM has so many components, its implementation will also increase the time required to check and personalize the workstation configuration (*T7*, *T8*).

TFDM will provide controllers with a new tool for scanning the control environment (*New TE*). Having all of this information at the workstation will simplify the scanning task; controllers will not be required to go to multiple places to gather information, which should reduce the amount of time required for these scanning Tasks (*T11*, *T13*, *T14*) However, TFDM will also increase the time required to scan because TFDM includes many new DSTs that do not currently exist for line controllers. Because TFDM has multiple displays, controllers may need more time to monitor its status (*T20*) or to receive information about its status (*T21*).

Activity 3: Manage Flight Plan Data
TFDM's Electronic Flight Strip Transfer System (EFSTS) will change the processing of flight plan data. The primary difference is that controllers will use the EFSTS instead of FDIO; the Tasks remain essentially the same. More specifically, controllers may receive flight plan requests (*T44*), evaluate flight plans, (*T45*), enter flight plans (*T46*), and evaluate plans for accuracy (*T47*) via EFSTS instead of FDIO. With regard to amending flight plans, controllers may receive requests for an amendment (*T50*), enter (*T51*) or update (*T53*) flight plan changes, and review amendments (*T52*). Finally, they may request a flight plan amendment (*T55*) or receive notice of a flight plan amendment status (*T56*) via EFSTS.

Controllers will no longer mark flight progress strips by hand, but rather will electronically transfer the flight information to the next controller. Controllers will receive or request the flight progress information electronically (*T58, T59*). Controllers will still utilize strip marking (*T62*) and sequence (*T63*) flight progress information, but they will do this via the EFSTS display as opposed to on the paper strip, although it is not currently known how data entry will be accomplished (e.g., touch screen, keyboard entry). The filing (*T65*) and forwarding (*T66*) of flight progress information will be done electronically.

Activity 4: Manage Air Traffic
The Taxi Route Generation DST is projected to monitor conformance to taxi routing. Consequently, this DST will provide another source of information to controllers regarding non-conformance situations (*T119*). The existence of this information on automation should aid controllers in identifying potential runway incursions in especially low visibility conditions, and represents another DST that helps controllers prevent runway and taxiway incursions.

Activity 5: Resolve Conflicts
The Taxi Route Generation DST monitors for conformance to the taxi route. Consequently, controllers will have an additional method for verifying pilot conformance with instructions (*T134*).

Activity 6: Manage Departing and Arriving Traffic
Currently, controllers evaluate the control environment and develop routing options independently. However, in the mid-term, the Taxi Route Generation, the Sequencing and Scheduling DST, and the Departure Routing DST will provide optimized taxiway and routing options, including options for sequencing and scheduling from the gate to the runway for controllers. Consequently, controllers will spend less time evaluating the situation (*T180*) and developing sequencing options (*T181*).

Because these DSTs provide optimized routing that will be dynamically updated (and fewer changes will be needed), the time spent coordinating with others, including the time spent coordinating sequences with others (*T184*) and time spent communicating with pilots regarding taxi instructions (*T182*), will be reduced. Because the options are generated by the DSTs, controllers will spend less time projecting ground traffic for sequencing (*T185*).

However, controllers will still be required to evaluate the quality of options provided by automation. Hence, controller workload may be changing but not necessarily increasing or decreasing.

The Taxi Route Generation DST will monitor for aircraft conformance to the taxi route and will provide an alert or alarm to notify controllers in the case of nonconformance. This will aid controllers in terms of observing the established traffic sequence to identify cases of nonconformance (*T186*), which adds another layer of safety. However, it adds another alert that they will have to differentiate from the already existing alarms in the work environment, which could increase cognitive workload.

Controllers will still receive flight progress information for departing aircraft and they will still review it. However, controllers will gather the electronic flight information from the EFSTS display for performing these two Tasks (*T190*, *T191*).

Controllers will use information provided by the Sequencing and Scheduling DST to assist them with determining the appropriate interval for departure (*T193*). In addition, the Departure Routing DST will help controllers to determine whether the runway environment is clear of traffic and weather, which will help them ensure that conditions are safe for takeoff (*T200*) and landing (*T227*).

To the extent that an aircraft takeoff cancellation results in the need for resequencing, respacing, or rerouting of aircraft on the airport surface, the Taxiway Route Generation, Sequencing and Scheduling, Runway Assignment, and Departure Routing DSTs will aid the controller in quickly adjusting the plan to accommodate required changes (*T210*).

When responding to flow constraints, the Sequencing and Scheduling DST will assist controllers in determining the optimal sequence (*T236*). Similarly, the Taxi Route Generation DST will assist controllers in determining the appropriate taxi instructions to establish the appropriate sequence (*T237*). Assuming that DSTs are capable of taking into account TMI restrictions, discussions with TMU regarding the impact of TMIs or reroutes will be eased due the substantive amount of information controllers will now have access to regarding routing (*T242*).

Finally, the Taxi Route Generation DSTs' conformance monitoring capability will assist controllers in verifying compliance with instructions (*T249*).

Activity 8. Assess the Impact of Weather
The Taxi Route Generation, Airport Configuration, and Runway Assignment DSTs will provide information that will aid controllers when discussing the actions needed in response to runway or taxiway changes (*T300*).

Activity 9: Manage Airspace and Movement Areas
Taxi Route Generation, Sequencing and Scheduling, Runway Assignment, Departure Routing, and Airport Configuration DSTs will provide information to controllers that will be useful in determining the need for (*T305*) and evaluating the feasibility of the temporary release of movement areas (*T313*).

The coordination of changes in the status (*T319*) or restrictions of (*T320*) movement areas will be more efficient, because controllers will have access to the same information about the DST recommended options regarding the movement of traffic on the airport surface. The Taxi Route Generation, Runway Assignment, and Airport Configuration DSTs will help controllers respond more quickly and with less effort to changes in runway conditions. Controllers will have access to new DST-provided information regarding the new runway and taxiway configurations (*T329*), which will help them to develop new aircraft taxiway routing (*T332*). In addition, it should reduce the coordination with others that is required to change the configurations (*T330*), as all ATCT controllers will have access to the new configuration on their TFDM displays.

Activity 11: Respond to Emergencies and Unusual Situations
Assuming that the Sequence and Scheduling DST allows controllers to input situational information such as the closure of a runway into the DST, these tools will assist controllers when resequencing traffic during emergencies (*T363*). In addition, DST-provided information may assist controllers in determining an appropriate plan of action for responding to emergencies (*T359*) and unusual situations (*T372*).

Changes to Characteristics Required of ATCT Controllers

When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics or KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List
TFDM does not require the addition of new Skills or Abilities, and it does not require editing or deleting existing Skills or Abilities. However, its implementation does require adding two new Knowledges. The first will capture human factors knowledge (*New K-ATC Automation*). The second captures information regarding how existing facility Tools and Equipment will work in conjunction with TFDM (*New K-Interoperability*). The introduction of TFDM also creates the

need to add a new Other Personal Characteristic that consists of positive attitudes towards, perceived usefulness of, and perceived ease of use of technology (*New O-Technology Acceptance*).

Changes to Curriculum Required to Teach Knowledges
New training content that should be taught as part of the new knowledge (*New K-ATC Automation*) includes: (a) Evolution of ATC automation; (b) Risks including Improper Reliance on Automation or Procedures; (c) Benefits of automation, including freeing up of cognitive resources so that controllers can focus on more complex tasks; (d) Automation design considerations, including appropriate allocation of Tasks to people and to machines; (e) DST and Decision-Making Tool (DMT) continuum; (f) Evaluation strategies based on the type of tool (DST vs. DMT); and (g) Algorithms. Note that this content is general in nature and is not designed to address the specifics of any given piece of automation; these specifics are already covered under the category that captures information about specific equipment that is at the facility (*K19-Knowledge of Facility Tools and Equipment*). In addition, controllers will need to be taught curriculum for the new Knowledge regarding how the new set of tools and equipment work in conjunction with the other facility Tools and Equipment *(New K-Interoperability).* In the case of TFDM, since so many sub-systems are being combined, curriculum would include information regarding how the various functionalities work together, including the relationship between weather as shown on the weather display and weather as shown on an overlay of the radar/traffic display (*New K-Interoperability*).

Controllers will also need to be taught new procedures associated with managing flight plan data using EFSTS, which could be taught as part of the existing knowledge category for flight plan data (*K16-Knowledge of Flight Plan Data*). More specifically, controllers will be taught new curriculum related to the filing process (*K16.3-Filing process*), to the processing of flight plans (*K16.5-Flight plan processing*), and to how the flight plan data will be displayed (*K16.6-Flight plan data display methods*) using the EFSTS.

Controllers will also need to be taught new training content particularly with regard to DSTs including: (a) types and functionalities of specific DSTs, (b) algorithms used by DSTs, (c) sources of information, including sensors (if relevant), (d) limitations of the sensors (if applicable), (e) operation of DSTs, (f) evaluation of DST options and whether/how to override them, and (g) degradation indicators of DSTs. This training curriculum will likely be taught as part of the current knowledge sub-category regarding interpretation of information from tools and equipment (*K19.4-Knowledge of interpretation of information provided*). In addition to learning about the new DSTs, controllers will need to be taught new curriculum regarding how to use TFDM more generally (*K19-Knowledge of Facility Tools and Equipment*) and all of the associated knowledge sub-categories (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators; K19.7-Minor troubleshooting; K19.8-Backup systems*).

As with other tools, the introduction of a new tool in the ATCT work environment will mean that controllers will need to know new scanning strategies (*K22.3-Scanning strategies*). That is, TFDM has many components and is primarily a “heads down” tool. Controllers will need to learn how to search the tool to find the information needed, how to optimally shift attention back between this tool and other "heads down" tools, and how to allocate attention to the "heads down" versus the OTW view.

Finally, the addition of the Departure Sequencing and Scheduling DST will result in the need for new training curriculum to teach controllers how to use DST-provided options to develop departure sequences (*K25.1-Knowledge of departure sequence*) and taxiway and departure routes (*K25.2-Taxi and Departure Routes*). Controllers will also need to be taught how to use information from the Airport Configuration DST to develop departure information to be broadcast or disseminated directly (*K25.3-Departure information*).

Changes to Properties of Knowledges

The addition of several DSTs in TFDM means that controllers will utilize the appropriate knowledge less often. Controllers will use Knowledge of how to identify current airport configuration less often because the Airport Configuration DST will provide this information (*K18.12-Airport configurations*). More specifically, the addition of the Taxi Route Generation DST will facilitate conformance monitoring; consequently controllers will use their knowledge of how to evaluate conformance less often (*K22.8-Conformance assurance*).

The addition of the Sequencing and Scheduling DST in TFDM will have a mixed effect on other Knowledges, especially those Knowledges associated with departure sequences (*K25.1-Departure sequences*). First, controllers will spend less time using their knowledge of how to generate sequencing options because these options will be generated by the DST. On the other hand, they will need to spend more time using their knowledge of how to evaluate and change (if required) sequencing options provided by the DST. Similarly, the addition of the Departure Routing Tool and the Taxi Route Generation tool will change two facets of taxi and departure routes (*K25.2-Taxi and departure routes*). First, it will allow controllers to spend more time using their knowledge of how to evaluate and change taxi and departure routes and, second, less time using their knowledge of how to generate taxi and departure route options.

Assuming that the Airport Configuration DST has access to all the pertinent information that will affect the airport's configuration (e.g., construction, obstacles, closures, weather, staffing issues, outages), then the addition of this tool will mean controllers will use their knowledge of integrating this information to reach optimum alternatives for arrivals (*K24.1-Approach/arrival information*) and departures (*K25.3-Departure information*) less often; the DST will help controllers make these determinations.

Changes to Curriculum Required to Teach Skills

The introduction of TFDM will require the addition of training content to teach several Skills. First, controllers may need to be taught Skills at applying scanning strategies (*Sk25-Strategic Scanning*) to quickly and accurately search for relevant information on TFDM. Further, controllers will need to be taught Skill in operating TFDM (*Sk52-Tool and Equipment Operation*), recognizing when the TFDM is failing or operating in a degraded mode (*Sk53-Tool and Equipment Status Recognition*), and responding to TFDM degradation or failure (*Sk54-Tool and Equipment Degradation/Failure Response*).

Changes to Properties of Skills
To the extent that all the ATCT controllers will have access to the same information, this may reduce the need for Skills associated with information exchange and relay. Skill at working with others and engaging in two-way exchanges of information to accomplish air traffic tasks (*Sk23-Coordination*) may be used less often. Similarly, Skills associated with verbally communicating information (*Sk1-Oral Communication*) will be used less often. Finally, Skill at attending to what others are saying, taking time to understand the information being relayed, and asking questions to clarify if necessary (*Sk3-Active Listening*) among the ATCT controllers will be required less often.

Because TFDM is proposed to have four displays, and because this new Tool must be used in conjunction with controllers' out-the-window view, its implementation will likely require an increase in how often controllers have to utilize their Skills in rapidly shifting their attention among sources of information (*Sk5-Attention Switching*).

Skills associated with sequencing and spacing will change because controllers will be evaluating strategies developed by DSTs rather than generating their own. Hence, Skill at developing the sequencing strategies (*Sk35-Sequencing Strategy Development*) and spacing strategies (*Sk38-Spacing Strategy Development*) will be required less often and Skill at evaluating and selecting a sequencing strategy (*Sk36-Sequencing Strategy Selection*) and spacing strategies (*Sk39-Spacing Strategy Selection*) will be different. That is, instead of evaluating the relative merits of their own self-generated strategies, controllers will need to either compare the strategies developed by the DST to their own preferred strategies, or compare the relative merits of the DST-generated options. The impact of the preferred approach likely depends to a large degree on the quality of the options provided by the DSTs and is hence unknown. However, the training curriculum will have to take these differences into consideration and will have to address them accordingly.

Changes to Properties of Abilities
The implementation of TFDM will decrease the number of verbal communications as a result of electronic sharing of information among ATCT controllers. Consequently, TFDM will reduce how often controllers need to be able to communicate information and ideas verbally (*Ab1-Oral Expression*), to perceive and understand principles governing the use of verbal concepts (*Ab4-Verbal Reasoning*), and to listen to and understand information and ideas presented verbally (*Ab5-Oral Comprehension*).

Because the DSTs associated with TFDM will generate at least the first set of options for many common Tasks, controllers may need to utilize the ability to quickly develop a large number of potential strategies (*Ab16-Fluency of Ideas*) less often.

TFDM will also increase the use of several Abilities. If the TFDM display(s) increases the use of color for coding information, which seems likely given the substantive amount of information that will be part of TFDM, then the Ability to detect differences between colors (*Ab8-Visual Color Discrimination*) will be required more often. Because TFDM will have multiple displays and a substantive amount of information, controllers will need the ability to shift quickly among multiple sources of information (*Ab34-Time Sharing*) more often as well.

Finally, controllers will need to be able to adjust and adapt to the changes that the implementation of TFDM will bring, including having a multi-display workstation (*Ab24-Flexibility*). Controllers will also need to be able to learn the Knowledge and Skills associated with TFDM and to apply lessons learned from experience using this new concept (*Ab28-Learning*).

Changes to Properties of Other Personal Characteristics

Having the belief that individuals have influence over outcomes of events (*O14-Internal Locus of Control*) is an important characteristic of today's ATCT controller, but it will become more important as a result of implementing TFDM, because controllers need to perceive that they have control over the technology and the situation, and are not simply responding to technology.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 15 risks associated with ATCT NextGen Drivers is presented in Appendix B. AIR identified 11 potential risks with regard to the implementation of TFDM. They are:

- *Change in Culture*: Incumbent and incoming line controllers will need to demonstrate willingness to learn to use DST-provided information when managing air traffic. A lack of interest in learning and using new DSTs may lead to underutilization of these tools, which may lead to inefficiency and an increase in the possibility of making an error in the selection of the best option.
- *Deficiencies in Technology*: If the DSTs do not take dynamic data regarding the overall operating environment (e.g., runway, closures, TMI restrictions) into account, then controllers will be required to return to manual processes for determining the best route, sequence, and spacing from the gate or the spot to the runway. In addition, if the algorithms used by the DSTs do not take the same or more information into consideration that controllers would when generating options, then controllers will be reluctant to use them. Both of these factors may result in the tools not being used to their full potential, which decreases efficiency and benefits from the investment in the automation.
- *Degradation or Failure of Equipment or Systems*: The implementation of TFDM is dependent upon many other systems, including ground-based, aircraft-based, and space-based equipment and systems. If there is degradation or failure in any of these, controllers will have to revert to backup procedures, many of which rely on older and inferior technologies and systems that are less efficient. In addition, controllers may be inefficient in their use, which has the potential to cause delays or increase the possibility of errors.
- *Improper Allocation of Tasks Automation*: The implementation of the Taxi Route Generation DST requires the allocation of monitoring conformance to the route Task to aircraft and facility automation. The result is that controllers will be monitoring aircraft in this stage instead of actually managing them. A potential risk is that, because human operators are not typically adept at monitoring and vigilance, this could result in inattention to the Tasks at hand, which poses a threat to safety.
- *Improper Reliance on Automation or Procedures*: If controllers do not feel comfortable using TFDM's DSTs, they may not fully utilize them. This could result

in unrealized benefits from the investment in the automation. Conversely, if controllers over-rely on the DSTs, they may simply accept DST-generated options without fully considering whether they represent viable options, which could negatively affect efficiency.

- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities of TFDM and of its limitations may result in inefficient controller decision-making, especially as it relates to the sequencing and spacing of aircraft. For example, the Sequencing and Scheduling DST will provide multiple options. Controllers need to understand the algorithms that are being used to create these options so that they may fully evaluate them for use in achieving their operational goals.
- *Mixed ATC Tools, Equipment, or Procedures*: TFDM will not be implemented in all towers, and in addition, it will likely be implemented on significantly different schedules and in different versions. This will create an added training requirement on the facility if controllers arrive at the facility without any training on this tool. This could increase the time required to certify controllers, thus reducing efficiency.
- *Poor Computer-Human Interface Design*: If the display that provides line controllers with potential sequencing and spacing options is not designed to present the information in a meaningful way (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), this could increase the possibility for error, thus reducing efficiency.
- *Skill Decay*: The implementation of TFDM's DSTs has the potential for the decay of Skills required for developing sequencing and spacing strategies that maximize throughput without automation. Any resulting lack of preparedness by line controllers to self-generate options could negatively influence their ability to evaluate the DST-provided options, or to self-generate options. This reduces efficiency and increases the possibility of errors.
- *Technology Development and Maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is highly unlikely that TFDM will be released into the NAS with known deficiencies, the full impact of using it in an operational context may be not realized until the system goes "live." For example, the system may not have reliable interoperability with other systems. In addition, it is not until technologies are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, then they will be unable to provide feedback that is vital to system evolution.
- *Unknown Impact of Experience*: Controllers with varying levels of experience may perform cognitive information processing involved in evaluating controller-generated versus DST-generated options differently. Until such differences, if any, are identified, it will be impossible to optimize training or utilization of TFDM's DSTs.

Driver Impact Summary

TFDM is a consolidation of multiple ATCT systems and sub-systems. The addition of new DSTs as part of TFDM will significantly impact ATCT controllers' job tasks and worker requirements, as well as lay a foundation for future DSTs. Note that Data Comm is part of

TFDM but, since AIR discussed it in an earlier section titled Data Comm, it is not summarized again here.

TFDM and more specifically, DSTs associated with it will change the assignment of work within the ATCT. For example, if the tower is operating three separate positions (i.e., flight data/clearance delivery, ground control, and local control), then the implementation of the TFDM DSTs related to taxi routes, sequencing/scheduling, runway assignment, departure routing, and airport configuration, is projected to shift to different controllers. To the extent the DSTs associated with TFDM are capable of providing more viable options, the tool increases efficiency. However, increased efficiency depends on how sophisticated the algorithm is to take into account more information, which controllers are otherwise able to perform mentally.

The addition of TFDM will result in increased situation awareness and more effective decision-making for controllers. In sum, DSTs provide controllers with optimized options. However, controllers will still be required to evaluate the quality of options provided by automation and to develop their own options if required. Hence, controller workload may be changing but not necessarily increasing or decreasing.

Driver 8: Wake Turbulence Mitigation for Departures

Wake Turbulence Mitigation for Departures (WTMD) is a set of procedures that will allow for reduced wake turbulence separation minima on closely spaced parallel runways (CSPRs) when there are favorable crosswind conditions. Specifically, WTMD is based on an automated algorithm that will use information from wind sensors on the airport surface and winds aloft forecasts to determine when ATCT line controllers can use reduced departure spacing on CSPRs. It will provide an indicator light on the display of controllers and supervisors indicating when conditions are favorable for reduced wake turbulence spacing, and when conditions are no longer favorable.

Overview of Changes From Implementing Wake Turbulence Mitigation for Departures

The following table provides a visual summary of the changes that will occur as a result of implementing WTMD. Additional details regarding these changes can be found in the sections that follow.

Table 15. Overview of the Impact of WTMD

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:	Add: • Coordinate the change in the separation minima with others (New T) • Check the WTMD indicator status (New T)	Add: • Interoperability (*New K*)			Add: • Technology Acceptance (*New O*)	Add: • WTMD Indicator (*New TE*)

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver otherwise affects existing Task or KSAO:	T3 T13 T25 T83 T84 T131 T135 T180 T193 T202 T226 T230	K8.7 K18.21 K19.1 K19.2 K19.3 K19.4 K19.5 K19.6 K19.7 K19.8 K20.1 K20.2 K20.3 K20.4 K20.5 K21.2 K22.2 K22.3 K22.4 K25.1 K25.2 K25.3 K25.4 K25.5 K25.6 K25.7	Sk1 Sk3 Sk6 Sk12 Sk15 Sk17 Sk18 Sk23 Sk25 Sk38 Sk39 Sk40 SK53 Sk54	Ab1 Ab4 Ab5 Ab11 Ab14 Ab23 Ab24 Ab28 Ab33	O4 O12 O14	

Changes to ATCT Job Tasks

When determining the impact of a NextGen Driver on the job of the ATCT line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks), as well as whether the Driver would change *how* Tasks would be performed (e.g., how frequently Tasks are performed; what Tools and Equipment are used; the source, type, amount, or quality of the information used; which person in the facility performs it; work tempo; time required to complete the Task). Considering both impacts on individual Tasks allows for a more complete understanding of how the job overall will change.

Changes to Current Task List

AIR suggests that WTMD will produce changes to the current ATCT Task list. Specifically, it will add new Tasks associated with Activity 6:

- Activity 6: Manage Departing and Arriving Traffic

Activity 6: Manage Departing and Arriving Traffic

The introduction of WTMD to the ATCT work environment may require adding two new Tasks associated with implementing new wake turbulence separation standards. There will need to be a new Task to coordinate the change in the separation minima—both starting and stopping—with both pilots and other controllers (*New T*). There may also need to be a new Task about checking the WTMD indicator status light (*New T*).

Changes to How Tasks Are Performed

In addition to changing the current ATCT Task list, the implementation of WTMD will have an impact on *how* controllers in ten major airports with CSPRs will perform. AIR proposes that WTMD will most directly affect the following four of the 11 ATCT job Activities:

- Activity 1: Establish Situation Awareness
- Activity 4: Manage Air Traffic
- Activity 5: Resolve Conflicts
- Activity 6: Manage Departing and Arriving Traffic

Activity 1: Establish Situation Awareness

WTMD will affect situation awareness by providing ATCT line controllers with information regarding when conditions are favorable for reducing separation minima for operations on CSPRs. This is new information that is not currently available to controllers (*New TE*). Controllers will now have an indicator to scan for acquiring situation awareness, which could increase controllers' scanning time (*T13*). It could also increase the time it takes to receive (*T3*) or conduct a position briefing (*T25*). For example, WTMD will add a new parameter (i.e., current separation minima) to be discussed during the briefing. In addition, the briefing may also require discussion regarding the pattern of shifting between two different sets of separation rules.

Activity 4: Manage Air Traffic

The WTMD algorithm will give controllers a new piece of information to take into consideration when providing separation services. Having information on whether conditions are favorable or not for reduced wake turbulence separation will change the control actions that are available to controllers (*T83*) when performing visual and radar separation. For example, controllers will have to choose runway assignments based on the current wake separation minima (i.e., standard or reduced). Information on whether conditions are favorable or not for reduced wake turbulence separation will have to be taken into account when controllers are prioritizing their control actions (*T84*).

Activity 5: Resolve Conflicts

WTMD may have an effect on conflicts depending on how the alerts for loss of separation on tools like ASDE-X are calibrated. If wake turbulence separation standards are less than what the current conflict alerts are designed to accept—and if the conflict detection algorithms are not adjusted to account for reduced wake turbulence separation standards—then controllers may have to spend more time evaluating (*T131*) and responding to alerts (*T135*).

Activity 6: Manage Departing and Arriving Traffic

Controllers will take into consideration whether reduced wake turbulence separation standards are possible when evaluating the operational environment to determine optimal traffic flow (*T180*). Instead of applying a single set of wake turbulence separation standards, controllers will be required to switch between applying standard wake turbulence separation standards and reduced standards. This switch may occur several times during a shift and may lead to an increase in the cognitive workload of controllers as they switch between separation standards, while determining the appropriate departure interval (*T193*) and developing and issuing departure instructions (*T202*). Controllers will be required to take into account the current wake turbulence separation standard when issuing arrival instructions (*T226*) and when formulating a landing clearance (*T230*).

Changes to Characteristics Required of ATCT Controllers

When determining the impact of a NextGen Driver on the characteristics required of ATCT line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of Knowledges, Skills, Abilities, or Other Personal Characteristics or KSAOs (i.e., addition, deletion, or modification of an existing KSAO), as well as whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increasing or decreasing how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows for a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List

The introduction of WTMD does not require adding new Skills or Abilities, nor does it require deleting or modifying a Knowledge, Skill, Ability, or Other Personal Characteristic. It does, however, require the addition of one new knowledge associated with understanding how existing facility Tools and Equipment work together with WTMD (*New K-Interoperability*). It also requires the addition of one new Other Personal Characteristic to the existing list. More specifically, it adds the need for controllers to have interest in or willingness to learn and use automation appropriately (*New O-Technology Acceptance*). WTMD adds a new piece of automation to the ATCT environment. In order to be used most effectively to help ATCT line controllers perform their jobs efficiently, they must be comfortable using and trusting the automation.

Changes to Curriculum Required to Teach Knowledges

WTMD will require controllers to learn new course curriculum regarding how weather—and wind in particular—can impact operations (*K8.7-Impact on operations*). In particular, controllers will need to be taught about wake turbulence mitigation in operations, since they do not currently have this capability. The implementation of WTDM allows ATCT controllers to take advantage of reduced wake turbulence separation minima. However, TRACONs have a corresponding tool for arrivals. The coordination between controllers in these two facilities will be driven in part by new intra and inter-facility specific agreements (*K18.21-Knowledge of facility specific directives and procedures*).

Controllers will also need to learn about the WTMD system. Although controllers only interact with WTMD by monitoring a small indicator light (i.e., controllers do not interact with the sensors that gather information or with the "box" that interprets the information), they will still need to be taught about the new system as a whole (*K19-Knowledge of Facility Tool and Equipment*) including the sensors, the automation that interprets weather, including its algorithms, and whether/when/how controllers will be given the permission to reduce wake turbulence separation minimums. This will include teaching all of the knowledge sub-categories for WTMD under this knowledge category (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators;*

K19.7-Minor troubleshooting; K19.8-Backup systems). Controllers will also need to be taught content for the new Knowledge topic (*New K-Interoperability*, which would include how the tool/equipment interacts with the other Tools and Equipment of the ATCT line controllers. In the case of WTMD, curriculum would include information regarding the relationship between when the supervisor receives information from the wind sensors and when the indicator light illuminates at controllers' workstations.

Although the exact details of the new WTMD procedures have not yet been determined, controllers will likely need to be taught a new communication process related to informing others of the switchover from standard to reduced separation minima (*K20-Knowledge of ATC Communication Processes*), including all of the associated sub-categories (*K20.1-Types of ATC communications; K20.2-Components of each type of communication; K20.3-Proper phraseology; K20.4-Roles and responsibilities of communicators; K20.5-Communication procedures*). Additionally, since WTMD will allow controllers to reduce wake turbulence separation minima in favorable wind conditions, controllers will need to be taught new content with regard to the knowledge of the concept of separation. More specifically, they will need to be taught a new separation minima (*K21.2-Separation minima*).

Controllers will need to be taught new curriculum regarding the provision of air traffic services, including new procedures and new strategies for scanning the work environment for the presence of the WTMD indicator light (*K22.3-Scanning strategies*) and creating clearances (*K22.4-Procedures for composing clearances and control instructions*). For instance, the introduction of WTMD may mean that controllers have to include verbiage to communicate a disclaimer when using reduced wake turbulence separation minima.

Changes to Properties of Knowledges

WTMD, because it creates a reduced separation standard situation that must be closely monitored to be maintained, will change how often controllers must re-evaluate their duty priorities (*K22.2-Duty priorities*). It will also increase the frequency of controllers' scanning of the radar display to verify separation of the aircraft flying these reduced minima (*K22.3-Scanning strategies*).

WTMD will also increase how often controllers will use knowledge about departures under reduced wake turbulence separation standards (*K25-Knowledge of Departure Operations*). Since WTMD is designed for use for aircraft departures on CSPRs, controllers may need the knowledge of how to release aircraft for departure on parallel runways more often than they do today. The number of departures on CSPRs should increase with WTMD. Thus, controllers will need to learn information associated with all of the knowledge sub-categories (*K25.1-Departure sequence; K25.2-Taxi and departure routes; K25.3-Departure information; K25.4-Conventional standard instrument departures [SIDs]; K25.5-Area navigation [RNAV-enabled] departure routes; K25.6-Visual flight rule [VFR] departures; K25.7-Missed approach procedures*).

Changes to Curriculum Required to Teach Skills

Although controllers will not directly interact with WTMD equipment other than monitoring the indicator, they may still need to learn new Skills at recognizing and responding to degradation/failure of WTMD (*Sk53-Tool and Equipment Status Recognition; Sk54-Tool and Equipment Degradation/Failure Response*). Controllers need to be certain the automation is working properly, because they will be basing separation decisions on the information received from it.

Changes to Properties of Skills
WTMD will increase the importance of several skills. Although the procedures associated with WTMD have not yet been specified, controllers will be required to communicate their intention to use reduced separation minima to pilots and other controllers. As a result, Skills at verbally communicating information (*Sk1-Oral Communication*), Skill at attending to what others are saying, processing the information thoroughly and asking questions if needed (*Sk3-Active Listening*), and working with others to accomplish air traffic Tasks (*Sk23-Coordination*) may become more important because of the additional communications required to safely reduce separation standards.

Skill at maintaining awareness after being interrupted by the temporarily reduced separation standard may also become more important (*Sk6-Interruption Recovery*). The importance of rule application skills (*Sk12-Rule Application*) will not necessarily increase, but it may become more difficult because the rules will not consistent. Sometimes controllers will have to use one standard and at other times they will have to use another. This increases the possibility for error.

Skill at recognizing high workload may also become more important (*Sk15-High Workload Recognition*). WTMD will allow controllers to space departing aircraft closer together and to increase departure throughput. However, just because they have the capability does not mean controllers should do this in every case. Controllers will also need to consider the current workload. Skill at identifying the appropriate order of work Tasks will become more important (*Sk17-Task Prioritization*), as WTMD adds more aircraft that require priority treatment. Similarly, task timing will also become more important because the spacing between the aircraft has already been minimized (*Sk18-Task Timing*). Skill at applying scanning strategies to identify relevant information will also become more important (*Sk25-Strategic Scanning*) as WTMD will require controllers to maintain such close watch on these priority aircraft.

Finally, controllers will likely need more proficiency with spacing aircraft since the restrictions will be changing depending on wind conditions. This includes skill at developing viable spacing strategies (*Sk38-Spacing Strategy Development*), selecting the most appropriate strategy (*Sk39-Spacing Selection*), and implementing these strategies (*Sk40-Spacing Strategy Implementation*).

Changes to Properties of Abilities
WTMD will increase the importance of several communication abilities. The ability to communicate information and ideas verbally (*Ab1-Oral Expression*), the ability to perceive and understand principles governing the use of verbal concepts (*Ab4-Verbal Reasoning*), and ability to listen to and understand information presented verbally (*Ab5-Oral Comprehension*) may become more important because additional communications will likely be required to communicate changes in separation standards.

The increase in operational tempo brought about by the increase in throughput and the reduction in separation minima will increase the importance of being able to perceive information quickly and accurately (*Ab11-Perceptual Speed and Accuracy*).

The ability to remember information long enough to manage the situation (*Ab14-Working Memory*) will become more important, because the changes in separation standards are only temporary. Controllers will have to keep in mind which separation standard is in place for CSPRs. Recognizing and attending to detail will increase in importance, as the consequence of missing something is greater when the aircraft are closer together (*Ab23-Attention to Detail*) and controllers will have less time to make a correction. The ability to return to the standard wake turbulence separation minima quickly after being interrupted by a change in minima will also become more important (*Ab33-Recall from Interruption*).

Further, the Ability for controllers to adapt to changing situations (*Ab24-Flexibility*) will become more important because the separation rules could change during the shift and perhaps multiple times during a shift. Controllers will have to be willing to learn the knowledge and skills associated with WTMD (*Ab28-Learning*). Similarly, they will need to be willing to use this new tool in their job Tasks (*Ab24-Flexibility*). '

Changes to Properties of Other Personal Characteristics

The importance of being thorough will be even more important as a result of WTMD, again, because the aircraft are closer together and controllers will have less time to make a correction (*O4-Conscientiousness*). WTMD will increase the importance of the controllers' accepting risks associated with the job, while embracing the requirements of the job (*O12-Risk Tolerance*). As controllers put more planes closer together during conditions that they cannot verify visually, they are putting trust in the automation that it is correctly interpreting the wind conditions. At the same time, spacing planes closer together increases the risk of a potentially large consequence of error if the planes do experience heavy impacts of wake turbulence that was supposed to be dissipated. Controllers will have to be willing to take this risk if they are going to use WTMD automation.

The addition of technologies generally requires an increase in the importance of controllers' having the belief that they have influence over outcomes (*O14-Internal Locus of Control*). Controllers need to see themselves as actually being in control of the technology and, hence, responsible for the outcomes, instead of simply responding to the technology. This is especially the case with WTMD, where the decision to space aircraft closer together is the result of information provided by automation, and where the consequence of error for spacing aircraft closer is higher.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS (see Appendix B for the full list). The eight potential risks identified with regard to the implementation of WTMD are:

- *Change in Culture*: Incumbent and incoming line controllers will need to demonstrate willingness to learn to use WTMD when managing air traffic. An inability to learn to use, or lack of interest in learning and using, the new automation may lead to underutilization of these tools, which may lead to inefficiency and increases in the possibility of making an error.
- *Deficiencies in Technology*: If the automation that determines when conditions are favorable, or if adequate backup procedures and/or system redundancies do not exist, this

creates a threat to safety due to the close proximity of the aircraft and the very real hazards associated with wake turbulence. If the use of WTMD information is implicated in an accident, then its use could be suspended or discontinued, which would eliminate the efficiencies it was designed to create.

- *Degradation or Failure of Equipment or Systems*: If WTMD fails or degrades, then controllers will have to return to using previous wake turbulence separation standards. These procedures are less efficient in terms of aircraft operations. In addition, to the extent that a failure/degradation could occur during reduced separation minima operations on CSPRs, this could require the implementation of further backup procedures and could increase the possibility of error, especially during the transition.
- *Improper Reliance on Automation or Procedure*: If controllers do not feel comfortable utilizing reduced separation minima based on WTMD's wake turbulence mitigation guidance, they may not implement the reduced separation minima in cases when it is available. This will reduce efficiencies that WTMD was designed to support.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the functions of WTMD, its indicator, and its algorithms, which will assist controllers in achieving minimum separation, and also of its limitations, may result in poor controller performance with regard to aircraft separation; this could increase the possibility of error, thus reducing safety and efficiency.
- *More Dynamic Work Environment*: WTMD will require controllers to shift between standard and reduced separation, perhaps multiple times during a shift. It also adds another feature of the operational environment that requires priority treatment. Collectively these create a more dynamic work environment for the controller, and may increase mental workload and thus the possibility of error.
- *Reduced Separation Minima*: Reducing wake turbulence separation minima through the use of WTMD will require more precise and timely judgments by controllers, especially with regard to remediating conflicts, because the aircraft are closer together. If conflicts are not remediated in time, loss of life or property may result.
- *Technology Development and Maturation*: Although safety risk management analyses are required on every new tool and procedure before implementation, these are often developed and tested as stand-alone systems. Although it is highly unlikely that WTMD will be released into the NAS with known deficiencies, the full impact of using it in an operational context may be not realized until the system goes "live." For example, the system may not have reliable interoperability with other systems. In addition, it is not until technologies are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, then they will be unable to provide the feedback that is vital to system evolution.

Driver Impact Summary

Overall, WTMD will improve the situation awareness of ATCT line controllers by informing them when wake turbulence separation minima for departing aircraft on CSPRs can be reduced and which set of procedures to apply. It will allow controllers to make more efficient sequencing and increase use of airport capacity and departure throughput at 10 major airports, by taking advantage of favorable crosswind conditions.

The WTMD tool does not require much input of information or much interaction on the part of controllers. However, the use of wind data (which cannot be seen) to reduce separation standards that have likely changed little in many years will likely prove to be a substantive change for controllers and for pilots. It may be difficult for controllers to get used to instructing aircraft on CSPRs to take off so close together.

Finally, WTMD will likely increase the number of aircraft that controllers must manage in any given time period. Again, this will lead to an increase in workload for controllers.

Section VI. Conclusions and Next Steps

CONCLUSIONS

NextGen

The Next Generation Transportation System (NextGen) will revolutionize the National Airspace System (NAS) by providing stakeholders with new technology, automation, and procedures that will allow them to perform their jobs more efficiently. The end result is proposed to be increased capacity and efficiency, while maintaining or exceeding current levels of safety. The impact of NextGen will be far-reaching due in large part to the fact that NAS stakeholders' functions are to a great degree interdependent and changes that affect one consequently affect the others. However, NextGen brings with it some potential risks. The effort put forth by NextGen system engineers, hardware and software developers, human factors researchers, and other aviation professionals in the months and years to follow will determine whether these risks materialize and whether and how they can be mitigated.

The Job of the NextGen ATCT Controller

This report describes the job of the Air Traffic Control Specialist (ATCS) working in the Federal Aviation Administration's (FAA's) Airport Traffic Control Tower (ATCT) environment. To summarize, NextGen—and the technology, automation, and procedures that it will bring—will have an impact on the job of the ATCS. While NextGen will not substantively change the actual work that gets done, NextGen will affect *how* line controllers perform the work. Similarly, NextGen will not have a large impact on the characteristics required of workers to perform the job, but it will have an impact on the training required to teach Knowledges and Skills required to do the job and on the relative importance of certain human characteristics.

Limitations of the Current Research

Several specific limitations regarding the current research and its results should be noted. First, little is known about some of the NextGen technologies, automation, and procedures. The type and the amount of information available vary substantively from source to source and from topic to topic. Some technologies have been conceptualized but not built; others have been built but are not complete; still others have been built and implemented, but only on a limited or experimental basis. Information regarding which NAS stakeholders will be affected by which NextGen technologies, automation, and procedures or how they will be affected has in most cases not been specified. In sum, a large amount of required information is simply not yet available.

Fortunately, NextGen is evolving. Technologies that are not well understood are being researched. New automation is being tested. Problems are being identified and addressed. However, the ever-changing nature of the concept means that AIR's description of the ATCT NextGen Drivers and the assumptions with regard to what will exist by 2018—and hence the description of how the job will change—is likely already somewhat outdated.

NEXT STEPS

Conduct Strategic Training Needs Assessment

Now that the Strategic Job Analysis (SJA) is complete, AIR's next step is to complete a modified Strategic Training Needs Assessment (STNA). AIR intends to identify the NextGen training requirements for 2018, including the development of learning objectives.

Once the STNA is complete, AIR plans to gather SME input regarding this report, and to work toward updating and further refining the ideas it contains. AIR would then work with the FAA to ensure that the data are relayed to the individuals within the FAA who can effect the changes necessary to prepare the workforce for work in 2018.

Expand the Current ATCS Job Analysis

In addition to completing the current project, AIR hopes to work with the FAA to develop a plan for enhancing the current ATCS job analysis to develop ATCS responsibilities not included in the current job analysis or in this SJA, including ATCS training, supervisory, and Oceanic airspace management responsibilities.

Develop NextGen Job Description for Additional Jobs

Because the management of air traffic is becoming increasingly trajectory based, additional work should endeavor to develop NextGen Job Descriptions for other ATC positions that interact directly with the line controller. An important job to consider first is the job of the traffic management unit (TMU) coordinator, with whom the line controller interacts. Additionally, NextGen technologies and automation will likely impact—and increase the importance of—the FAA's Technical Operations family of jobs and, consequently, the impact on these jobs should also be identified.

Update ATCS NextGen Job Descriptions

NextGen concepts are continually being developed and refined. In addition, the Job Description for the NextGen mid-term ATCT controller contained in this report is based on NextGen documentation as of January 2011[11] and is already in some regards outdated. Taken together, these facts suggest that an important step will be to reevaluate the impact of NextGen on the ATCS job again before 2018. The timing of this research should be determined by stakeholder progress in developing, evaluating, and implementing NextGen technologies, automation, and procedures.

Evaluate Pre-Employment Selection Test Battery

The FAA's pre-employment selection test battery is comprised of a series of tests that measure specific ATCS Knowledge, Skills, Abilities, and Other Personal Characteristics that were identified as important through a comprehensive, selection-oriented job analysis conducted in 1995. The current research supports only minor changes in the KSAOs required to perform the job. However, a review of the coverage of the Air Traffic Selection and Training (AT-SAT) battery is likely warranted based on minor fluctuations in frequency of use of various aptitudes. More specifically, the FAA may want to consider whether increases in the need for Knowledge

[11] An exception is that the Operational Improvements referenced in this report are from November 2010.

and Skills required to support basic computing should be added as a pre-employment selection criterion or whether they should be taught at the Academy or facility level.

Develop Training Plan

It is clear that NextGen will substantively change the training requirements for ATCS Knowledges and Skills. Consequently, it is recommended that the FAA begin now to identify the processes that need to be put into place to support these changes, including determining how to develop high quality standardized training, and identifying and procuring the resources required to make these modifications. AIR's STNA will provide the FAA with the foundation for the development of actual training content. Although some of the Drivers will likely still be in the developmental phase, other Drivers will perhaps be mature enough to begin content development.

Address Risks

In Section V, AIR identified 17 potential risks associated with the implementation of NextGen Drivers in the ATCT environment. A high level summary of the risks and AIR's recommendations are provided below. The impact of the risks varies, with some risks being associated with only one or two Drivers, and others being associated with all eight. A more comprehensive discussion of all 17 risks can be found in the technical report that details the research conducted to support the development of this Job Description (AIR, 2011b). Note that this is only a summary of the issues, not a comprehensive review of the current literature or research. Much of this research is currently being conducted.

Risks Associated With Technology

AIR identified seven risks associated with the implementation of technology:

- Coordination of Multiple Stakeholders
- Deficiencies in Technology
- Improper Allocation of Tasks to Automation
- Mixed Aircraft Equipage
- Mixed ATC Tools, Equipment, or Procedures
- Poor Computer-Human Interface Design
- Technology Development and Maturation

For example, although the FAA is in the position to standardize automation for use by ATCT controllers, air carriers have many choices with regard to the development of onboard avionics. If the multiple stakeholders do not work together to ensure interoperability, the resulting systems may be unreliable.

Each of these seven risks poses a potential threat to the design or implementation of technologies and could potentially result in decreases in efficiency, increases in the possibility of controller error, and, more generally, an increase in the likelihood that the benefits proposed by the Driver will not be realized. Fortunately, much is known, is being researched, or is otherwise discoverable regarding the design and implementation of technology. AIR recommends several remediations for these risks.

AIR recommends continued and increased communication and collaboration among the experts who are designing the NextGen products. These experts should strive to inform and be kept informed of the products being developed by other experts to reduce inconsistencies and increase interoperability in the resulting systems. Because some deficiencies in technology have already been identified (e.g., latency in delivery and receipt of Data Comm messages), existing research should be continued and perhaps additional research could be conducted to determine how to address these deficiencies. The research could address the problem from both an engineering standpoint (i.e., how might the latency be eliminated) and a human performance standpoint (i.e., how can controllers manage the task fragmentation that will result). In addition to deficiencies in technology creating challenges, differences in the installation of technologies will also create challenges. NextGen will exacerbate what is already a mixed equipage environment. AIR recommends training for controllers in the specific capabilities offered by various NextGen avionics, and how their presence will affect aircraft performance. In addition, controllers will need access to real-time accurate and easily accessible information about the equipage of specific aircraft.

Human factors research could also address issues regarding the proper allocation of tasks to automation. Again, both current and future research could assist in addressing the challenges. More generally, existing human factors principles and standards provide guidance that would improve the likelihood that the investment in NextGen technologies, automation, and procedures is realized. First, the application of human factors standards to the design of Computer-Human Interfaces (CHIs) will ensure that they are usable by controllers. Standards that are currently being developed, such as the standardized color palette and symbology, could also be consulted as soon as they are complete. Finally, testing and troubleshooting high-fidelity prototypes, testing the coordination between automated tools in an operational context, and conducting human-in-the-loop (HITL) evaluations would likely be beneficial.

Risks Associated With the New Policies and Procedures

AIR identified two risks associated with the implementation of new NextGen policies and procedures:

- Best Equipped, Best Served (BEBS)
- Reduced Separation Minima

Research could be conducted to identify how controllers can and should balance potentially competing goals of safety, efficiency, and BEBS. Similarly, research could examine whether reduced separation minima are possible and, if so, determine the impact of this policy on controllers.

Because reduced separation minima have not yet been approved, AIR did not consider any potential impact on the ATCS job in this report. However, additional training will certainly be required. In addition, the increased precision and timeliness required for control actions in this environment may require new or different types or levels of controller KSAOs. For example, controllers may simply need to be able to work more quickly. In this case, two remediations are possible. First, new pre-employment selection requirements could be added or existing ones modified so that all incoming controllers would have the KSAOs required to perform in this new environment. Second, controllers could be assigned to work in facilities on the basis of their proficiency in the required aptitudes.

Risks Associated With the New Work Environment
Three risks were identified with regard to the new NextGen work environment. They are:

- Change in Culture
- Loss of Party Line Information
- More Dynamic Work Environment

To ensure that controllers work efficiently in the new NextGen work environment, AIR anticipates that several remediations will be required.

Training will need to include specific information regarding the benefits of the new NextGen technologies, automaton, and procedures. More important, this information could be accompanied by information regarding the limitations of the new tools (i.e., what is going on in the "black box"?). To the extent that loss of party line information that will result from the implementation of Data Comm reduces situation awareness, research could be conducted to inform whether and how information entered into the Data Comm system by one controller should be made available to both pilots and controllers not directly involved in the exchange.

The increase in the dynamic nature of the work will mean a less predictable work environment for controllers. Controllers will need training on the new tools and procedures. Research could be conducted to determine the effects of individual Drivers (e.g., whether controllers can adjust to changing airspace boundaries) and to determine the impact on controllers working in this airspace. If research confirms that controllers will be required to process information and make decisions more quickly, new KSAOs may need to be added or existing KSAOs will become more important. In this case, it would be necessary to ensure that new incoming controllers possess minimum levels of these KSAOs and/or to assign controllers to work in facilities on the basis of their level of proficiency in these KSAOs.

Risks Associated With Individual Controller Performance
Although all NextGen risks potentially affect controller performance in some way, the implementation of ATCT NextGen Drivers creates five direct potential risks with regard to individual controller job performance. They are:

- Degradation or Failure of Equipment or Systems
- Improper Reliance on Automation or Procedures
- Lack of/Inadequate Training
- Skill Decay
- Unknown Impact of Experience

The more the NextGen automation helps the ATC system approach and perhaps even surpass the limits of what human operators can easily achieve unaided, the more likely it is that the ATCS will be unable to continue to manage air traffic should the automation fail completely or in part. AIR recommends considering the roles, responsibilities, and capabilities of human operators early in the design process so that resulting systems make appropriate assumptions about what controllers could actually do in an unusual situation. In addition, testing NextGen systems under both normal and emergency or off-nominal/unusual situations (including those involving degradation or failure of equipment and systems) before they are implemented is suggested. It is critical to train line controllers to an extent where they can overrule the system during unusual situations. Specifically, automated aids could be considered to be partners of human operators, where controllers are working together with the automation to identify critical errors in the system when they occur. Further, it is unknown whether job experience will influence controllers' processing of information provided by decision support tools (DSTs). Until such differences, if any, are identified, it will be difficult to optimize training or utilization of DST-provided options. The introduction of the aids, because they automate Tasks for controllers, may create skill decay. Consequently, research is needed to identify Skills and associated Knowledges that are most likely to decay and to develop a recurrent training program for these Skills.

Finally, all NextGen Drivers require that developmental- and CPC-level ATCSs receive training and practice on Knowledges and Skills. Training should include information on how to operate the new automation and about what the automation and any embedded DSTs can and cannot do. For example, training could include instruction on how systems arrive at recommendations (i.e., algorithms). Teaching controllers the limitations of the automation should reduce both over- and under reliance on the automation. Feedback presented to line controllers by the automation, if properly designed and appropriately delivered, may also improve their performance.

In sum, the most important steps in addressing the 19 potential risks that were identified as part of this research are research and training. The number of Drivers and the number of individuals to be trained will create a substantive impact on the agency overall. However, if care is given to these requirements, these risks can likely be remediated.

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Appendix A: Current Job Analysis Data

ATCT Activities, Sub-Activities, and Tasks

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity* (*S-italics*) Task (T)		
A1	**Establish Situation Awareness**	
S1	*Assuming position responsibility*	
	T1	Review system status information areas to gain situation awareness
	T2	Consider current and projected traffic/weather/workload
	T3	Receive briefing from controller being relieved
	T4	Review briefing checklist to assure comprehensiveness of coverage
	T5	Determine if ready to accept position responsibility
	T6	Log into designated display/workstation in controller role
	T7	Adjust workstation parameters and display to personal preference
	T8	Check workstation for proper configuration, usability, and satisfactory status
	T9	Update system status information if required
	T10	Update automatic terminal information service (ATIS) broadcast
S2	*Assessing position data*	
	T11	Scan control environment to gather information about aircraft and vehicles
	T12	Scan control environment to gather current and trend weather data
	T13	Scan control environment for information regarding temporary and permanent changes to the NAS
	T14	Scan control environment for information about traffic outside your airspace/movement area
	T15	Request pilot and vehicle position reports
	T16	Interpret data gathered above to identify patterns and irregularities
	T17	Project current situation into the future to identify potential threats to safe and efficient flow of air and ground traffic
S3	*Monitoring equipment and automation system status*	
	T18	Review current airport status information
	T19	Monitor airport lighting and equipment status indicators for changes
	T20	Monitor equipment and automation system status
	T21	Receive information regarding equipment and automation status from status information areas, notices, pilots, and relief briefings
S4	*Relinquishing position responsibility*	
	T22	Review system status information for comprehensiveness and accuracy
	T23	Review briefing checklist and/or notes to assure comprehensiveness of briefing coverage
	T24	Initiate mandated recording of briefing
	T25	Brief relieving controller
	T26	Sign off position log if required
A2	**Manage Communications**	
S5	*Establishing and terminating radio communications*	
	T27	Receive initial radio communication from pilot
	T28	Establish two way radio communications
	T29	Issue most current automatic terminal information service (ATIS) information
	T30	Determine frequency in use by receiving sector
	T31	Issue change of frequency to pilot

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity* (*S-italics*) Task (T)		
S6	*Issuing clearances, instructions, or other messages*	
	T32	Identify need for communication
	T33	Receive request requiring response
	T34	Determine appropriate recipient(s)
	T35	Construct clearance, instruction, or message with proper phraseology
	T36	Issue clearance, instruction, or message
	T37	Listen for read back
	T38	Verify correct read back
	T39	Restate clearance, instruction, or message if required
	T40	Listen for read back
	T41	Verify correct read back
	T42	Evaluate situation to determine need for additional communications
	T43	Issue additional clearance, instruction, or messages if required
A3	**Manage Flight Plan Data**	
S7	*Entering flight plan data*	
	T44	Receive request for flight plan
	T45	Evaluate flight plan request
	T46	Enter flight plan locally or into NAS as required
	T47	Evaluate flight plan for accuracy
	T48	Issue clearance as appropriate
S8	*Amending flight plan data*	
	T49	Determine need for an amendment
	T50	Receive request for flight plan amendment
	T51	Enter flight plan changes locally or into NAS
	T52	Review amended flight plan for accuracy
	T53	Update information locally or in the NAS if required
	T54	Ensure other controllers are advised of amendment status
	T55	Request a flight plan amendment
	T56	Receive notice of flight plan amendment status
	T57	Coordinate with others as required
S9	*Managing flight progress strips*	
	T58	Receive flight progress strip
	T59	Request flight progress strip from other facilities
	T60	Evaluate flight progress strip elements for accuracy
	T61	Ensure flight progress strip is most current amendment
	T62	Utilize appropriate strip marking
	T63	Sequence flight progress strips
	T64	Update traffic count/status manually
	T65	File flight progress strips as necessary
	T66	Forward flight progress strip to other controller
	T67	File records (e.g., facility log)
	T68	Drop flight plan and track from the NAS

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity* (*S-italics*) Task (T)		
S10	*Processing departure or en route time information*	
	T69	Enter departure or en route time message
	T70	Receive departure or en route time notices
	T71	Monitor departure or en route time notices
A4	**Manage Air Traffic**	
S11	*Establishing and maintaining positive aircraft or vehicle identification and position*	
	T72	Observe aircraft or vehicles entering airspace or ground movement areas
	T73	Identify appropriate position correlation procedure(s)
	T74	Perform appropriate position correlation procedure(s)
	T75	Verify aircraft or vehicle identification by observing procedure results
	T76	Transfer radar identification
	T77	Verify aircraft/vehicle leaving airspace/movement area
S12	*Performing visual and radar separation of aircraft and vehicles*	
	T78	Observe aircraft or vehicles in airspace or on ground movement areas
	T79	Project mentally an aircraft's or vehicle's trajectory
	T80	Identify potential or actual conflicts
	T81	Establish required separation
	T82	Maintain required separation
	T83	Determine potential control actions
	T84	Prioritize control actions
	T85	Issue appropriate control instructions
	T86	Verify pilot and vehicle operator conformance to instructions
S13	*Performing nonradar procedures for aircraft*	
	T87	Request current pilot position report
	T88	Record flight information on flight progress strip
	T89	Track aircraft movement on flight progress strip
	T90	Issue appropriate control instructions
	T91	Verify pilot conformance to instructions
S14	*Responding to special operations*	
	T92	Receive notice of special operation
	T93	Evaluate impact of special operation
	T94	Determine appropriate plan of action
	T95	Implement plan of action as required
	T96	Re-evaluate plan of action
	T97	Revise plan of action if required
	T98	Coordinate special operation with others
	T99	Receive notice of termination of special operation

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity* (*S-italics*) Task (T)		
S15	*Processing requests for VFR flight following*	
	T100	Receive request for flight following
	T101	Evaluate conditions for providing flight following
	T102	Approve or deny flight following request
	T103	Enter flight information into the automation locally and the NAS if required
	T104	Ensure correct data entry for flight following requests
	T105	Issue beacon code to aircraft if applicable
	T106	Issue appropriate clearance or control instructions as required
	T107	Ensure compliance with clearance or control instructions as necessary
	T108	Receive request for cancellation of air traffic services
	T109	Acknowledge request
S16	*Monitoring uncontrolled objects/aircraft*	
	T110	Observe uncontrolled object/aircraft
	T111	Receive information on uncontrolled object /aircraft
	T112	Coordinate with others if appropriate
S17	*Responding to pilot requests for flight path deviation*	
	T113	Receive pilot request to deviate
	T114	Evaluate pilot request for deviation
	T115	Determine alternative clearance if required
	T116	Issue appropriate control instructions if required
	T117	Coordinate deviation with the next controller if required
S18	*Responding to airborne or ground nonconformance*	
	T118	Observe aircraft or vehicle nonconformance
	T119	Receive notice of aircraft or vehicle nonconformance
	T120	Inform other controller of nonconformance in that controller's position or sector
	T121	Query pilot or vehicle operator about intentions
	T122	Determine appropriate action to resolve nonconformance
	T123	Issue appropriate control instructions to correct nonconformance
	T124	Issue advisory or alert if required
	T125	Verify compliance with instructions
	T126	Inform supervisor of nonconformance and if necessary of violation

ATCT Activities, Sub-Activities, and Tasks Activity (A-bold) *Sub-Activity* (*S-italics*) Task (T)		
A5	**Resolve Conflicts**	
S19	*Performing aircraft conflict resolutions*	
	T127	Identify potential or actual loss of separation
	T128	Receive notice of potential or actual conflict
	T129	Inform other controller of potential or actual conflict in that controller's position or sector
	T130	Observe aircraft conflict alert indication
	T131	Determine validity of aircraft conflict
	T132	Determine appropriate action to resolve conflict situation
	T133	Issue appropriate control instructions to ensure separation
	T134	Verify pilot conformance with instructions
	T135	Suppress conflict alert if appropriate in accordance with procedures and directives
	T136	Issue advisory or safety/traffic alert as appropriate
	T137	Inform pilot when traffic no longer a factor
	T138	Report loss of separation as appropriate
	T139	Restore conflict alert function to normal
S20	*Performing unsafe altitude resolutions*	
	T140	Identify potential or actual unsafe altitude situation
	T141	Detect MSAW indication/alarm
	T142	Receive notice of potential or actual unsafe altitude situation
	T143	Inform other controller of unsafe altitude situation in that controller's position or sector
	T144	Determine validity of unsafe altitude/MSAW
	T145	Determine appropriate action to resolve unsafe altitude situation
	T146	Issue appropriate control instructions to resolve unsafe altitude situation
	T147	Suppress MSAW function if appropriate in accordance with procedures and directives
	T148	Issue advisory or safety alert as appropriate
	T149	Ensure pilot requesting IFR clearance from VFR receives appropriate beacon code for MSAW alert if necessary
	T150	Restore MSAW function to normal
S21	*Performing airspace or movement area violation resolutions*	
	T151	Identify potential or actual airspace or movement area violation
	T152	Receive notice of potential or actual airspace or movement area violation
	T153	Inform other controller of airspace or movement area violation in that controller's position or sector
	T154	Determine validity of airspace or movement area violation
	T155	Determine appropriate action to resolve airspace violation
	T156	Issue appropriate control instructions to ensure separation
	T157	Issue advisory or safety/traffic alert as appropriate
	T158	Report airspace or ground movement violation as appropriate

ATCT Activities, Sub-Activities, and Tasks Activity (A-bold) *Sub-Activity* (*S-italics*) Task (T)		
S22	*Performing vehicle conflict resolutions*	
	T159	Observe potential or actual vehicle conflict situation
	T160	Receive notice of potential or actual conflict
	T161	Inform other controller of vehicle conflict situation in that controller's position or sector
	T162	Determine validity of vehicle conflict
	T163	Determine appropriate action to resolve vehicle conflict situation
	T164	Issue appropriate control instructions to ensure separation
	T165	Verify conformance with instructions
	T166	Suppress conflict indication in accordance with procedures and directives
	T167	Issue advisory or traffic alert as appropriate
	T168	Inform others when traffic no longer a factor
	T169	Report vehicle conflict situation as appropriate
	T170	Restore conflict indication function to normal
S23	*Issuing unsafe condition advisories*	
	T171	Determine need for advisory or alert
	T172	Generate advisory or alert appropriate for situation
	T173	Issue advisory or alert
	T174	Monitor response to advisory or alert
	T175	Cancel advisory or alert when situation returns to normal
A6	**Manage Departing and Arriving Traffic**	
S24	*Managing ground departure traffic*	
	T176	Receive flight progress strip of departure aircraft
	T177	Receive pilot request for pushback/powerback instructions
	T178	Issue pushback/powerback instructions
	T179	Receive pilot request for taxi instructions
	T180	Evaluate control environment to determine optimal traffic flow
	T181	Sequence flight progress strips for optimal traffic flow
	T182	Issue taxi instructions
	T183	Record taxi start time
	T184	Coordinate sequencing with others
	T185	Project ground traffic for position sequencing
	T186	Observe ground traffic sequence
	T187	Forward flight progress strip to other controller
	T188	Direct pilot to contact other controller
	T189	Ensure taxi conformance with issued instructions

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity* (*S-italics*) Task (T)		
S25	*Issuing takeoff information and instructions*	
	T190	Receive flight progress strip of departure aircraft
	T191	Review flight progress strip/record of departure aircraft
	T192	Verify aircraft is ready for takeoff by observing aircraft awaiting takeoff clearance or receiving pilot request for takeoff
	T193	Determine appropriate interval for departure
	T194	Request release for departure
	T195	Issue amended clearance if required
	T196	Receive instructions to hold for release
	T197	Receive release for departure and amended clearance as necessary
	T198	Determine necessary additional traffic information
	T199	Issue appropriate departure information if required
	T200	Scan runway environment to insure conditions are safe for takeoff
	T201	Issue instructions to pilot to line up and wait if required
	T202	Issue departure instructions
	T203	Issue takeoff clearance
	T204	Ensure auto acquisition of flight data block including Mode C
	T205	Verify position correlation of aircraft that do not acquire if necessary
S26	*Managing aircraft takeoff terminations*	
	T206	Determine need to cancel takeoff clearance
	T207	Receive pilot notification of aborted takeoff
	T208	Observe aborted takeoff
	T209	Issue takeoff cancellation
	T210	Coordinate takeoff termination with others as appropriate
	T211	Forward flight progress strip to other controller
S27	*Managing airborne departures*	
	T212	Forward notification of departure
	T213	File flight progress strip
	T214	Receive notice of missed approach/go around
	T215	Inform departure controller of missed approach/go around
	T216	Enter departure message if necessary
	T217	Forward flight progress information as necessary

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity* (*S-italics*) Task (T)		
S28	*Managing arrivals*	
	T218	Observe arriving aircraft
	T219	Receive manual or automated arrival aircraft data
	T220	Receive notice of inbound aircraft
	T221	Receive pilot request for arrival instructions
	T222	Verify position correlation
	T223	Verify pilot has current arrival information
	T224	Issue current arrival information as necessary
	T225	Issue appropriate traffic information
	T226	Issue arrival instructions
	T227	Evaluate airfield and traffic conditions for safe operations
	T228	Determine landing sequence
	T229	Coordinate landing sequence with another controller if necessary
	T230	Formulate a clearance with appropriate control instructions
	T231	Issue landing/option clearance
	T232	Record necessary flight plan data
S29	*Responding to flow constraints*	
	T233	Inform pilot of estimated departure clearance time
	T234	Issue instructions for gate hold
	T235	Advise pilot of ground delay
	T236	Determine departure sequence
	T237	Issue taxi instructions to effect desired sequence
	T238	Review departure restrictions
	T239	Determine aircraft is ready for departure
	T240	Adhere to departure restrictions
S30	*Responding to traffic management initiatives*	
	T241	Receive information regarding traffic management initiative
	T242	Discuss impact of traffic management initiative or traffic reroute with supervisor
	T243	Evaluate traffic management initiative for effect on traffic flow
	T244	Develop options for bringing aircraft into conformance with traffic management initiative
	T245	Determine appropriate action to bring aircraft into conformance with traffic management initiative
	T246	Advise pilot of a traffic management initiative if necessary
	T247	Coordinate with Traffic Management Unit (TMU) as necessary
	T248	Issue appropriate control instructions to comply with traffic management initiative
	T249	Verify compliance with instructions by pilot and other facilities
	T250	Revise plan if necessary
	T251	Receive notice of cancellation of traffic management initiative
	T252	Coordinate cancellation of traffic management initiative with others

ATCT Activities, Sub-Activities, and Tasks Activity (A-bold) *Sub-Activity (S-italics)* Task (T)		
A7	**Transfer of Radar Identification**	
S31	*Initiating handoffs*	
	T253	Receive request for transfer of radar identification
	T254	Determine need for transfer of radar identification
	T255	Ensure all conflicts are resolved
	T256	Initiate automated handoff
	T257	Initiate manual handoff
	T258	Observe automated handoff failure
	T259	Retract handoff if required
	T260	Receive manual handoff acceptance
	T261	Receive automated handoff rejection
	T262	Coordinate restrictions with receiving controller as necessary
	T263	Issue appropriate control instructions as required
	T264	Issue appropriate control instructions to redirect aircraft from airspace as required
S32	*Accepting handoffs*	
	T265	Receive handoff request
	T266	Determine response to handoff request
	T267	Coordinate restrictions with initiating controller as necessary
	T268	Accept handoff
	T269	Deny handoff
	T270	Receive control of aircraft according to Letter(s) of Agreement (LOAs) and Standard Operating Procedures (SOPs)
S33	*Issuing pointouts*	
	T271	Identify need for pointout
	T272	Initiate pointout
	T273	Receive approval of pointout with restrictions if required
	T274	Adhere to restrictions if required
	T275	Receive rejection of pointout
	T276	Issue appropriate control instructions to remain clear of airspace if rejected
	T277	Initiate handoff if rejected
S34	*Responding to pointouts*	
	T278	Receive pointout request
	T279	Ensure appropriate target is displayed
	T280	Determine response to pointout
	T281	Approve pointout with or without restrictions
	T282	Deny pointout
	T283	Declare radar contact
	T284	Suppress automated track after pointout is no longer a factor

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
A8	**Assess the Impact of Weather**	
S35	*Processing weather information*	
	T285	Observe changed weather conditions
	T286	Observe record of changed weather conditions
	T287	Receive notice of changed weather conditions
	T288	Request weather reports
	T289	Request braking action report
	T290	Determine whether runway or airport conditions have changed
	T291	Determine whether control zone is IFR or VFR
	T292	Receive request to obtain weather reports
	T293	Record weather data or airport environmental data
	T294	Update automatic terminal information system (ATIS) message to reflect new weather information
	T295	Inform others of changed airport conditions
S36	*Responding to severe weather information*	
	T296	Observe severe weather intensity and trend
	T297	Observe display or record of updated severe weather data
	T298	Request severe weather information
	T299	Evaluate severe weather information to identify potential impact
	T300	Discuss actions to respond to runway or taxiway change
	T301	Determine the need for severe weather updates
	T302	Formulate severe weather or airport environmental information for distribution
	T303	Disseminate severe weather or airport environmental information to others
	T304	Acknowledge receipt of severe weather information
A9	**Manage Airspace and Movement Areas**	
S37	*Requesting temporary release of airspace or movement areas*	
	T305	Determine need for temporary release of airspace or movement area under other control
	T306	Request temporary release/use of airspace or movement area
	T307	Receive release/use of airspace or movement area including conditions if any
	T308	Issue appropriate control instructions
	T309	Return airspace if no longer needed
	T310	Receive rejection of use of airspace or movement area
S38	*Responding to requests for temporary release of airspace or movement areas*	
	T311	Receive request for temporary use of airspace or movement area
	T312	Observe affected traffic
	T313	Evaluate feasibility of releasing airspace or movement area temporarily
	T314	Release airspace with conditions as appropriate
	T315	Issue appropriate control instructions
	T316	Receive notification that released airspace or movement area is returned
	T317	Change automation associated with temporary use of airspace

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
S39	*Responding to changes in airspace or movement area status*	
	T318	Receive notice of change in status of airspace or movement area
	T319	Coordinate change in status of airspace or movement area with others
	T320	Coordinate airspace or movement area restrictions with others
	T321	Utilize visual aids/memory joggers as appropriate
	T322	Determine appropriate actions to ensure separation from airspace or movement area
	T323	Issue appropriate control instructions
	T324	Ensure status information areas are updated
	T325	Receive notice that restriction is terminated
	T326	Inform others that restriction is terminated
	T327	Discontinue use of visual aids/memory joggers
S40	*Responding to changes in runway or taxiway usage or conditions*	
	T328	Receive notice of changes to runway or taxiway usage or conditions
	T329	Review traffic situation to optimize movement of aircraft
	T330	Coordinate change in runway or taxiway usage or conditions with others
	T331	Utilize visual aids/memory joggers as appropriate
	T332	Determine appropriate action to accommodate changes in runway or taxiway usage or conditions
	T333	Issue appropriate control instructions
	T334	Ensure status information areas are updated
S41	*Transferring position/sector for reconfiguration*	
	T335	Advise receiving controller to prepare for position/sector reconfiguration
	T336	Give briefing to the receiving controller taking the airspace
	T337	Verify that the receiving controller has necessary settings for communication system and automation system
	T338	Configure communication and automation system to reflect changes
	T339	Adjust display for the new configuration
S42	*Receiving position/sector for reconfiguration*	
	T340	Receive notice to prepare for sector or position reconfiguration
	T341	Adjust display for the new configuration
	T342	Configure communication and automation system to reflect changes
	T343	Receive briefing from the controller relinquishing airspace
	T344	Determine if ready to accept position responsibility
	T345	Assume control of position/sector
A10	**Manage Resources**	
S43	*Managing personal and position workload*	
	T346	Ensure fitness for duty
	T347	Identify current or potential overload situations
	T348	Identify potential overload reduction strategies
	T349	Inform supervisor of current or potential overload
	T350	Request assistance if required
	T351	Implement overload reduction strategy as appropriate
	T352	Receive supervisor notice of implementation of overload reduction strategy

ATCT Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
S44	*Supporting teamwork environment*	
	T353	Participate in training and other professional development activities
	T354	Maintain tower awareness
	T355	Inform supervisor of important situations
A11	**Respond to Emergencies and Unusual Situations**	
S45	*Responding to emergencies*	
	T356	Receive notice of emergency
	T357	Detect an emergency
	T358	Evaluate the situation
	T359	Determine appropriate plan of action
	T360	Respond to emergency as required
	T361	Review emergency checklist
	T362	Declare emergency if necessary
	T363	Amend traffic flow and sequence to expedite emergency aircraft
	T364	Coordinate emergency information with others
	T365	Re-evaluate plan of action
	T366	Revise plan of action if required
	T367	Report emergency declared and action taken to supervisor
S46	*Responding to unusual situations*	
	T368	Detect unusual situation
	T369	Receive notice of unusual situation
	T370	Evaluate situation
	T371	Report situation to supervisor
	T372	Determine appropriate plan of action
	T373	Issue required security notifications immediately, if necessary
	T374	Comply with security notifications and/or coordination as required
	T375	Implement plan of action
	T376	Re-evaluate situation
	T377	Revise plan if appropriate
	T378	Implement revised plan
	T379	Coordinate information with others as appropriate
S47	*Responding to system/equipment degradation or failure*	
	T380	Detect degradation or failure
	T381	Receive notice degradation or failure
	T382	Coordinate degradation or failure information with others
	T383	Initiate backup system if appropriate
	T384	Implement backup procedures
	T385	Follow nonradar procedures as directed by controlling authority if required
	T386	Coordinate with others regarding repair if required
	T387	Receive notice of return to service
	T388	Verify accuracy of system data
	T389	Resume normal operations
	T390	Notify others of return to normal operations

ATCT Knowledges

ATCS Knowledges for ATCT		
K1	Knowledge of Federal Aviation Administration	
	K1.1	FAA organizational structure
	K1.2	Evolution of air traffic control (ATC)
	K1.3	Safety culture
	K1.4	NextGen initiative
	K1.5	Payroll, compensation, and benefits
	K1.6	Employee representation
K2	Knowledge of General Air Traffic Structure	
	K2.1	Decoding facility identifiers
	K2.2	Types of ATC facilities
	K2.3	Roles of each facility type
	K2.4	Types of ATCS positions in each facility type
	K2.5	ATCS responsibilities for each position in each facility type
	K2.6	Types of Traffic Management Unit (TMU) positions
	K2.7	Traffic Management Unit (TMU) responsibilities
	K2.8	Automated Flight Service Station (AFSS)
K3	Knowledge of Professional ATCS Requirements	
	K3.1	Aeromedical requirements
	K3.2	Training requirements
	K3.3	Credentialing requirements
	K3.4	Certification requirements
K4	Knowledge of Aviation Science	
	K4.1	Aircraft aerodynamics
	K4.2	Wake turbulence
	K4.3	Speed regimes
	K4.4	Phases of flight
K5	Knowledge of Human Factors in Aviation	
	K5.1	Human cognitive performance limitations
	K5.2	Human physical performance limitations
	K5.3	Team concept
K6	Knowledge of Geography	
	K6.1	National geography
	K6.2	International geography
	K6.3	Types of obstructions
	K6.4	Types of altitude references (AGL,MSL)
	K6.5	Types of distance metrics (NM, SM)
K7	Knowledge of Navigation	
	K7.1	Air route structure
	K7.2	Types of navigation aids (NAVAIDS)
	K7.3	Types of navigation
	K7.4	Aeronautical charts
	K7.5	Compass properties
	K7.6	Geo-referencing
	K7.7	Compulsory position reporting
	K7.8	Terrain features

ATCS Knowledges for ATCT		
K8	Knowledge of Basic Weather Concepts	
	K8.1	Atmospheric properties
	K8.2	Sources of weather information
	K8.3	Weather terminology
	K8.4	Weather features
	K8.5	Weather observation
	K8.6	Weather data interpretation
	K8.7	Impact on operations
	K8.8	Impact on flight/aircraft
	K8.9	Pilot Report (PIREP) solicitation requirements
	K8.10	Weather information recording
	K8.11	Weather information dissemination requirements
	K8.12	Weather minimums
K9	Knowledge of Surveillance Systems Architecture	
	K9.1	Types of surveillance systems
	K9.2	Fundamentals
	K9.3	Components
	K9.4	Utility
	K9.5	Limitations
K10	Knowledge of Communication Systems Architecture	
	K10.1	Types of communication systems
	K10.2	Fundamentals
	K10.3	Components
	K10.4	Utility
	K10.5	Limitations
K11	Knowledge of Aircraft Characteristics and Features	
	K11.1	Categories
	K11.2	Weight classes
	K11.3	Designators
	K11.4	Performance characteristics
	K11.5	Identification features
	K11.6	Avionics
K12	Knowledge of Aircraft Operations	
	K12.1	Types of flight operations
	K12.2	Types of surface operations
	K12.3	Flight rules
	K12.4	Altimeter setting criteria
	K12.5	Aircraft transponder modes
K13	Knowledge of General Airport Characteristics	
	K13.1	Decoding airport identifiers
	K13.2	Components of airport diagram
	K13.3	Movement versus non-movement area
	K13.4	Services and equipment
	K13.5	Types of signage
	K13.6	Types of airport lighting
	K13.7	Noise abatement concepts
	K13.8	Types of obstructions/obstacles

ATCS Knowledges for ATCT		
K14	Knowledge of Aeronautical Publications and ATC Procedures and Directives	
	K14.1	Types of aeronautical publications and ATC procedures and directives
	K14.2	Purpose
	K14.3	Authoritative source of the information
	K14.4	Location and format of current version
	K14.5	Subject areas contained in each ATC publication
	K14.6	Types of sensitive documents
K15	Knowledge of Airspace	
	K15.1	Airspace classification
	K15.2	Air defense identification zone (ADIZ)
	K15.3	ARTCC delegated airspace concept
	K15.4	Special Activity Airspace
K16	Knowledge of Flight Plan Data	
	K16.1	Types of flight plans
	K16.2	Required components
	K16.3	Filing process
	K16.4	Evaluation strategies
	K16.5	Flight plan processing
	K16.6	Flight plan data display methods
K17	Knowledge of Air Traffic Management Procedures	
	K17.1	Purpose of traffic management units
	K17.2	Reasons for traffic management initiatives
	K17.3	Types of traffic management initiatives
	K17.4	Strategies for managing traffic management initiatives
K18	Knowledge of Facility-Specific Characteristics	
	K18.1	Facility identifier
	K18.2	Facility level
	K18.3	Physical location
	K18.4	Facility/airport contact information
	K18.5	Airport diagram
	K18.6	Facility radio frequencies
	K18.7	Local navigation aids (NAVAIDS)
	K18.8	Airport services
	K18.9	Airspace dimensions
	K18.10	Adjacent airspace
	K18.11	Sector configurations
	K18.12	Airport configurations
	K18.13	Local geography
	K18.14	Impact of local topography on flight
	K18.15	Local obstructions/obstacles
	K18.16	Local weather patterns
	K18.17	Tower blind spots
	K18.18	Facility traffic flows
	K18.19	Local traffic patterns
	K18.20	Areas with high potential for confliction (hot spots)
	K18.21	Facility specific directives and procedures
	K18.22	Airspace coordination procedures

ATCS Knowledges for ATCT		
K19	Knowledge of Facility Tools and Equipment	
	K19.1	Types of tools and equipment
	K19.2	Functionality of tools and equipment
	K19.3	Operation of tools and equipment
	K19.4	Interpretation of information provided
	K19.5	Limitations
	K19.6	Degradation indicators
	K19.7	Minor troubleshooting
	K19.8	Backup systems
K20	Knowledge of ATC Communication Processes	
	K20.1	Types of ATC communications
	K20.2	Components of each type of communication
	K20.3	Proper phraseology
	K20.4	Roles and responsibilities of communicators
	K20.5	Communication procedures
K21	Knowledge of the Concept of Separation	
	K21.1	Types of separation standards
	K21.2	Separation minima
	K21.3	Conflict resolution strategies
	K21.4	Operational and personal impact of loss of separation
K22	Knowledge of Providing ATC Services	
	K22.1	Types of air traffic services
	K22.2	Duty priorities
	K22.3	Scanning strategies
	K22.4	Procedures for composing clearances and control instructions
	K22.5	Application of separation standards
	K22.6	Radar services procedures
	K22.7	Nonradar procedures
	K22.8	Conformance assurance
	K22.9	Course trend information
	K22.10	Strategies for severe weather avoidance
	K22.11	Transfer of control requirements
	K22.12	Transfer of communication requirements
	K22.13	Approach control service
	K22.14	Notice to Airmen (NOTAM)
K23	Knowledge of Additional ATC Services	
	K23.1	Direction finding (DF) services
	K23.2	Visual flight rule (VFR) flight following
	K23.3	Flight information service (FIS)
	K23.4	Glidepath trend information
	K23.5	Uncontrolled aircraft
	K23.6	Tower en route control service

ATCS Knowledges for ATCT		
K24	Knowledge of Approach / Arrival Operations	
	K24.1	Approach/arrival information
	K24.2	Instrument approaches
	K24.3	Arrival routes
	K24.4	Conventional standard terminal arrival routes (STARs)
	K24.5	Area navigation (RNAV-enabled) arrival routes
	K24.6	Visual approaches
	K24.7	Missed approaches
	K24.8	Visual flight rule (VFR) arrival
	K24.9	Practice approaches
	K24.10	Arrival sequence
	K24.11	Landing operations
K25	Knowledge of Departure Operations	
	K25.1	Departure sequence
	K25.2	Taxi and departure routes
	K25.3	Departure information
	K25.4	Conventional standard instrument departures (SIDs)
	K25.5	Area navigation (RNAV-enabled) departure routes
	K25.6	Visual flight rule (VFR) departures
	K25.7	Missed approach procedures
K26	Knowledge of Special Operations	
	K26.1	Types of special operations
	K26.2	Required clearances and control instructions
	K26.3	Coordination requirements
	K26.4	Notification requirements
K27	Knowledge of Emergency and Unusual Situations	
	K27.1	Types of ground emergency or unusual operations
	K27.2	Types of in-flight emergency or unusual operations
	K27.3	Required clearances and control instructions
	K27.4	Search and rescue
	K27.5	Emergency assistance techniques
	K27.6	Coordination requirements
	K27.7	Notification requirements
	K27.8	Reporting requirements
	K27.9	National security contingency plans

ATCS Skills

No.	Skill Group	Skill Label	Skill Definition
Sk1	Communication	Oral Communication	Skill at verbally communicating properly formatted clearances, instructions, and other air traffic information clearly and concisely in English using the appropriate tone.
Sk2	Communication	Written Communication	Skill at recording control actions completely and accurately by writing on flight strips, scratch pads, and other forms.
Sk3	Communication	Active Listening	Skill at attending to what others are saying during air traffic communications, taking time to understand the information being relayed, and asking questions to clarify if necessary.
Sk4	Time Sharing	Task Switching	Skill at shifting rapidly between tasks during periods of high workload.
Sk5	Time Sharing	Attention Switching	Skill at shifting rapidly between auditory and visual sources to obtain information needed.
Sk6	Time Sharing	Interruption Recovery	Skill at maintaining situation awareness and returning quickly to work tasks after being interrupted.
Sk7	Information Management	Information Location	Skill at finding and cross-referencing information in ATC sources.
Sk8	Information Management	Decoding	Skill at interpreting air traffic related symbols, acronyms, abbreviations, and other truncated data such as data blocks.
Sk9	Information Management	Encoding	Skill at converting air traffic information into codes, symbols, and abbreviations for use in managing air traffic.
Sk10	Information Management	Reading Comprehension	Skill at understanding regulations, charts, operating procedures, and other air traffic rules.
Sk11	Information Management	Information Filtering	Skill at identifying the information needed from among all the air traffic information available.
Sk12	Information Management	Rule Application	Skill at consistently applying regulations, rules, procedures, and directives from air traffic information sources to manage air traffic.
Sk13	Math and Science	Basic Math Operations	Skill at performing basic math operations including addition, subtraction, multiplication, and division.
Sk14	Math and Science	Principle Application	Skill at applying the basic principles of mathematics, geometry, and physics to conduct air traffic operations.
Sk15	Task Management	High Workload Recognition	Skill at recognizing high workload situations at the position or sector level that indicate a need for additional resources.
Sk16	Task Management	Performance Monitoring	Skill at checking your own work performance, evaluating the effectiveness of your decisions, and altering your performance if necessary.
Sk17	Task Management	Task Prioritization	Skill at identifying the appropriate order of work tasks and addressing them in that order.
Sk18	Task Management	Task Timing	Skill at performing work tasks at the appropriate time to ensure safe and efficient air traffic operations.
Sk19	Task Management	Composure Maintenance	Skill at performing safely and effectively even in busy or stressful situations.

No.	Skill Group	Skill Label	Skill Definition
Sk20	Teamwork	Position Relief Briefings	Skill at conducting thorough and timely position relief briefings in proper format.
Sk21	Teamwork	Shared Responsibility Position Teamwork	Skill at working collaboratively when control responsibility is shared among two or more controllers.
Sk22	Teamwork	Inter-position Teamwork	Skill at working collaboratively with other controllers both within your facility and in other facilities.
Sk23	Teamwork	Coordination	Skill at working with other individuals and organizations to accomplish air traffic work tasks safely and efficiently. This requires two-way exchange of information to develop and implement a common agreed upon solution.
Sk24	Teamwork	Cue Recognition/Comprehension	Skill at picking up subtle verbal or nonverbal cues from others and taking appropriate action.
Sk25	Situation Awareness	Strategic Scanning	Skill at applying scanning strategies to quickly and accurately search for ATC relevant information.
Sk26	Situation Awareness	Operational Comprehension	Skill at combining the elements identified during the operational scan to develop a meaningful mental picture of the operational context.
Sk27	Situation Awareness	Object Projection	Skill at mentally projecting an object's future position to identify conflicts, determine conformance, and evaluate sequencing and spacing.
Sk28	Situation Awareness	Facility Monitoring	Skill at monitoring activity in adjacent sectors while managing air traffic in your position/sector.
Sk29	Air Traffic Management	Flight Strip Utilization	Skill at using flight strips to manage air traffic.
Sk30	Air Traffic Management	Spatial Information Application	Skill at using a dynamic four-dimensional mental picture generated from two-dimensional information for managing air traffic.
Sk31	Air Traffic Management	Object Identification and Position Establishment	Skill at establishing the identification and position of objects using appropriate correlation procedures.
Sk32	Air Traffic Management	Separation Strategy Development	Skill at developing viable separation strategies.
Sk33	Air Traffic Management	Separation Strategy Selection	Skill at selecting the separation strategy that creates or maintains separation standards.
Sk34	Air Traffic Management	Separation Strategy Implementation	Skill at implementing separation strategies in a timely and effective manner.
Sk35	Air Traffic Management	Sequencing Strategy Development	Skill at developing viable sequencing strategies.
Sk36	Air Traffic Management	Sequencing Strategy Selection	Skill at selecting the sequencing strategy that achieves safe and efficient flow of traffic.
Sk37	Air Traffic Management	Sequencing Strategy Implementation	Skill at implementing sequencing strategies in a timely and effective manner.
Sk38	Air Traffic Management	Spacing Strategy Development	Skill at developing viable spacing strategies.

No.	Skill Group	Skill Label	Skill Definition
Sk39	Air Traffic Management	Spacing Strategy Selection	Skill at selecting the spacing strategy that optimizes use of airspace and/or ground movement areas while adhering to applicable regulations and policies.
Sk40	Air Traffic Management	Spacing Strategy Implementation	Skill at implementing spacing strategies in a timely and effective manner.
Sk41	Conflicts	Conflict Identification	Skill at quickly and accurately identifying potential or actual conflicts.
Sk42	Conflicts	Conflict Resolution Strategy Development	Skill at developing viable conflict resolution strategies.
Sk43	Conflicts	Conflict Resolution Strategy Selection	Skill at selecting an effective and efficient conflict resolution strategy.
Sk44	Conflicts	Conflict Resolution Strategy Implementation	Skill at implementing conflict resolution strategies in a timely and effective manner.
Sk45	Conflicts	Advisories/Alerts Utilization	Skill at utilizing advisories and alerts to mitigate threats to safety.
Sk46	Weather	Weather Data Interpretation	Skill at interpreting weather data.
Sk47	Weather	Current Weather Assessment	Skill at assessing the impact of weather on current ATC operations.
Sk48	Weather	Weather Projection	Skill at projecting weather information to determine its potential impact on future ATC operations.
Sk49	Weather	Weather Strategy Development	Skill at developing viable weather mitigation strategies for minimizing the impact of weather on ATC operations.
Sk50	Weather	Weather Strategy Selection	Skill at selecting an appropriate weather mitigation strategy that minimizes the impact on ATC operations.
Sk51	Weather	Weather Strategy Implementation	Skill at applying weather mitigation strategies in a timely and effective manner.
Sk52	Tools and Equipment	Tool & Equipment Operation	Skill at effectively using tools and equipment including input devices and peripherals and optimizing their usage.
Sk53	Tools and Equipment	Tool & Equipment Status Recognition	Skill at recognizing equipment degradation or failure.
Sk54	Tools and Equipment	Tool & Equipment Degradation/Failure Response	Skill at responding to tool/equipment degradation or failure including minor troubleshooting and executing backup procedures.
Sk55	Emergencies	Emergency Recognition	Skill at recognizing the existence or development of an emergency situation.
Sk56	Emergencies	Emergency Response Development	Skill at formulating viable effective response options.
Sk57	Emergencies	Emergency Response Selection	Skill at selecting a response option that quickly and effectively downgrades or resolves the emergency situation.
Sk58	Emergencies	Emergency Response Implementation	Skill at implementing response options and alternatives if necessary until the emergency is fully resolved.

ATCS Abilities

No.	Ability Label	Ability Definition
Ab1	Oral Expression	The ability to communicate information and ideas verbally so others can understand.
Ab2	Written Expression	The ability to communicate information and ideas in writing so others will understand.
Ab3	Written Comprehension	The ability to read and understand information and ideas presented in writing.
Ab4	Verbal Reasoning	The ability to perceive and understand principles governing the use of verbal concepts and symbols.
Ab5	Oral Comprehension	The ability to listen to and understand information and ideas presented through spoken words and sentences.
Ab6	Hearing Sensitivity	The ability to detect or tell the differences between sounds that vary in pitch and loudness.
Ab7	Auditory Attention	The ability to focus on a single source of sound in the presence of other distracting sounds.
Ab8	Visual Color Discrimination	The ability to match or detect differences between colors, including shades of color and brightness.
Ab9	Vision	The ability to see details of objects close by and at a distance in wide range of lighting conditions.
Ab10	Movement Detection	The ability to detect physical movement of objects and to judge their direction.
Ab11	Perceptual Speed and Accuracy	The ability to perceive visual information quickly and accurately and to perform simple processing (e.g., comparison) tasks with it.
Ab12	Number Facility	The ability to add, subtract, multiply, or divide quickly and correctly.
Ab13	Mathematical Reasoning	The ability to perceive and understand principles governing the use of quantitative concepts and symbols.
Ab14	Working Memory	The ability to remember information long enough to manage the current situation.
Ab15	Long-Term Memory	The ability to remember information over longer periods of time such as days, weeks, or years.
Ab16	Fluency Of Ideas	The ability to quickly develop a number of strategies regarding various situations (the number of strategies is important, not their quality, correctness, or creativity).
Ab17	Problem Sensitivity	The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.
Ab18	Deductive Reasoning	The ability to apply general rules to specific problems to produce answers that make sense.
Ab19	Inductive Reasoning	The ability to combine pieces of information from specific cases to form general rules or conclusions. This includes being able to find relationships among seemingly unrelated events.
Ab20	Creativity	The ability to identify alternative but approved solutions to potential problems when existing or established solutions no longer apply.
Ab21	Sustained Attention	The ability to stay focused on the job for long periods of time (up to 120 minutes).
Ab22	Concentration	The ability to focus on job activities amid distractions for short periods of time.

No.	Ability Label	Ability Definition
Ab23	Attention To Detail	The ability to recognize and attend to the details of the job that others might overlook.
Ab24	Flexibility	The ability to adjust or adapt to changing situations or conditions.
Ab25	Composure	The ability to think clearly in stressful situations.
Ab26	Chunking	The ability to quickly and accurately organize stimuli into meaningful groups or units.
Ab27	Mechanical Reasoning	The ability to perceive and understand the relationship of physical forces and mechanical elements in a prescribed situation.
Ab28	Learning	The ability to apply lessons learned from experience. Note that these are changes that occur over time that are not due to maturation or aging.
Ab29	Visuospatial Reasoning	The ability to perceive and understand principles governing relationships among several objects.
Ab30	Visualization	The ability to imagine how an object will look after it is moved around or when its parts are moved or rearranged.
Ab31	Two-Dimensional Mental Rotation	The ability to identify a two-dimensional figure when seen at different angular orientations.
Ab32	Three-Dimensional Mental Rotation	The ability to identify a three-dimensional object when seen at different angular orientations either within the picture plane or about the axis in depth.
Ab33	Recall From Interruption	The ability to recall a deferred or interrupted action when priorities permit, and to be able to resume the action appropriately.
Ab34	Time Sharing	The ability to shift back and forth between two or more tasks or sources of information (such as speech, sounds, touch, or other sources).
Ab35	Wrist/Finger Speed	The ability to make fast, simple, repeated movements of the fingers, hands, and wrists.
Ab36	Control Precision	The ability to adjust the controls of a machine to exact positions.

ATCS Other Personal Characteristics

No.	Other Personal Characteristics Label	Other Personal Characteristics Definition
O1	Professionalism	Having the desire to establish respect and confidence in your abilities among others.
O2	Motivation	Having the motivation to learn through challenges on the job and to progress to a higher level of skill.
O3	Career Orientation	Having the desire to be a highly skilled air traffic control specialist.
O4	Conscientiousness	Being careful, thorough, responsible, organized, proactive, hardworking, achievement-oriented, and persevering.
O5	Integrity	Demonstrating honesty and trustworthiness at work by displaying impulse restraint and avoiding counterproductive work behaviors such as displaying hostile and aggressive behaviors.
O6	Cooperativeness	Being willing to work with others to achieve a common goal. This includes a willingness to voluntarily assist another controller if the situation warrants.
O7	Interpersonal Tolerance	Being willing to accommodate or deal with differences in personalities, criticisms, and interpersonal conflicts in the work environment.
O8	Self-Confidence	Believing that you are the person for the job and that your processes and decisions are correct.
O9	Taking Charge	Being willing to take control of a situation – to reach out and take corrective action as the situation warrants.
O10	Self-Awareness	Having an internal awareness of your actions and attitudes. This includes knowing your own as well as others' limitations.
O11	Interest in High Intensity Work Situations	Having an interest in or preference for working in high intensity work situations.
O12	Risk Tolerance	Accepting the substantial risks inherent in aviation while simultaneously embracing the requirements of the job including the role you play in mitigating risks.
O13	Realistic Orientation	Having a preference for activities that have tangible and measurable consequences; enjoys activities that require skill; is reinforced by accomplishing realistic tasks.
O14	Internal Locus of Control	Having the belief that individuals have influence over the outcome of an event; takes responsibility for outcomes.

ATCT Tools and Equipment

No.	Category	Full Name	Acronym	Description
TE1	Automation	Digital Bright Radar Indicator Tower Equipment /Remote ARTS Color Display/Tower Display Workstation	D-BRITE/RACD/TDW	▪ D-BRITE/RACD/TDW are the primary radar surveillance display used in the ATCT environment. ▪ The D-BRITE/RACD/TDW displays aircraft position, identification, track, and beacon information pulled from the associated TRACON's primary and secondary radar system. It may also provide weather data. The location of the D-BRITE/RACD/TDW in any given facility is a function of that facility's unique configuration. ▪ Controllers monitor the radar display for information regarding aircraft identification, track, and position, and weather. Controllers can make or modify the datablock by using the keyboard, trackball, or knobs to adjust display preferences. Some systems allow each controller to save display preferences. ▪ RACD augments and incorporates features and capabilities found in earlier systems such as Automated Radar Terminal System (ARTS) and Digital Bright Radar Indicator Tower Equipment (D-BRITE) display system.
TE2	Automation	Airport Surface Detection Equipment-Model X	ASDE/ASDE-X	▪ ASDE/ASDE-X is a hardware and software surveillance system that uses radar and satellite technology to gather information about aircraft and vehicles on the ground and aircraft in close proximity to the landing area. ▪ ASDE/ASDE-X aids in the tracking of the surface movement of aircraft and vehicles on movement areas. It also aids in the detection of potential conflicts on the runways through the use of alerts. ASDE/ASDE-X data comes from surface movement radar located on the air traffic control tower or remote tower, multilateration sensors, ADS-B sensors, terminal radars, the terminal automation system, and from aircraft transponders. An important ASDE/ASDE-X function is the capability of ASDE/ASDE-X to identify and alert controllers of potential or actual conflicts on runways. ▪ Controllers interact with ASDE/ASDE-X by monitoring a 20-inch flat panel color display, and by providing inputs via a QWERTY keyboard and a trackball. Also, controllers receive aural conflict alerts generated by the system. ▪ This is relatively new equipment for the tower environment and is not currently certified for separation.

No.	Category	Full Name	Acronym	Description
TE3	Automation	Electronic Flight Strip Transfer System	EFSTS	▪ EFSTS is a hardware and software system including a scanner and printer. It transmits flight plan information from FDIO, which is fed by systems housed in the ARTCC. ▪ The TRACON controller receives the electronic flight strip indicating that an aircraft has departed, which allows the ATCT/TRACON controllers to silently coordinate departures. An audible beep indicates that the system accepted the departure strip. ▪ Controllers interact with the system via flight strip printer and an associated monitor.
TE4	Automation	Flight Data Input/Output System	FDIO	▪ FDIO is a hardware and software system that serves as a portal to the Host/local radar system and that also provides a tracking system for flight plan data and a printing system for paper flight strips. ▪ Controllers use the FDIO to enter and amend flight plan data, weather data, and general information concerning the NAS. Once entered into FDIO, these data are sent to Host/local radar system and then shared with other facilities. Controllers also monitor flight plan data and generate paper flight strips using FDIO. ▪ Controllers monitor the FDIO screen, input data using the FDIO QWERTY keyboard, and collect paper strips from the FDIO printer. ▪ FDIO is associated with the use of paper flight progress strips. It is being replaced with the EFSTS, which generates electronic flight strips.
TE5	Communications	Rapid Deployment Voice Switch/ Enhanced Terminal Voice Switch	RDVS/ETVS	▪ RDVS is the primary voice communication system. It is comprised of both hardware and software components, and supports both radio transmission and landline capability. ▪ RDVS allows ATCT controllers to establish air-to-ground communication with aircraft and ground-to-ground communication with other controllers. Enhanced Terminal Voice Switch (ETVS) is available in smaller terminal facilities. Due to the critical nature of these communications ATCTs are required to have a backup system. The specifics of what that system looks like vary from facility to facility (e.g., it might be a stand-alone system or embedded as part of the larger system). ▪ Controllers monitor the RDVS/ ETVS control panel to see system status. Controllers use input devices such as a foot pedal, hand switch, and buttons, switches or knobs on the control panel to engage the system, toggle between radio frequencies and landlines, and to change volume. Controllers listen to communications with headsets connected to dual jacks with override and volume features. ▪ Some facilities may be using VSCS for this same function.

No.	Category	Full Name	Acronym	Description
TE6	Communications	Light Gun		▪ A light gun is a directed color-coded illumination device used for communication. ▪ Controllers send signals with the light gun to communicate with aircraft, ground vehicles, and personnel that are not equipped with radio or that have lost radio communication. The light gun has the capability to display red, green, or white rays of light in a steady state or flashing mode depending on the intended message, and the location and type of receiver. ▪ Controllers interact with the light gun by pointing it out the tower cab window in the direction of the aircraft, vehicle, or person being controlled and activating the appropriate signal.
TE7	Communications	Crash Phone		▪ The crash phone is a landline telephone. ▪ Controllers use the crash phone to call fire rescue, military, police, airport operations personnel, and airport management to disseminate airborne/ground emergency information simultaneously. Controllers typically access this landline during emergency situations only. ▪ The crash phone is typically located near the supervisor's desk and controllers interact with it via a handset that automatically calls relevant parties when it is picked up.
TE8	Information Management	Traffic Situation Display	TSD	▪ TSD is a hardware and software system that receives radar track data from all ARTCCs and organizes these data into a mosaic display. ▪ Controllers view the TSD to see the volume of traffic entering their airspace. The main TSD display provides high level information regarding traffic flows but the system can also be used to gather information regarding specific flights. ▪ Controllers monitor the TSD on either on a large centrally located monitor and/or a smaller monitor(s) located elsewhere in the facility depending on the facility's unique configuration.

No.	Category	Full Name	Acronym	Description
TE9	Information Management	Digital – Altimeter Setting Indicator	DASI	▪ DASI is a small box that displays the airfield altimeter. It shows the common number that all airplanes would use to ensure they have the proper altitude on descent. ▪ DASI displays information gathered from a certified weather sensor. Controllers are responsible for providing the altimeter setting to pilots, which when input by the pilot into the aircraft's avionics, enables the aircraft to display a consistent and barometrically adjusted altitude. ▪ Controllers read out the altimeter value to pilots using the RDVS system. Controllers monitor altimeter setting visually and use knobs to change the altimeter setting intensity high or low. Depending on the facility, DASI information is displayed on a stand-alone small box, integrated into the IDS, or integrated into the automation system to update automatically for display on radar display.
TE10	Information Management	Information Display System	IDS	▪ IDS is a hardware and software system that displays control-related information gathered from multiple sources. Depending on the facility, IDS may display information that has been pulled from ASOS, ITWS, DASI, or others. Automated Surface Observation System (ASOS) is a surveillance system that collects weather data from the airport's weather station. Integrated Terminal Weather System (ITWS) is a software system providing automated weather information for use by air traffic controllers and supervisors in airport terminal airspace. ▪ IDS data enhance ATCT controllers' situation awareness by providing information regarding many relevant parameters in a single display. The display is located in the vicinity of controllers' workstations with the actual location varying from facility to facility. ▪ Controllers monitor the IDS display visually and respond to oral alerts as prescribed by each facility.
TE11	Information Management	Runway Visual Range System	RVR System	▪ RVR is a hardware and software system that supports precision landing and takeoff operations in the NAS. ▪ RVR works in conjunction with the airport lighting system. RVR data are used as one of the main criteria for minima on instrument approaches. Controllers transmit RVR information to aircraft, which allows pilots to assess whether it is prudent to make an approach. Controllers can set alerts to facility specifications on RVR to alert for certain RVR readings. ▪ Controllers monitor RVR for alerts on either a separate RVR display(s) or on the Information Display System (IDS). Controllers use trackball to set preferences on the IDS display.

No.	Category	Full Name	Acronym	Description
TE12	Information Management	Low Level Wind Shear Alert System	LLWAS	▪ LLWAS is a hardware and software system that measures wind speed and direction at remote sensor station sites situated around an airport. ▪ LLWAS provides real time collection and processing of wind data to detect the presence of hazardous wind shear and microburst events near an airport. Further, LLWAS gives visual and audio alerts to controllers in clear and concise numerical and/or graphical form in order to warn pilots so they can take appropriate evasive. ▪ Controllers interact with LLWAS via the LLWAS display located at the local controller position. LLWAS is its own stand-alone display. In TRACON, LLWAS could be adopted into IDS or stand-alone display.
TE13	Information Management	Weather Systems Processor	WSP	▪ WSP is a hardware and software system that provides information about potentially hazardous microburst and wind shear weather events. ▪ WSP provides current and predicted local severe weather on two computer size screens. The ribbon display provides weather information as text. The graphic situation display provides a color 2-D picture of weather conditions, movement, and predicted future position of weather cells in relation to airport runways. Information from WSP is used to assess the near-term impact of severe weather on terminal operations, such as anticipated changes in runway configurations. ▪ Depending on the facility type, WSP display can be located centrally or near controllers' workstations. Controllers interact with WSP display via a QWERTY keyboard and a mouse for information on direction and speed of wind. ▪ WSP is designed to replace LLWAS.
TE14	Information Management	NAVAID Panel		▪ The NAVAID panel displays information on the status of NAVAIDs for which the facility is responsible. ▪ The NAVAID panels can be used to switch between approach types or to indicate that VORs are out of service. Additionally, panels can be used for monitoring components of the approach system with both audio and visual alarms. ▪ Depending on the panel type, controllers can interact with the NAVAID panel through various types of switches. Also, depending on the facility, the panel could be located on a wall or elsewhere in the facility.

No.	Category	Full Name	Acronym	Description
TE15	Information Management	Airfield Lighting Panel		▪ The airfield lighting panel displays information on the status of lighting at the airport. ▪ The airfield lighting panel is used to adjust airfield lighting as weather changes, to adjust the intensity of lights and to turn them on and off. ▪ Depending on the panel type, controllers can interact with the airfield lighting panel through various types of switches or a touch screen. Also, depending on the facility, the panel could be located at controllers' workstations or on a wall or surface elsewhere in the facility.

Appendix B: Potential Risks

Potential Risk to ATCT Driver Matrix

	ATCT NextGen Driver							
Potential Risk	4-D Wx Data Cube	ASDE-X	ADS-B Out	Data Comm	IADS	TFDM	WTMD	**# of Drivers Affected**
Best Equipped, Best Served			●	●				**2**
Change in Culture				●		●	●	**3**
Coordination of Multiple Stakeholders			●	●				**2**
Deficiencies in Technology			●	●		●	●	**4**
Degradation or Failure of Equipment or Systems	●	●	●	●	●	●	●	**7**
Improper Allocation of Tasks to Automation						●		**1**
Improper Reliance on Automation or Procedures	●	●				●	●	**4**
Lack of/Inadequate Training	●	●	●	●		●	●	**7**
Loss of Party Line Information				●	●			**1**
Mixed Aircraft Equipage			●	●				**2**
Mixed ATC Tools, Equipment, or Procedures	●			●		●		**4**
More Dynamic Work Environment		●			●		●	**2**
Poor Graphical User Interface Design	●	●	●	●	●	●		**6**
Reduced Separation Minima					●		●	**2**
Skill Decay	●		●	●		●		**5**
Technology Development and Maturation	●	●	●	●	●	●	●	**7**
Unknown Impact of Experience						●		**1**
# of Risks Cited Per Driver	**7**	**6**	**10**	**12**	**6**	**11**	**8**	

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Appendix D: Core 30 Airports

Core 30 Airports

1. ATL - Hartsfield-Jackson Atlanta Intl
2. BOS - Boston Logan Intl
3. BWI - Baltimore/Washington Intl
4. CLT - Charlotte Douglas Intl
5. DCA - Ronald Reagan Washington National
6. DEN - Denver Intl
7. DFW - Dallas/Fort Worth Intl
8. DTW - Detroit Metropolitan Wayne County
9. EWR - Newark Liberty Intl
10. FLL - Fort Lauderdale/Hollywood Intl
11. HNL - Honolulu Intl
12. IAD - Washington Dulles Intl
13. IAH - George Bush Houston Intercontinental
14. JFK - New York John F. Kennedy Intl
15. LAS - Las Vegas McCarran Intl
16. LAX - Los Angeles Intl
17. LGA - New York LaGuardia
18. MCO - Orlando Intl
19. MDW - Chicago Midway
20. MEM - Memphis Intl
21. MIA - Miami Intl
22. MSP - Minneapolis/St. Paul Intl
23. ORD - Chicago O`Hare Intl
24. PHL - Philadelphia Intl
25. PHX - Phoenix Sky Harbor Intl
26. SAN - San Diego Intl
27. SEA - Seattle/Tacoma Intl
28. SFO - San Francisco Intl
29. SLC - Salt Lake City Intl
30. TPA - Tampa Intl