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JOB DESCRIPTION FOR THE NEXTGEN MID-TERM TRACON CONTROLLER

DELIVERABLE 2B 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 Terminal Radar Approach Control (TRACON) 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, developers, and human factors 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 TRACON-specific NextGen technologies, automation, and procedures (i.e., Drivers) that are proposed to exist in 2018. The result is this description for the TRACON 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 managing live traffic at a TRACON workstation. It does not describe 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 Federal Aviation Administration's (FAA's) 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 TRACON environment is based on the NextGen technologies, automation, and procedures (i.e., NextGen TRACON Drivers) that are proposed to impact the job responsibilities, KSAOs, and the work environment more generally.

NextGen TRACON Drivers

AIR identified nine primary NextGen technologies, automation, and procedures—or NextGen Drivers—that will influence the TRACON work environment in 2018. These Drivers are:

- 4-Dimensional Weather Data Cube (4-D Wx Data Cube)
- Automatic Dependent Surveillance-Broadcast Out (ADS-B Out)
- Flexible Airspace Management (FAM)
- Integrated Arrival/Departure Air Traffic Control Service (also known as Big Airspace)
- Integrated Arrival, Departure, and Surface (IADS)
- Optimized Profile Descents (OPDs)
- Performance-Based Navigation (PBN)
- Terminal Automation Modernization and Replacement, Phase 3 (TAMR 3)
- Wake Turbulence Mitigation for Arrivals (WTMA)

Although at least some of these Drivers do not require satellite-based technology, they are in many cases recently being supported directly or indirectly by satellite technology. However, they will not affect all TRACON facilities equally. For example, WTMA will only affect facilities that have closely spaced parallel runways and only when cross winds are favorable for reducing wake turbulence. Consequently, it will only affect 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 TRACON Tasks

AIR's analysis suggests that the aforementioned nine TRACON 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 little by 2018. Relatively speaking, few additions, deletions, or modifications will need to be made to the existing list of 362 current TRACON job Tasks (see Appendix A for a full list). The changes are:

- The addition of three new Tasks across two Drivers.
- The deletion of six Tasks across one Driver.
- The modification of 16 Tasks across two Drivers. However, these modifications are primarily associated with one Driver (i.e., ADS-B Out) and involve a minor change, which is removing the word "radar" from Tasks to account for the fact that aircraft identification may be performed via traditional radar or via new satellite-based technologies.

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; Task statements are typically written to 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 TRACON Task list, there will be a number of changes regarding *how* the job Tasks contained in that list are performed. The nine Drivers influence between 7 and 77 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, FAM, and ADS-B Out—which affect 32 or more Tasks each—will arguably affect the most change. 4-D Wx Data Cube affects 77 Tasks in nine TRACON job Activities: FAM will affect 35 Tasks in seven Activities. Finally, ADS-B Out will affect 32 Tasks across six Activities.

Net Impact of NextGen on KSAOs Required of TRACON Controllers
A summative evaluation of the detailed impacts by Drivers described in Section V of this report suggest that there are several net effects of the NextGen technologies, automation, and procedures on the Tasks of the TRACON controller. First, controllers will be using more automation than ever before. They will be using new procedures to perform their work. These new tools and procedures will bring them access to more information and also more accurate information, which will improve their situation awareness and decision-making. For example, the implementation of 4-D Wx Data Cube will provide controllers with more accurate weather data from multiple sources.

Some Tasks will be performed more often and others will be performed less often as a result of TRACON Drivers, but the net effect will be an increase in efficiency for the controller. This will lead to NAS-wide improvements in efficiency of operations. For example, because ADS-B Out will provide controllers with positional information in areas that previously had little, no, or unreliable radar coverage, controllers will perform Tasks associated with radar separation more often and those associated with nonradar separation less often. This will make better use of available airspace.

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 aircraft equipage before developing control instructions for PBN-based operations. Similarly, dynamic resectorization, which is part of FAM, will require controllers to evaluate both current and future sectorization when developing control actions.

NextGen TRACON KSAOs
In addition to having an impact on job Tasks, the nine TRACON 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. The only exceptions are the:

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

As with the Tasks, part of the reason for the lack of impact of the Drivers on the KSAOs is due to the characteristics of the Drivers themselves, and partly to how the KSAOs are written. For example, the Knowledge and Skills required for the job represent the end Knowledge 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 nine TRACON 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 utilized more or less often or will otherwise become more or less important as a result of the implementation of a NextGen Driver(s).

The nine Drivers influence the properties of between 23 and 45 KSAOs each, with many KSAOs being affected by more than one Driver. Based on the number of KSAOs affected, WTMA, PBN, 4-D Wx Data Cube, FAM, and OPDs, which affect 41 or more KSAOs each, will arguably effect the most change. For example, WTMA affects 45 KSAOs. It will require that controllers be taught new Knowledges associated with communicating the shift between two different wake turbulence separation standards. PBN affects 44 KSAOs. It will require controllers to learn new course content both with regard to recognizing which aircraft are equipped with this technology, and also with regard to knowing how to use the new aircraft capabilities to their advantage when managing air traffic. 4-D Wx Data Cube affects 41 KSAOs, such as decreasing the need for Abilities associated with verbally communicating information, since the information will be shared among controllers. FAM and OPDs also affect 41 KSAOs each. FAM will require that controllers use their Ability to imagine how an object will look after it is moved around more often because this will allow them to consider how the airspace/route will look after the decision has been made to change it but before the change is implemented. Finally, the implementation of OPDs will make conscientiousness more important because aircraft that are flying OPD routes will not be managed actively but rather monitored. Controllers will have to maintain their vigilance even when they are not actively managing and communicating with pilots.

Net Impact of NextGen on KSAOs Required of TRACON Controllers

A summative evaluation of the impact of the Drivers as described in Section V of this report suggests that there are several net effects on the KSAOs required of TRACON controllers. First, it will increase the Knowledge 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.

TRACON Drivers will have a more limited impact on the Abilities and Other Personal Characteristics required of TRACON controllers. No new Abilities are required; only one new Other Personal Characteristic is required (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 TRACON Drivers. More specifically, several Drivers either reduce the need for communications directly (i.e., OPDs, PBN) or otherwise create shared situation awareness through the sharing of information (i.e., 4-D Wx Data Cube, FAM, IADS), thus reducing the need for Abilities that support verbal communication.

Another net impact is that the job of the TRACON line controller will become more dynamic and, consequently, 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 because some TRACON Drivers introduce requirements for controllers to switch quickly and often between two Tasks or ways of performing Tasks. For example, FAM requires controllers to respond to more frequent changes in airspace and route configurations. Similarly, WTMA requires controllers to shift between applying two different wake turbulence separation standards. ADS-B Out and Data Comm are only implemented onboard some aircraft, and PBN operations and OPDs can only be performed by aircraft that are equipped with the required avionics. 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 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 19 potential risks as a result of the implementation of TRACON Drivers in the mid-term (see Appendix B). 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 3 to 10, with Big Airspace only having 3 identified risks. ADS-B Out, PBN, and WTMA have the most associated risks at 10 each. Similarly, the 15 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 9, with Change in Culture and Coordination of Multiple Stakeholders each being associated with only one Driver, and Lack of/Inadequate Training and Technology Development and Maturation being associated with all nine TRACON Drivers.

Net Impact of Risks

In summary, although 15 is a substantial number of risks, three represent the primary potential threats to safety and efficiency of the NAS. These risks are: (a) lack of/inadequate training, (b) improper design or implementation of technologies, and (c) mixed aircraft equipage. All of the NextGen Drivers require that developmental and CPC-level ATCSs receive training and practice on Knowledges and Skills. Even though the impact of some TRACON Drivers is very limited (e.g., WTMA only applies to TRACONs serving airports with closely spaced parallel runways during conditions where cross winds are dissipating wake turbulence), this will still create a substantive overall impact on the FAA. In addition, if controllers do not receive or implement the training they receive, they will perform less efficiently, are 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, as well as the design of the human interface. If either of these 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. Although the specifics of the best equipped, best served concept 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 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.

OUTCOMES AND BENEFITS

There are several outcomes from the implementation of TRACON NextGen Drivers. First, the lines between controllers working at different facilities will be blurred in 2018 due to the implementation of Drivers such as Big Airspace and IADS. That is, controllers will have much more involvement in the operations in neighboring airspace than ever before. This increases controllers' situation awareness and provides some opportunities for cross training.

The workplace will become more dynamic. For example, FAM allows air routes and airspace configurations to change as operational conditions change. Although predefined, these changes will be able to be made as operational conditions warrant, which will smooth out controllers' workload. Similarly, WTMA, which allows for the application of reduced separation standards when cross winds are dissipating turbulence, will require controllers to switch between using standard and reduced wake turbulence separation standards. While increasing efficiency in the NAS overall, these changes may increase workload and the possibility for error.

This increase in workload may be at least partially offset by the introduction of decision support tools (DSTs) such as those associated with WTMA. These DSTs are designed to help controllers work more quickly and to allow them to focus on other more challenging aspects of their job. However, note that the net effect on cognitive workload is currently unknown.

In sum, if designed and implemented properly, the Drivers will improve controllers' Ability to function more efficiently. This will translate into individual flight efficiencies which in turn will lead to system wide efficiencies.

NEXT STEPS

AIR's next step is to begin the second part of this project, which involves conducting a Strategic Training Needs Assessment (STNA) to identify to identify the high-level training requirements for the 2018 ATCS. This research will begin immediately. Additional next steps include evaluating the results of this Job Description to determine whether changes are needed to the ATCS pre-employment selection test; developing a strategy for how and when to implement the substantive training and recurrent training that will be required to support NextGen in 2018; to enhance the current job analysis by conducting research to identify ATCS training, supervisory, and Oceanic responsibilities; and to develop NextGen job descriptions for additional aviation industry jobs such as traffic management unit and FAA Technical Operations personnel. Finally, research should be conducted to address the potential risks.

Section I. Introduction

BACKGROUND

In 2003, Congress passed the VISION 100 —Century of Aviation Reauthorization Act (P.L. 108176) establishing and empowering the Joint Planning and Development Office (JPDO) to lead a combined public/private initiative entitled 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 to 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 Knowledge, 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. This is 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. A strategic job analysis 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 (Schneider & Konz, 1989). 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 (see Krokos, Baker, Norris, & Smith, 2008). Once the job analysis of the current ATCS was complete, AIR identified the 2018 job requirements by 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), as well as 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, AIR created a NextGen job description for the ATCS job as it will be performed in each facility type.

This NextGen ATCS job description – which is captured in this report – contains proposed changes to the job Tasks and worker characteristics. The descriptions reflect 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 requires a substantial financial investment. Consequently, the information contained in deliverables must be based on information available at the time. It is fully expected that the information contained 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 TRACON 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 TRACON 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[1] 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 TRACON 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 TRACON. The Drivers are critical in that

[1] 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.

they provide the basis for the changes that are proposed to occur to the ATCS job and to the requirements needed to perform it.

- *Characteristics of NextGen TRACON 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.[2] It is fully expected to change as NextGen concepts mature and as NextGen technologies are developed and implemented.

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

Section II. Methodology

Overview

As stated in Section I, the American Institutes for Research's (AIR's) approach to developing a description of the line controller job for the Next Generation Air Transportation System (NextGen) mid-term Terminal Radar Approach Control (TRACON) environment was to conduct a strategic job analysis. While a traditional job analysis involves gathering information from job incumbents, a strategic job analysis requires a different process, as 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, 2008). This job analysis consists of a hierarchical description of work behaviors in terms of Activities, Sub-Activities, and Tasks. The job analysis 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. 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 worked to develop drafts of these documents (if draft versions did not exist) and to work with SMEs to edit them.

AIR gathered input from SMEs who are experts in the job to ensure the job analytic data were 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 who are currently certified air traffic controllers. In addition to these formal focus groups, AIR conducted numerous informal telephonic interviews to gather additional 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 were not the result of 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 so as to be more consistent with today's air traffic control culture; and edited to follow the proper format.

The edits to the KSAO and Tool and Equipment lists were more substantive. The existing Knowledge list had not been updated since the late 1980's. There was no list of Tools and Equipment, and the existing Abilities list included a combination of Skills and Abilities. AIR updated the existing or draft lists to be more consistent with today's air traffic control work; sorted information into separate lists; reorganized the entries to be more logical; and reworded the labels and definitions to be clearer. Finally, AIR checked for correspondence between the lists. That is, AIR worked to ensure that the Knowledges required to perform the Tasks were captured in the Knowledge list and the Skills needed to perform the Tasks were 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] facility, 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 contained 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 work to develop the vision for the job as it will exist in 2018. This was a substantive research process comprised of several steps. First, AIR reviewed the available NextGen documentation, including the FAA's 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 capture 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 concerning *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 policy makers. The job titles of the SMEs who participated can be found in Table 1 below.

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, En Route & Oceanic Services
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 also 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 on-going human factors evaluations of ATC equipment. AIR's first visit took place in May 2010 and included interviews with five human factor 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 below.

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 additional 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.

Review Academic Literature

The last stage in the data collection process involved conducting a targeted review of the academic literature regarding various topics, including human performance and automation.

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 completed, the next step was to begin synthesizing and consolidating the information in a format that could be used as the foundation for evaluating and describing how the ATCS job would 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 TRACON 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 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 would 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 roadmap 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 roadmap 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 inception worked independently to identify the facility type or types that would be most directly affected by the 51 near-term and mid-term OIs listed on the FAA's Enterprise Architecture web site 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 over 30 years experience in air traffic control, and who is also a human factors researcher and a pilot. The final results for TRACON are shown in Table 3 below. 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 only included mid-term OIs, and to the fact that AIR assigned NextGen improvements associated with aircraft arrival to the TRACON environment, while the FAA assigned them to the ATCT environment.

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

OI No.	OI Name
102118	Delegated Responsibility for In-Trail Separation
102137	Automation Support for Separation Management
102141	Improved Parallel Runway Operations
102144	Wake Turbulence Mitigation for Arrivals: CSPRs
103116	Initial Improved Weather Information from Non-Ground Based Sensors
103119	Initial Integration of Weather Information into NAS Automation and Decision Making
103305	On-Demand NAS Information

OI No.	OI Name
104117	Improved Management of Arrival/Surface/Departure Flow Operations
104120	Point-in-Space Metering
104122	Integrated Arrival/Departure Airspace Management
104123	Time Based Metering Using RNAV and RNP Route Assignments
104124	Use Optimized Profile Descent
104128	Time-Based Metering in the Terminal Environment
105208	Traffic Management Initiatives with Flight Specific Trajectories
107107	Ground Based Augmentation System (GBAS) Precision Approaches
107117	Low Visibility/Ceiling Approach Operations
107118	Low Visibility/Ceiling Landing Operations
108206	Flexible Airspace Management
108209	Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigation Performance (RNP)
108212	Improved Management of Special Activity Airspace
109305	Improved Safety for NextGen Evolution
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 in 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 were proposed to occur in the NextGen mid-term and that would most likely and most directly affect the work environment (and hence the job) of the ATCS in the TRACON environment. This list of nine NextGen Drivers included:

- 4-Dimensional Weather Data Cube (4-D Wx Data Cube)
- Automatic Dependent Surveillance-Broadcast (ADS-B)
- Flexible Airspace Management (FAM)
- Integrated Arrival/Departure Air Traffic Control Service (Big Airspace)
- Integrated Arrival, Departure, and Surface (IADS)
- Optimized Profile Descents (OPDs)
- Performance-Based Navigation (PBN)
- Terminal Automation Modernization and Replacement (TAMR)
- Wake Turbulence Mitigation for Arrivals (WTMA)

To ensure this list of Drivers was comprehensive, AIR researchers independently assigned these Drivers to the OIs identified for the TRACON environment and then reconvened and discussed them to reach consensus. With one exception, the results suggest that the list of Drivers was complete. All of the TRACON Drivers were mapped onto at least one OI and with the exception of one OI (*OI 105302-Continuous Flight Day Evaluation*), each of the OIs had at least one TRACON Driver mapped onto it. While 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 the line controller 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 ADS-B In, which will not be widely available by 2018.

Account for Differences in TRACON Facilities

As discussed in Section I, the primary impetus for the NextGen initiative is increasing capacity and efficiency of the National Airspace System (NAS). Additional benefits include reduced environmental impact and noise. While these benefits are relevant for all TRACONs, 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 would affect the work environment at TRACON facilities disproportionately, with the larger facilities that manage more dense and complex airspace—and hence controllers working in those facilities—being affected most directly. On the basis of this observation, AIR decided to, where appropriate, describe in the report which facility types (e.g., TRACONs with complex airspace and dense traffic) would 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 would affect both TRACON 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 TRACON NextGen Driver would 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 would change *how* an Activity, Sub-Activity, or Task would be conducted in 2018, or whether some characteristic or property would change. For example, researchers endeavored to identify whether and how the curriculum required to teach the Knowledges and Skills would change, whether the frequency with which an Ability might be required would change, or whether the relative importance of an Other Personal Characteristic would change. In each case, researchers were required to explain the rationale for their decision.

After the researchers completed their exercises, they met to discuss their independent results and reach consensus. The individual rating exercises and consensus building meetings resulted in a shared vision of what the job would be like in the mid-term. These results were then used for writing this TRACON 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 following the hierarchy used for describing the current TRACON 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 would change by Activity. For example, when describing TRACON 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, a decision was made by the team to first present information regarding how the job is currently performed by job Activity, to be 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 January 2011, 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 the TRACON line controller 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 first in Section III below to help readers familiarize themselves with the structure, as it is also used to organize information about the job as it will exist in the NextGen mid-term.

Section III. Characteristics of Current TRACON Work and Workers

In this section of the report, the American Institutes for Research (AIR) describes the job of the Terminal Radar Approach (TRACON) line controller as it is performed today. While 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 of the job analytic data). Understanding this organizational structure is critical for interpretation of the NextGen 2018 job description presented in see Section V, as the description is organized in a similar fashion.

Current TRACON Job Characteristics

As previously stated, ATCS work that is currently performed in the TRACON 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 TRACON 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 Traffic Flows and Sequences
- Activity 7. Transfer of Radar Identification
- Activity 8. Assess Impact of Weather
- Activity 9. Manage Airspace
- Activity 10. Manage Resources
- Activity 11. Respond to Emergencies and Unusual Situations

Each of these is described below.

Current TRACON Activity 1: Establish Situation Awareness

Activity 1 for TRACON line controllers includes the responsibility to achieve and maintain optimal situation awareness about activities that either are, 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 are relieved by another controller.

As the TRACON line controllers begin working their assigned positions, they must relieve other controllers who are responsible for the positions. During this period, the relieving controllers must become thoroughly familiar with the current status of the airspace for which they will be responsible. Controllers accomplish this by conducting a thorough review of current and projected operational information by accessing status/information areas (SIAs), position relief checklists, and information contained on alphanumerical data blocks (e.g., ARTS/CARTS/STARS). The relieving controller then begins to actively monitor the airspace via surveillance radar, flight strips, and weather data systems by "plugging in" to the position. The position relief briefing will then commence as an exchange of information between the two controllers using recorded lines, position checklists, and associated logs.

The purpose of accumulating and updating information is to allow the TRACON line controller the means to maintain a continuous and accurate awareness of operations—one that can be consistently communicated to other NAS operators such as other relieving controllers, pilots, supervisors, technicians, or those in system administration.

Current TRACON Activity 2: Manage Communications

TRACON line controllers control the flight path of aircraft and ensure separation primarily by communicating air traffic clearances and other instructions to pilots. This information is vital to the operation of the NAS and is contained in the constant flow and exchange of information.

More specifically, the TRACON line controller is responsible for establishing, initiating, maintaining, transferring, and terminating two-way radio communications with pilots as well as coordinating with other controllers and other control facilities via landlines. TRACON controllers will use the Rapid Deployment Voice Switch (RDVS), but may have other communications options available).

The quality and accuracy of this information is vital to the establishment of a communications "loop." Specific procedures define the content and phraseology allowed for communications. Both controllers and system users are responsible for updating and correcting information if it is in error, incomplete, or if it is unclear. Operational information concerning airspace and airport conditions is relayed in a timely manner, so that the recipient is not overloaded or confused by the information and can in turn comply with given instructions.

Communications provide the key link to air traffic control system functionality. Each communication "element" of this system must be relayed in a complete, timely, and accurate manner in order to affect a smooth, safe flow of air traffic and flight plan information.

Current TRACON Activity 3: Manage Flight Plan Data

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.

TRACON line controllers access flight plan data electronically via the Flight Data Input Output system (FDIO). Flight data controllers will remove the generated flight plan "strip" and pass the strip physically or electronically to the associated control positions. Line controllers issue clearances via radio, landline, or alphanumeric inputs on keyboards in order to relay pertinent updates and changes. Controllers can initiate and process an amendment to a flight plan if they determine what changes or modifications need to be made. Controllers access critical flight information from two key sources: (1) the flight data block located on the primary radar display (i.e., ARTS/CARTS/STARS) to determine the aircraft's current position and speed, and (2) from flight progress strips, in order to evaluate the impact of amendments to the flight plan.

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

Current TRACON Activity 4: Manage Air Traffic

TRACON 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 the line controller 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 consequently medical, rescue, and security operations are given priority status over normal operations.

In order to provide radar separation, TRACON controllers must first make positive radar identification and establish two-way radio contact with the pilot. Using procedures outlined in controller handbooks, SOPs, and LOAs, they properly identify each target using information available on their radar display (i.e., ARTS/CARTS/STARS). Each radar system includes associated automation capabilities, which allow controllers to follow near real-time and accurate flight data information. Controllers may also employ non-radar separation procedures. This approved control method requires greater-than-normal separation standards and is accomplished by controllers obtaining pilot position reports via voice communications and making notations on flight strips.

Other services provided by the TRACON line controller are operations that involve pre-planned flight movements that are of a special nature, such as VIP, national security, presidential or foreign dignitary operations. These evolutions are pre-coordinated by TRACON supervisors and/or traffic managers who advise the TRACON line controller of the beginning, end, and expected duration of each event. Another additional service provided by TRACON controllers includes Visual Flight Rule (VFR) flight following, during which controllers provide traffic services to VFR pilots who request it on a workload permitting basis. In this case, controllers receive a request, evaluate conditions, radar identify the target by issuing an appropriate beacon code and then provide traffic information accordingly. Other additional services that are provided regularly by TRACON controllers include the monitoring of uncontrolled objects, responding to pilot requests for weather deviations, and responding to non-conformance issues. In each case, information is obtained and verified, and a control plan is formulated and executed by the TRACON line controller, who then acts in accordance with established procedures, making required notifications, and performing the necessary coordination.

The management of traffic flows and associated additional services that are provided by TRACON line controllers are crucial to system efficiency and allow system users in various phases of flight to operate in a positively controlled environment. This radar environment provides users with assurances of safety and gives them pre-planning capabilities for different phases of flight; however, conflicts are also inherently a part of this system, due to the number and complexity of flight path trajectories that occur within this airspace. The TRACON line controller is responsible for detecting and resolving those conflicts, which are covered in the next activity.

Current TRACON Activity 5: Resolve Conflicts

The primary job responsibility for TRACON line controllers is not only to provide radar separation, but to ensure that any potential or actual conflicts that occur in their airspace are resolved quickly and efficiently. Conflicts can occur between two aircraft, between an aircraft and the ground, between aircraft and airspace, and between aircraft and severe weather phenomena.

For TRACON line controllers to resolve a conflict, they must first identify a potential or actual loss of separation. The conflict could occur in their area of jurisdiction or it could happen in another controller's airspace. Each instance must be evaluated carefully and the pilot's intentions must be verified in order to determine the most appropriate course of action. Issuing safety alerts, conflict advisories, and warning pilots of terrain are the TRACON line controller's first priority. These are similar in nature because controllers must first identify, validate, and then formulate a resolution, which involves issuing an appropriate instruction to the pilot(s) involved so they can take evasive action. These alerts must be accurate, timely, and must be performed thoroughly in order to achieve a complete resolution. Sometimes, automation parameters are exceeded and conflict or terrain alert alarms sound in error or unnecessarily, in which case controllers may suppress the aural alarm and wait until the appropriate time to restore the alarm's functionality. Airspace violations or the issuance of unsafe condition reports must also be identified, validated, and resolved to completion. These situations require controllers to gather information, determine necessary responses, and make proper notifications to system users and supervisors.

Conflicts cannot be eliminated entirely in terminal environments. However, by using proper established procedures TRACON controllers can reach resolutions quickly and efficiently. As controllers manage traffic and attempt to mitigate conflicts, they are also responsible for overseeing the arrivals, departures, and over flights to and from high volume airports in densely populated areas. These flows and sequences determine overall system efficiency and throughput and are integral to the smooth operation of the NAS.

Current TRACON Activity 6: Manage Traffic Flows and Sequences

TRACON line controllers are responsible for coordinating departing and arriving traffic in a manner that maximizes efficiency but that does not compromise safety. Balancing these two, sometimes competing, goals requires substantive planning and evaluation by the controller. This is especially true for the TRACON controller as they normally work many different airports and airspace configurations simultaneously.

TRACON line controllers must be in constant communication with the local controllers who are located at airports within their areas of jurisdiction. They also direct and assist pilots as they transition to and from these airports, feeding the departures into en-route traffic streams and blending and sequencing the arrivals. Because the TRACON is responsible for airspace that overlies airports, controllers must request departure releases for all IFR aircraft that depart their runways. TRACON line controllers will receive, verify, correct, and amend these requests if necessary in order to adhere to a flow or sequence that will optimize the use of their airspace. They will then allow the departure aircraft to enter their airspace, establish radar contact, provide radar separation, and oversee the flight as it continues into en-route airspace, completing the outbound transition. The arrival phase is similar to departure, but with the reverse action of the TRACON line controller receiving the inbound aircraft from the en-route sector controller and coordinating with the ATCT controller to ensure the most effective use of the arrival stream of traffic.

In order to maximize efficiency in operations, TRACON controllers must also work within the constraints of air traffic management initiatives (TMIs). In order to ensure that these programs are followed closely, a controller must coordinate in real time with pilots, other controllers, and with the traffic managers. Although TMIs ensure more even flow to traffic for downstream controllers, due to the limiting nature of traffic restrictions, workload is usually increased and becomes more complex for the originating facility's controllers as they determine which course of action is most appropriate to achieve the program goals. As implementation can vary widely depending upon the intent and extent of the program(s), line controllers need to remain flexible to adapt to changing conditions to achieve an optimum result.

Total aircraft throughput is a major consideration of TRACON line controllers, and they accomplish this goal by working aircraft as efficiently as possible during the transitions to and from major airports within their areas of responsibility. Automatic flight data information embedded in the radar systems helps them accomplish this goal in a seamless manner, and is a key component of overall effectiveness. These automated data transfer systems will be covered in the next activity.

Current TRACON Activity 7: Transfer of Radar Identification

Radar identification is a crucial means for establishing and maintaining radar separation and control. As an aircraft leaves one sector and enters another, the TRACON line controller responsible for that aircraft must make a positive transfer of control. This requirement ensures flight data integrity, allows for a continuous surveillance of the flight, and allows for minimum of voice communications, which reduces workload and conserves controllers' resources for other air traffic management tasks.

TRACON line controllers perform the function of radar identification transfer by initiating and receiving pointouts and handoffs from other controllers. They use the alphanumeric keyboard inputs on radar displays (i.e., ARTS/CARTS/STARS) in order to change and maintain information contained in data blocks. These displays allow controllers to silently communicate with other controllers and facilities. TRACON line controllers receive requests for a radar handoff, which essentially is a change in control from one sector to another, and must evaluate conditions to determine if additional information needs to be provided or supplemented. Flight progress strips are also used to track and record information. Sometimes, instead of a complete transfer of control, a pointout is made. A pointout is an approval request made from one controller to another as an aircraft transitions through airspace. A pointout is similar to a handoff in that the initiating controller must formulate a request and the receiving controller must formulate a response, either approving or disapproving the pointout request. Sometimes the approval will contain conditions or restrictions that the initiating controller must include with the clearance.

Controllers complete the transfer of important information in order to provide the system user with a seamless transition along their route of flight. The controller continues to update and modify this information in a manner that allows for less frequency congestion, more situation awareness, and better overall system performance. Automation provides a means for controllers to devote time and attention to other important issues critical to system operation, such as assessing the impact of weather.

Current TRACON Activity 8: Assess Impact of Weather

Controllers must constantly observe, assess, and predict how weather conditions will affect airport operations. Responding to changing weather conditions is critical because it allows aircraft operators to avoid potentially unsafe conditions during critical phases of flight.

To respond appropriately to these often rapidly changing conditions, TRACON line controllers actively monitor information that is displayed on Status Information Areas (SIAs). This information lists weather conditions at local airports located in the terminal areas of jurisdiction and is derived from weather sensing equipment located at those airports. These local weather data are then communicated to graphical or textual displays such as the Integrated Terminal Weather System (ITWS), the Automated Surface Observation System (ASOS), and the Automatic Terminal Information System (ATIS). These are in turn incorporated into the system status areas located at the control positions. Other sources of weather information can be derived from other 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, NWS Rapid Update Cycle data, and the Meteorological Data Collection and Reporting System. Controllers must also solicit and disseminate pilot reports (PIREPs), significant weather reports (SIGMETs), or airmen's meteorological information (AIRMETs). This information is broadcast to pilots or to other control facilities using ATIS or the RDVS.

As TRACON controllers determine strategies to help pilots avoid significant weather conditions, they will determine if altitude or route changes are necessary and also coordinate with other control facilities in order to comply with pilot requests for avoidance. When necessary, controllers will also work with supervisors and traffic managers to ensure that disruptions to service are minimal, and that flight path deviations can occur in a safe, orderly manner.

Weather is the single most important variable in ATC system performance. Severe weather poses a very dangerous and ever changing threat to the safety of flight. Early detection and mitigation by TRACON line controllers can greatly enhance overall system performance, and allow for other duties to be performed such as the management of airspace, which is covered in the next section.

Current TRACON Activity 9: Manage Airspace

Controllers direct aircraft with the goal of maintaining an effective flow of traffic within their assigned airspace. This coordination of traffic is important to ensure safety and maximize throughput at each terminal facility and is influenced directly by how effective the TRACON line controller is at airspace utilization. Since airspace is not static and can dynamically change due to operational requirements, controllers must be extremely adept at the efficient use of airspace.

The management of TRACON airspace is especially challenging because of the changing boundaries that result from runway configurations that change regularly at airports. As a result of these demands, TRACON line controllers may require additional airspace. As controllers determine their need for the use of other airspace, they request approval and provide additional instructions to the pilot based on existing conditions. The line controller now assumes responsibility for separation and for the issuance of traffic/conditions information. This information will be relayed via radio or landline and input via keyboard on the radar display. These methods are also used when TRACON controllers transfer their own separation authority to others during sector reconfigurations, when positions are combined and de-combined. Each configuration change is accompanied by recorded briefings and adherence to checklist requirements as other controllers assume responsibility.

Airspace management translates into overall system effectiveness as the TRACON line controller uses proper procedures to make decisions in a fast and efficient manner. Also important is the management of position and controller resources, which is described in Activity 10 below.

Current TRACON Activity 10: Manage Resources

TRACON line controllers are responsible for ensuring that the levels of performance at their positions are maintained to a consistently high standard. In order to do this, they must be aware of traffic workload and the demands of system requirements in order to perform as a highly functional team.

TRACON line controllers must first determine whether they are fit for duty. This means recognizing fatigue, sickness, or any other condition that could cause impairment to performance. If some circumstance has left them unfit for duty, they must be prepared to remedy the situation appropriately. While fitness for duty may affect performance, performance may also be negatively influenced by work overload, which often occurs as a result of an overload of traffic volume or an increase in traffic complexity. Controllers must be aware of potential or actual work overload situations and must respond to these situations by requesting assistance from controllers, supervisors, or traffic managers. Finally, in addition to recognizing overload situations at their own stations, TRACON controllers also recognize and respond to these situations as they may occur to other controllers.

TRACON line controllers maintain positional and occupational currency requirements by participating in proficiency training, attending classes, and participating in computer-based instruction. These qualifications help TRACON controllers to be prepared to manage the day-to-day challenges associated with managing TRACON airspace.

Current TRACON Activity 11: Respond to Emergencies and Unusual Situations

Although redundancy is built into the systems in use by today’s TRACON controllers, there is still potential for unplanned outages and loss of functionality, or service degradation. Since the consequences of these types of failures have the very real potential for loss of life, the line controller must be well trained and proficient at executing several different contingency scenarios.

TRACON 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 unexpected situation occurs. For example, TRACON line controllers must detect system or equipment degradation or failure and respond to alarms. They must then forward the notice of the failure to supervisors and maintenance technicians, and immediately institute 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 and verify control actions during the transition from automated to manual stages. For Host (Host and Oceanic Computer System Replacement [HOCSR]) computer failures, controllers must revert to ARTS/CARTS/STARS stand-alone mode and manual writing of flight progress strip information; for sensor or tracking failures they will revert to non-radar procedures; and if there is a communications failure they must switch to backup radios or power supplies.

Controllers are also responsible for responding to security threats and will delegate the control of their airspace to different control entities as necessary. Lost or stolen aircraft procedures involve line controllers working closely with law enforcement, military, or search and rescue authorities. Specific protocols are often followed to ensure safety is not compromised during these emergency situations.

Off-nominal and/or emergency situations are defined by their imminent nature. TRACON line controllers must be able to act according to safety policies while still being able to find timely and appropriate solutions.

Current KSAOs

The sections above describe in detail the work performed by TRACON controllers. However, in addition to describing the work of the TRACON controller, a traditional job analysis also identifies the characteristics required of workers to perform the work. As previously stated, the characteristics required of TRACON controllers to perform the job are described in terms of Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs). A *Knowledge* is a body of factual, technical, or procedural information a person uses 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 a person possesses that gives him/her the capacity to carry out physical and mental acts required by a job's Tasks. An *Other Personal Characteristic* is an attitude, preference, opinion, or personality trait that influences how well a person 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 people can do their jobs. This training can take place either before a person enters 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 people before they are trained to perform a job, and consequently can be used as the basis for pre-employment selection tests. The following KSAOs required to perform the current job of the ATCS were recently updated by AIR, who worked closely with technical SMEs.

Current Knowledges

The current knowledge requirements for ATCS working in the TRACON 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 sub-categories. Note that these are topics only; they are not designed to represent an actual training curriculum. The complete list of current Knowledge categories and sub-categories can be found in Appendix A. As a convenience, the Knowledge categories are listed below in Table 4.[3]

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

[3] 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 sub-categories vary somewhat across facility type.

Current Skills

TRACON controllers must not only possess factual information about the work, but they must 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. These are provided below in Table 5. The list of Skills with their definitions can be found in Appendix A.[4]

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

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

No.	Skill Category	Skill Label
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
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 TRACON controllers must be taught, some required characteristics are more innate and are more immutable. ATCSs must possess 36 Abilities in order to perform well in the current TRACON environment. These are provided below in

Table 6. The list of Abilities, and their definitions, can be found in Appendix A.[5]

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
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

[5] 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
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 TRACON environment. The list of Other Personal Characteristics, and their definitions, can be found in Appendix A.[6]

Table 7. Current ATCS Other Personal Characteristics

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

[6] 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).

Section IV. Drivers of the NextGen TRACON Work Environment

INTRODUCTION

By 2018, new technology, automation, and procedures will change the environment in which Terminal Radar Approach Control (TRACON) 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, the American Institutes for Research (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 the TRACON line controller. 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 it will be implemented. In other cases, the information that is available is lacking in detail or is conflicting. In these situations, AIR took all available information into account and endeavored to make the best decisions 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.

Although AIR had enough information about these nine 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 Relative Position Indicator may have an important influence on the NextGen mid-term work environment for the TRACON line controller. However, subsequent research did not result in enough information to warrant its inclusion as a primary NextGen Driver for TRACON. 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 nine specific NextGen Drivers that are presumed to influence the job of the TRACON controller by 2018. For simplicity and convenience, the Drivers shown below in are presented in alphabetical order.

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

No.	TRACON NextGen Drivers
1	4-Dimensional Weather Data Cube
2	Automatic Dependent Surveillance-Broadcast
3	Flexible Airspace Management
4	Integrated Arrival/Departure Air Traffic Control Service (Big Airspace)
5	Integrated Arrival, Departure, and Surface
6	Optimized Profile Descent
7	Performance-Based Navigation
8	Terminal Automation, Modernization, and Replacement
9	Wake Turbulence Mitigation for Arrivals

However, before embarking on a discussion regarding these nine Drivers, it must be stated that 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 pre-defined points in space. This allows for 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 FAA to build—and for aircraft to fly—highly prescribed performance-based routes. These routes improve efficiency and reduce fuel burn. Finally, knowledge of accurate aircraft location improves situation awareness (SA) 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 in the NAS. Note that the aircraft in the terminal environment are already relatively 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 enable many specific NextGen technologies, automation, and procedures. More specifically, this technology supports and enables the nine NextGen Drivers identified above, which are most likely to affect the TRACON work environment by NextGen 2018 and are of particular interest for the purpose of building a description of the 2018 TRACON 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 a Federal Aviation Administration (FAA) authorized common weather picture to support effective and coordinated air traffic management decisions. More specifically, 4-D Wx Data Cube will organize the catalogued 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 platform in the TRACON 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 final phase of implementation and therefore 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 it 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 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. Currently, four-dimensional gridded data are already available for all of 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 the mid-term TRACON line controller. 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 the controller in 2018.

Driver 2: Automatic Dependent Surveillance-Broadcast

Automatic Dependent Surveillance Broadcast (ADS-B) is a surveillance technology onboard 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 pilot situation awareness. ADS-B Out refers to the broadcast of aircraft location information via ADS-B transmissions from equipment onboard the aircraft to ADS-B ground stations and to other aircraft if they are appropriately equipped, and is projected to provide more up-to-date and more precise information regarding aircraft position (and theoretically many other parameters) than is currently available to controllers through traditional radar. This increase in data accuracy will allow for 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:

- It will provide controllers more up-to-date and precise information regarding an aircraft's position, thus reducing uncertainty.
- It will provide enhanced visibility of aircraft located in remote or non-radar areas (e.g., Gulf of Mexico, parts of Alaska) to line controllers, thus allowing radar-like separation of equipped aircraft.
- It is projected to be more reliable compared to performance of 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) reference ADS-B but not 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 the TRACON line controller in 2018. While 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.

Driver 3: Flexible Airspace Management

Flexible Airspace Management (FAM) is a concept that supports the tactical reallocation of airspace and resources to match traffic demand and to alleviate chokepoints. The FAM concept is supported by pre-defined inter- and intra-facility airspace configurations and bi-directional routes. In cases of airspace constraints, overloads, or equipment outages, the traffic management unit (TMU) or the area supervisor will choose the appropriate configuration or adaption to be implemented in the line controllers' airspace. Automation will support the reallocation of air routes by remapping flight and radar information to the appropriate control positions. Moreover, at appropriate times certain airspace will have high-performance standards imposed (i.e., aircraft will need to be properly equipped to fly in that airspace). Note that the basic notion of FAM exists today. However, in the NextGen environment, FAM will support many new configurations and routes. That is, the ability to move air routes around airspace constraints will still exist, but in addition there will also be the ability to keep air routes intact and move the boundaries and ownership of the airspace around air routes. This will mean that the control of an air route and the aircraft on it can be moved to a different control position.

Important benefits of FAM as it will exist in the 2018 NextGen environment include improved efficiency and increased flexibility. Pre-defined airspace configurations and bi-directional routes will allow for strategic adjustments to be made to better manage traffic demand and to handle other constraints such as weather, Special Activity Airspace (SAA) activations/deactivations, and runway configuration changes. In addition, the reallocation of the control of aircraft to different TRACON line controllers will allow for tactical changes to be made to handle constraints such as controller workload and equipment outages. An initial human-in-the-loop simulation conducted in August 2010 to assess the potential user and system benefits of FAM was given overall positive ratings by the radar controller participants in terms of safety, situation awareness, airspace designs, and boundary change procedures implemented in the study.

FAM as it will exist in NextGen is still in the preliminary stages of development. While it is intended to be operational by the mid-term, the automation proposed to support this concept has not yet been specified. However, research groups are currently working to develop the concept and how it will work, and are exploring the tools needed. In addition, the FAA's automation roadmap and other sources indicate that the concept will be operational by 2018. While there is no documentation currently available that lists what components of FAM will be in existence by 2018, for the purpose of this report AIR presumes that new bi-directional arrival/departure routes will be in place in the busier TRACON environments and that new inter-facility airspace configurations will also be in place.

DRIVER 4: INTEGRATED ARRIVAL/DEPARTURE AIR TRAFFIC CONTROL SERVICE

The Integrated Arrival/Departure Air Traffic Control Service (known informally as "Big Airspace") is a concept designed to help overcome operational inefficiencies in major metropolitan areas. The Big Airspace concept will be accomplished with a series of changes to the NAS. First, TRACON and ARTCC controllers working in Super Density areas will be collocated to promote effective communication and coordination. Big Airspace will not integrate whole facilities, but instead will collocate only the sector controllers responsible for transition airspace into Super Density areas. Sector teams will consist of a radar controller and a handoff controller. Second, Big Airspace will also utilize Area Navigation-enabled routes (see section on Performance Based Navigation) and dynamic resectorization capabilities (see the section on Flexible Airspace Management) to make airspace boundaries more flexible so that traffic can be more easily rerouted when weather, equipment outages, or active special use airspace disrupt normal flows. Finally, the Big Airspace concept will be supported by the expanded use of 3-mile separation standards and current minima for diverging courses in all arrival and departure airspace, as well as the use of visual separation standards above 18,000 feet.

Super Density airspace creates specific operational inefficiencies for TRACON and ARTCC controllers. Currently, no single facility in these areas is responsible for the arrival and departure airspace associated with the airports. Managing this airspace is among the most difficult tasks controllers have, in large part because they are using different automated systems, and because they are located in different facilities without one central overseer for the highly congested airspace. In addition, complicated airspace layout compresses TRACON airspace, causing controllers to perform a lot of low-level vectoring and to separate aircraft from airspace rather than other aircraft. This leads to extreme inefficiencies, including increased workload.

Big Airspace operations are intended to reduce operational inefficiencies that occur when coordinating TRACON and ARTCC traffic across multiple facilities in Super Density airspace. Early studies provide positive support for this concept. More specifically, studies show that controllers had fewer ground-to-ground communications and required less holding and less assistance to maneuver aircraft when working in Big Airspace operations. Overall, validation efforts for Big Airspace indicate that it will result in reduced workload for controllers with aircraft being managed more efficiently.

Big Airspace validation results indicate that there are seven potential areas for Big Airspace facilities (i.e., New York, Philadelphia, Baltimore/Washington, Chicago, Atlanta, central Florida, northern California, and southern California). However, early analyses show that since new large TRACON buildings exist in most major metropolitan areas, it would be most economical to locate Big Airspace operations in these facilities, at least for an initial implementation of Big Airspace. Based on this information, AIR presumes that the Big Airspace Concept will be operational by 2018 in the major metropolitan areas where a new facility would not need to be built. In addition, AIR assumes that the control of the transition airspace sectors will be become the responsibility of the TRACON facility. Consequently, ARTCC controllers managing sectors for transition airspace into Super Density areas will be collocated in the TRACON facilities for these areas. AIR further presumes that the control of these transition airspace sectors will be become the responsibility of the TRACON facility.

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 who are 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 TRACON line controllers to better plan for and execute arrival activities 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, current and future conditions including weather and runway configurations, and user preferences to allow for more efficient movement of aircraft from the TRACON to the runway. Since this is still an evolving concept, the actual DSTs have not been designated.

The major outcomes of the IADS concept are shared SA 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. These include:

- *Increased efficiency*: IADS will organize aircraft to follow their assigned routes from meter points to the runway. IADS may also increase throughput at the Core 30 airports (for a list of Core 30 airports, see Appendix C).
- *Increased predictability*: IADS may help to achieve better on-time performance from airlines and more up-to-date departure and arrival (predicted and actual) times.
- *Increased capacity*: IADS will allow for 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.

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 4-D Wx SAS, and Area Navigation (RNAV)/Required Navigation Performance (RNP) routes 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: OPTIMIZED PROFILE DESCENT

Optimized Profile Descent (OPD) is a process that starts at an aircraft's point of descent or "top of descent" and requires the arriving aircraft to descend continuously by exerting minimum engine thrust before reaching the final approach fix. The ability to implement OPDs will depend upon the limitations of the local airport, airspace, environment, traffic, aircraft capabilities (e.g., on-board monitoring equipment like RNP), and air traffic control. OPDs are often associated with standard instrument arrival (STAR) procedures and are enabled by Performance Based Navigation (PBN). Note that OPD is one method of performing Continuous Descent Operation

(CDO). The other method is an Initial Tailored Arrivals (ITAs), a procedure that currently exists and is initiated by ARTCCs, and hence is not considered in this report.

OPDs will provide several benefits in the mid-term:

- Increased fuel savings for NextGen equipped aircraft
- Reduced carbon dioxide emissions due to reduction in fuel consumption for aircraft
- Reduced controller-pilot communication and consequently reduced radio frequency congestion. This reduction in controller-pilot communication will allow controllers extra time to scan their operational environment and work with other traffic.

OPDs are currently in use at some of the nation's busiest Core 30 airports (for a list of Core 30 airports, see Appendix C). Specifically, OPDs have been implemented at Phoenix, Los Angeles, San Diego, Atlanta, and Las Vegas, while development is in progress at Anchorage, Honolulu, Charleston, and Reno. According to the NextGen Implementation Plan, FAA plans to expand OPD operations through the fiscal year 2011, where feasible. Currently, it is unknown how many cities with Core 30 and non-Core 30 airports will have OPD operations by 2018. However, considering the ongoing implementation and prototyping of OPD procedures, and the substantive benefits to both the FAA and the air carriers, AIR proposes that OPDs will be operational in at least 60% of the cities with Core 30 airports by 2018.

DRIVER 7: PERFORMANCE-BASED NAVIGATION

Performance-Based Navigation is a concept that describes performance requirements for aircraft and the associated infrastructure required to fly more direct routes. More specifically, the two main components are: (a) navigation specifications and (b) navigation aid infrastructure. A navigation specification refers to a set of aircraft and aircrew performance requirements that support navigation in a particular defined airspace. For example, the specifications provide better consistency and predictability that allow TRACON controllers to manage air traffic similar to ARTCC controllers. For example, instead of issuing a series of instructions for four or five turns, TRACON controllers might issue a single clearance. Consequently, these RNAV/RNP specifications will substantively reduce voice communications.

These performance requirements are applied to air traffic routes, instrument procedures, or defined airspace, thus restricting their use to properly equipped aircraft. The navigation aid infrastructure refers to the ground-based as well as space-based navigation stations that are required to support the navigation specifications. PBN is primarily enabled by satellite-based (i.e., GPS) navigation aids and is applied to air traffic routes or defined airspace. PBN is a foundational concept for NextGen. Currently, PBN enabled routes exist at many of the nation's Core 30 airports, but are projected to expand to the remaining Core 30 airports by mid-term 2018.

There are two types of navigation specifications: (a) Area Navigation, and (b) Required Navigation Performance.

Area Navigation: RNAV is a navigation specification that removes the requirement for a direct association between aircraft navigation and ground-based navigation aid, thus allowing flexibility in point-to-point operations. Hence, pilots will be able to fly more direct routes (i.e., RNAV procedures) to their destinations instead of conventional routes from one ground navigation station to the other. These RNAV-based procedures can be categorized into Standard Instrument Arrival (STAR) and Standard Instrument Departure (SID) procedures. A STAR is a designated published arrival procedure for IFR aircraft that details a transitional descent from higher altitudes through terminal airspace to a specific airport and/or runway. A SID is a designated published departure procedure for IFR aircraft that defines a departure from an airport/and or runway, through terminal airspace and into en route airspace.

RNAV procedures provide the following potential benefits to the users of the NAS:

- Reduced separation standards, as equipped aircraft fly more accurate routes
- Greater flexibility to aircraft users to negotiate their routes and perform point-to-point operations
- Reduced controller to pilot communications
- Reduced fuel usage by equipped aircraft
- Reduced congestion in TRACON airspace due to fewer miles flown as a result of Optimized Profile Descents
- Reduced departure delays because of diverging departure routes
- Reduced dependency between departure flows

Currently, the FAA has authorized 340 RNAV procedures at 118 airports (both Core 30 and non-Core 30 airports) at 30 states and territories. Furthermore, 27 of the nation's Core 30 airports are projected to have RNAV procedures by the NextGen near term. According to the PBN roadmap, the FAA intends to mandate RNAV for arrival and departures at most Core 30 airports by 2018. Consequently, AIR proposes that RNAV procedures will be operational at all or most of the Core 30 airports in the Continental United States by 2018. AIR also anticipates that RNAV procedures will be available at a substantial number of non-Core 30 airports engaged in commercial air operations.

Required Navigation Performance: RNP is RNAV as described above with the addition of an onboard performance monitoring and alerting system. More specifically, a critical feature of RNP is the capability of the aircraft's navigation system (e.g., flight management system) to manage and monitor the navigation performance the aircraft achieves and to inform the aircrew if the aircraft deviates from its predefined path. The existence of this onboard system is the key difference in terms of equipage between RNAV and RNP, although both the aircraft and the aircrew also have to be certified to fly RNP-enabled routes. RNP specification allows aircraft to fly more accurate and tighter routes along multiple "highways" built in the airspace, thus utilizing the NAS more efficiently.

RNP procedures provide several potential benefits to users of the NAS. These include:

- Onboard monitoring and alert systems that allow pilots to follow the specified trajectories more closely. This reduces controller to pilot communications.
- Improved departure performance through the use of multiple departure runway paths from each runway. These runway paths will accommodate more aircraft in TRACON airspace (increase capacity) and also improve on-time departures for airlines.

Currently, 30% of the US fleet is capable of using RNP procedures. A recent RTCA report suggests that airline operators will need to voluntarily equip and certify or be incentivized to equip and certify to reap the benefits of RNP-enabled routes. In addition, the FAA has authorized more than 200 RNP procedures around the airspace at 63 airports in 31 states, two US territories, and one country. Finally, 20 of the nation's Core 30 airports are projected to have RNP procedures by the NextGen near term. Consequently, for purposes of building the TRACON job description, AIR assumes that 50% of the US fleet will be equipped with necessary technology to fly RNP procedures by 2018. Furthermore, based on the current and projected number of RNP procedures, AIR anticipates that RNP procedures will be operational by 2018 at least 90% of Core 30 airports.

DRIVER 8: TERMINAL AUTOMATION MODERNIZATION AND REPLACEMENT

Terminal Automation Modernization and Replacement (TAMR) is a program that modernizes the radar display that controllers use at TRACONs and their associated ATCT facilities. The purpose of the TAMR program is to replace the aging systems that currently exist in the nation's TRACONs and their associated ATCTs and make them compatible with the 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 was projected to replace automation systems (specifically, Automated Radar Terminal System or ARTS IIE) at five additional TRACONS and modernize ARTS IIIE at four large TRACONS. In TAMR Phase 3 (or TAMR 3), the existing Common Automated Radar Terminal System (CARTS) automation systems at the remaining 106 sites will either be replaced or upgraded.

The major goal of TAMR 3 program is to build a system that is compatible with other NextGen systems (e.g., ADS-B), and that can be easily upgraded or used to replace older systems. In addition, TAMR 3 program will incorporate functionalities (e.g., weather products) into the automation without drastically changing the original platform. Specifically, TAMR 3 program may incorporate Data Comm systems and the Electronic Flight Strip Transfer System (EFSTS). Data Comm will allow controllers to communicate with pilots via data communications (as opposed via voice communication over the radio) and EFSTS supports the transmission of flight information between the ATCT and the TRACON. However, the Data Comm component will not be implemented in TRACON facilities by midterm 2018, so it will not be discussed in this section.

The consolidation of various functionalities will reduce the amount of time controllers and traffic managers spend seeking information, which should assist controllers in processing more traffic in a shorter period of time. It is currently unknown whether other users of the NAS outside line controllers and traffic managers will have access to the electronic flight plan information. Having a standardized automated terminal display system will ensure that TRACON air traffic controllers and traffic managers can access the same information regardless of the facility or sector they manage. The resulting shared mental model will ensure that TRACON controllers will coordinate more efficiently with controllers from other facilities, reducing the amount of time spent reconciling information affecting En Route and Tower controllers. For example, TRACON controllers and traffic managers will have more accurate understanding of airport delays, making it easier for them to reroute traffic as needed.

Currently, little information exists regarding the TAMR 3 program completion timeline. However, the FAA's current automation roadmap shows that TAMR 3 program 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 upon variables such as air traffic volume, current automation status, and resources available. Consequently, for purposes of building the TRACON job description, AIR assumes that TAMR 3 modernization will be completed in at least 50% of the busiest TRACONs and their associated ATCTs by 2018.

Driver 9: Wake Turbulence Mitigation for Arrivals

Wake Turbulence Mitigation for Arrivals (WTMA) is a system that uses automated surface observing system (ASOS) weather information to forecast how crosswinds will mitigate the presence of wake turbulence vortices on parallel approach courses to closely spaced runway operations. When WTMA is in use as designated by supervisors, line controllers will see a light on their radar displays indicating that separation minima can be reduced for parallel approach courses. The capability for reduced separation is based on wind sensing and prediction systems that ascertain when crosswinds are stable and strong enough to dissipate wake turbulence. Also, the Automated Terminal Proximity Alert (ATPA), an existing DST that is being implemented on color radar displays to help controllers consistently maintain precise minimum separation standards between aircraft on final approach courses and to alert controllers to any potential loss of separation, will be adapted to support WTMA. ATPA Phase II will incorporate a larger matrix of wake turbulence standards and will monitor and alert controllers to potential loss of separation between aircraft on CSPRs in addition to monitoring aircraft on the same approach course. Consequently, controllers will not have to know whether specific pairs of aircraft create potential wake turbulence problems. The diagonal separation distance is static but it may vary according to closely spaced parallel runway's (CSPRs) center line separation and aircraft wake categories. Fortunately, the ATPA will automatically check this for controllers.

The major benefits of wake turbulence mitigation include increased capacity and improved efficiency. That is, the reductions in separation minima will allow for an increase in airport arrival throughput during favorable wind conditions. Additionally, DSTs will inform TRACON line controllers of appropriate times to use reduced separation minima and of the smallest separation that can be used between aircraft pairs.

WTMA is still in the prototype phase and is currently being tested as a standalone system. The details regarding implementation (e.g., where the indicator light will be placed, how the DST's alerts will be communicated, or in which facilities WTMA will be implemented) are currently unknown. However, TRACON is the FAA's first priority for getting wake turbulence mitigation tools. In addition, the impact of WTMA is restricted to arrivals into airports with CSPRs and cross-wind availability, so it will only be implemented at TRACONs serving these airports. As a result, AIR assumes that WTMA will be available in 2018, but to less than 10 TRACONs.

Section V. Characteristics of NextGen TRACON Work and Workers

INTRODUCTION

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

This description of the NextGen TRACON line controller's job is organized by the nine TRACON NextGen Drivers that were described in Section IV: 4-Dimensional Weather Data Cube (4-D Wx Data Cube); Automatic Dependent Surveillance-Broadcast (ADS-B); Flexible Airspace Management (FAM); Integrated Arrival/Departure Air Traffic Control Service (Big Airspace); Integrated Arrival, Departure, and Surface (IADS); Optimized Profile Descent (OPD); Performance-Based Navigation (PBN); Terminal Automation Modernization and Replacement (TAMR); and Wake Turbulence Mitigation for Arrivals (WTMA). 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 is an overview of the impact of the Driver on the job of the Air Traffic Control Specialist (ATCS). Next, 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 Knowledge, Skills, Abilities, and Other Personal Characteristics (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 TRACON 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 TRACON 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 TRACON 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 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 TRACON 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.[7] 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-D WX 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 the controller's workstation. 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. It could be implemented as a stand-alone system, or the data could be sent through the Standard Terminal Automation Replacement System (STARS) platform and then presented to TRACON controllers on a separate display. In either case, it is assumed that the precipitation overlay that currently exists on radar/traffic display would continue to be available and could be selected at the controller's discretion.

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

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.

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 list:		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 T238 T7 T242 T8 T254 T11 T259 T15 T260 T16 T261 T22 T262 T42 T263 T46 T264 T78 T268 T82 T279 T85 T283 T86 T291 T92 T292 T95 T297 T96 T298 T101 T300 T108 T330 T124 T331 T125 T336 T137 T337 T138 T338 T150 T342 T155 T344 T163 T348 T168 T349 T173 T351 T176 T265 T177 T266 T181 T267 T182 T269 T185 T270 T194 T272 T196 T273 T205 T274 T207 T275 T212 T277 T217 T278 T231	K8.2 K8.5 K8.8 K8.9 K8.10 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 TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 4-D Wx Data Cube will not require changes to the list of Tasks that TRACON line controllers currently perform, AIR proposes that 4-D Wx Data Cube and the associated 4-D Wx SAS will affect *how* TRACON 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 TRACON 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 Traffic Flows and Sequences
- Activity 7: Transfer of Radar Identification
- Activity 8: Assess the 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 TRACON 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 fed through STARS system but will be displayed to controllers on separate screen(s). 4-D Wx Data Cube, then, represents a new tool or equipment (*New TE*) for TRACON controllers. Hence, controllers will scan a different piece of equipment or system to access weather information, such as wind shear and runway visual range (RVR) data, which are currently located on separate pieces of equipment, from a centralized location. This will reduce the number of places controllers are currently required to scan for weather data (*T11*) and, as a result, will reduce controllers' scanning time and workload.

The 4-D Wx Data Cube display will be customizable to individual controller preferences so that controllers will have another piece of equipment to adjust when assuming position responsibility (*T7*) and to scan for configuration (*T8*), which will increase overall scan 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*, *T22*). 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 (*T15*). 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 (*T16*). Furthermore, scanning fewer places will reduce the amount of time required to evaluate data to determine projected weather, which will again result in reduction in controller workload.

Activity 3: Manage Flight Plan Data

Controllers use weather information today when evaluating flight plan requests (*T42*) and when determining the need for flight plan amendments (*T46*). 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

When TRACON controllers evaluate flight plan data today as part of managing air traffic, they take weather information into account (*T78*). However, as stated above in Activity 3, 4-D Wx Data Cube provides better weather information; hence, the quality of the decisions made during this evaluation will improve.

While performing radar and nonradar separation of aircraft, TRACON controllers must identify potential conflicts (*T82, T92*), 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, and when providing radar assistance to visual flight rules (VFR) aircraft, controllers must also determine the appropriate control actions (*T85, T95, T124*). 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 (*T86, T96, T125*). 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 TRACON controllers when determining an appropriate plan of action in response to special operations (*T101*). 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 (*T108*). 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. Reductions in the disparity between the information the pilot has regarding the weather (e.g., pilot's out-the-window view, close proximity surveillance of weather via onboard sensors) and the information controllers have regarding the weather (e.g., remotely gathered and subsequently delayed distribution) will mean that controllers will be better able to coordinate with pilots to determine if such requests are advisable (*T137*). If a request for deviation is approved but restrictions are required, controllers will have to generate an alternative clearance. Again, the appropriate clearance is influenced by weather (*T138*). 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 (*T150, T163, T173*). 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 (*T155, T168, T177*). In addition, more accurate weather information will allow controllers to more precisely determine whether an airspace violation occurred as a result of weather (*T176*). This is important because controllers must ascertain facts and details regarding the potential airspace violation.

Controllers will be able to utilize 4-D Wx Data Cube information to more accurately determine the need for advisories or alerts (*T181*) 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 (*T182*). 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 (*T185*), thus reducing uncertainty in flight planning.

Activity 6: Manage Traffic Flows and Sequences
Knowing with greater accuracy the location of weather will allow controllers to better predict where chokepoints are likely to occur. This allows for more "real time" adjustments to sequences. First, it will allow them to determine the most appropriate sequences within the departure flows (*T194*) and arrival flows (*T205*), and also to assist them when reevaluating those departure (*T196*) and arrival flows (*T207*). 4-D Wx Data Cube will provide TRACON line controllers with weather information that looks much more like the weather information that traffic management unit (TMU) already has available. Consequently, this will make the discussion of traffic management initiatives (TMIs) (*T212*) and the coordination with TMU (*T217*) much easier for controllers. Furthermore, if the 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 then they will be looking at the exact same weather information (*T212, T217*). The availability of shared information is likely to improve the quality and timeliness of the 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 (*T231, T238*). 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 (*T242*). 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 point out requests (i.e., controllers will know whether a restriction is necessary and consequently will not unnecessarily restrict aircraft) (*T254*).

Activity 8: Assess the Impact of Weather
4-D Wx Data Cube is a new tool that will change where controllers will access the weather information they need and the format (graphical or text) in which it is presented (*T259, T260*). Although the exact information that 4-D Wx Data Cube will provide has not yet been specified in the 4-D Wx Data Cube Concept of Operations (ConOps), it is proposed to contain human-generated observations, which could include pilot weather reports (PIREPs) and instrument flight rules (IFR)/VFR/flight condition reports. If this is the case, then notices of runway condition/use, notice of runway or airport condition changes, and IFR/VFR status of airports would not need to be received from airport traffic control tower (ATCT) line controllers or forwarded to others. Instead, all subscribers will receive this information directly from the 4-D Wx Data Cube (*T261, T262, T263*). Similarly, receiving and requesting weather reports will no longer be active processes that require communication with controllers (*T266, T267*). Again, subscribers will scan the 4-D Wx Data Cube to get this information, thus greatly reducing coordination requirements for processing weather information.

4-D Wx Data Cube changes how often and to whom controllers disseminate weather information. Its availability to multiple NAS subscribers means that controllers will be disseminating weather information to fewer people and not as often (*T277*). Note that controllers will still have to forward runway condition data and weather reports 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 (*T264*, *T268*). Further, if 4-D Wx Data Cube is designed so that information about weather sensor degradation/failure is incorporated, then this could dramatically reduce coordination required by controllers to monitor, receive notice of, and forward reports of faulty airport environmental sensors (*T265*, *T269*, *T270*). This information would automatically be available in 4-D Wx Data Cube.

4-D Wx Data Cube will also change Tasks associated with responding to severe weather information. TRACON line controllers will receive information regarding weather intensity and trend from a new display that provides information of higher quality and timeliness (*T272*). This information will now be shared and displayed in the same manner to all subscribers in a 4-D Wx SAS. Thus, requesting this information or receiving a request for it will occur less often because everyone is seeing the same picture (*T274*, *T275*, *T277*). Note that in order for the information contained in 4-D Wx Data Cube to be truly four-dimensional, PIREPS and other reports will have to be formatted and communicated in four dimensions (*T273*). This will mean that pilots will have to provide the information in four dimensions and controllers will have to request it in that format. Finally, 4-D Wx Data Cube changes the quality and timeliness of weather data that controllers receive. Therefore, there may be a slight decrease in the amount of time controllers spend evaluating the impact of severe weather because more weather data will have been mined, synthesized, and presented (*T278*). Controllers will know with greater certainty the location of the perimeter and altitude of weather, so they will make more accurate altitude or route changes to bypass weather (*T279*). Again, this allows controllers to be more accurate, thus reducing inaccuracy and uncertainty in the NAS.

Activity 9: Manage Airspace

TRACON 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 (*T283*). 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 (*T291*). The coordination required for temporary release of airspace, once approved, will be eased and more productive because both controllers will have access to same weather information (*T292*).

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, these discussions (*T297*, *T298*) 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 they are more operationally appropriate, and prevent them from generating "one size fits all" options (*T300*).

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 (*T330, T337, T342, T348*). 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 (*T331, T338, T344, T349*) without over or under controlling.

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 (*T336, T351*). This is particularly true given that today's controllers are often coordinating with entities that have sophisticated satellite-based weather information already. For example, search and rescue operations are often conducted with the US Coast Guard or the US military and can cover large geographical areas in severe weather conditions. To the extent that 4-D Wx Data Cube will increase the quality of the line controllers' weather information to one that more closely matches that available to others, this will increase shared situation awareness and ease of communication.

Changes to Characteristics Required of TRACON Controllers
When determining the impact of a NextGen Driver on the characteristics required of TRACON line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing lists 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 TRACON 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 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 job 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 TRACON line controllers learn new training material to support existing 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., over or under reliance on automation); benefits of automation (e.g., freeing of cognitive resources for use on other tasks); automation design considerations, including appropriate task allocation to man and machine; and concepts associated with decision support tools (DSTs), including the decision support versus decision-making 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 (*K8.8-Pilot Report [PIREP] solicitation requirements*); in order for the information to be four-dimensional, controllers will have to know how to solicit the information from pilots in four dimensions. TRACON 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 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)*. 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 new curriculum for the new Knowledge regarding how the new facility Tools and Equipment work in conjunction *(New K-Interoperability)*. For example, in the case of 4-D Wx Data Cube, it would include information regarding how the new 4-D Wx Data will be depicted on the radar/traffic display, how the system as a whole interacts with the existing automation such as the ARTS/CARTS/STARS platform, and if 4-D Wx information will be displayed on other systems that currently display weather such as the 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 TRACON environment. Although Knowledge of scanning strategies is important, it is unclear if/how controllers are currently taught this Skill. Based on AIR's research, it appears to be taught only by some trainers.

Moreover, 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 when developing strategies 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 (*K8.5-Weather data interpretation*).

Since more NAS users will have access to the same common weather picture, the Knowledges associated with 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 from the Tower to the TRACON via a landline or flight data input/output (FDIO), there will be a reduction in the amount of weather information recording required of TRACON line controllers, because it will be displayed on 4-D Wx Data Cube. Consequently, this Knowledge will be used less often (*K8.9-Weather information recording*). Similarly, if controllers in ATCTs, TRACONs, and ARTCCs are viewing the same displayed weather information, TRACON controllers will disseminate this information less often to other controllers and hence will use this Knowledge less often *(K8.10-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 that 4-D Wx SAS has to collapse so many sources of raw data into a single display—then TRACON 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 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 regarding the impact of weather on operation (*Sk47-Current Weather Assessment*). Controllers will also need to be taught new Skills at projecting this new information and its impact on operations (*Sk48-Weather Projection*). Moreover, controllers will need to be taught new Skills at using this new information to develop viable weather mitigation strategies (*Sk49-Weather Strategy Development*).

Lastly, although the exact platform(s) that will house 4-D Wx Data Cube is unknown, 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 TRACON line controllers (e.g., TMU, ATCT 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, TRACON 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 Skill at 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 for the controller, 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 TRACON line controllers (e.g., ATCT controllers, TMU personnel) also get 4-D Wx Data Cube, it will reduce the amount of time TRACON 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 potential 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, this change could decrease the importance of being able to shift back and forth 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. 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-Visual Color Discrimination*) will be required more often. Also, 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 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 have more parameters. TRACON controllers will need to be able to adapt to having 4-D Wx Data Cube at their workstations (*Ab24-Flexibility*). 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*) described above, the addition of technologies increases the importance of believing that individuals have influence over the outcome of an event and taking responsibility for 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 17 risks associated with TRACON 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 in 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 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 all TRACONs, 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. In addition, if existing weather tools (IDS) are not decommissioned when 4-D Wx Data Cube is installed, controllers may need to use both, which creates an additional training requirement without substantially reducing existing training, at least in the short run.
- *Poor Computer-Human Interface Design*: If the Computer-Human Interface (CHI) that provides the line controller with synthesized information (in the 4-D Wx SAS) is not designed so as 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. .
- *Skill Decay*: 4-D Wx Data Cube will reduce the need for line controllers to coordinate with others, including pilots and other control facilities, to gather weather/flight condition information; 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 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

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 Task. This impact is relevant for nearly every Activity because nearly every Activity requires assessing the impact of weather or communicating weather information. Although 4-D Wx Data Cube is likely to affect TRACON controllers less than ATCT controllers because ATCT controllers are the observers and recorders of weather, it will still impact most Activities either directly or indirectly. The detailed information captured above regarding the impact of 4-D Wx Data Cube on the job of TRACON line controllers was presented in an effort to highlight the 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. The information that controllers will have will more closely match the sophistication of the information that pilots have via onboard avionics. This increases shared situation awareness among controllers, pilots, and the TMU. Controllers will be in a better position to understand and communicate the weather. Instead of waiting to react when pilots report weather events such as icing or turbulence, controllers should already have information about these events and be able to deal with it proactively.

4-D Wx Data Cube will impact the training content for TRACON line controllers because it is a new tool. 4-D Wx Data Cube will make the job easier for the TRACON line controller 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, controllers will need to be taught what information the automation has access to and the algorithms it is using to use it safely. They will also need to know which components are critical, or not, in cases of degradation or outages.

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: ADS-B OUT

ADS-B Out is a satellite-based system that is deployed on aircraft that 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 TRACON controllers use because ADS-B Out is aircraft equipage. Additional details regarding these changes can be found in the sections that follow.

Table 10. 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:[8] • T68 • T69 • T70 • T71 • T72 • T73 • T75 • T76 • T113 • T191 • T202 • T223 • T224 • T257		Add: • Service Orientation (*New Sk*)		Add: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T10 T14 T15 T16 T42 T68 T73 T78 T79 T80 T81 T82 T83 T84 T85 T86 T87 T88 T89 T90 T91 T92 T93 T94	K7.1 K7.2 K7.3 K7.4 K7.6 K7.7 K7.8 K9.1 K9.2 K9.3 K9.4 K9.5 K11.5 K12.3 K12.4 K14.1 K14.2 K14.3 K14.4 K14.5 K14.6 K16.2 K16.4 K18.7	Sk17	Ab24 Ab28	O12 O14	

[8] 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 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)
	T95 T96 T97 T98 T330 T355 T356 T357	K18.17 K18.19 K19.4 K19.8 K21.2 K21.3 K22.6 K22.7 K27.4				

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 6. Manage Air Traffic Flows and Sequences
- Activity 7. Transfer of Radar Identification

Activity 4. Manage Air Traffic

All the Tasks associated with establishing and maintaining positive aircraft identification and position (*T68-T73*, *T75*, *T76*) will be modified by deleting the term “radar” because with the existence of ADS-B Out as aircraft equipage, controllers will not technically be using radar. However, aircraft identification and position procedures will look the same but will use different TRACON equipment. Additionally, under processing requests for flight following under Visual Flight Rules (VFR), controllers will still be identifying aircraft, but using ADS-B Out instead of radar (*T113*).

Activity 6. Manage Air Traffic Flows and Sequences

Similarly, radar identification of aircraft (*T191*) will need to be modified by deleting the word “radar” because ADS-B Out will provide a method to identify and correlate aircraft position that does not technically use radar. Identification procedures for ADS-B Out equipped aircraft will be performed in the same manner as radar identification procedures.

Accepting transfer of radar identification (*T202*) will also need to be modified by replacing the word “radar” with “aircraft.” Again, ADS-B Out will provide a method to identify aircraft position that does not use radar. Transfer procedures for ADS-B Out equipped aircraft will remain the same as those for radar identified aircraft.

Activity 7. Transfer of Radar Control

Finally, 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 (*T223*). Similarly, controllers will determine the need for transfer of aircraft identification as opposed to radar identification (*T224*). Lastly, controllers will still declare aircraft contact (*T257*). 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 several Activities are proposed to be affected, the proposed impact on these Activities is narrow and is constrained to impacts associated with increases in accuracy of positional data. ADS-B Out will have a direct impact on four of the 11 TRACON 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. Additionally, ADS-B Out will provide more accurate and more up-to-date information about the position of aircraft (*T10*). Also, assuming that equipage information is encoded in some way into the data block, controllers will also require more time scanning to gather information regarding whether aircraft are ADS-B Out-equipped (*T10*).

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 (*T14*). To the extent that more aircraft will be displayed on the radar/traffic display, this could increase the volume of data that controllers need for interpretation of the scanned data (*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 (*T16*) 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 (*T42*).

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 currently have no, little, or unreliable radar coverage, the implementation of ADS-B Out will mean that controllers will observe aircraft entering airspace (*T68*) more often and will perform radar-based position correlation procedures more often (*T73*). Controllers will perform Tasks associated with radar separation (*T78-T88*) 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 (*T89-T98*) less often.

Activity 11. Respond to Emergencies and Unusual Situations

ADS-B Out will enhance emergency alerting for TRACON 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 (*T330*) and shown on the radar/traffic display. To the extent that aircraft are ADS-B Out-equipped, controllers will initiate backup systems (*T355*), implement backup procedures (*T356*), and initiate nonradar separation procedures (*T357*) 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 TRACON Controllers

When determining the impact of a NextGen Driver on the characteristics required of TRACON line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing lists 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 require the addition of new Other Personal Characteristics. TRACON controllers will need to adopt positive attitudes toward technology (*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. Introduction of ADS-B Out will change air route structure and airspace systems architecture to reflect new system accuracy (e.g., terrain obstruction clearance, special airspace avoidance). For example, the Federal Aviation Administration (FAA) could add new ADS-B Out enabled routes, reduce how often other routes that previously required a certain altitude due to Navigation Aid (NAVAID) and communications reception requirements are used, or modify existing routes by making them narrower (*K7.1-Air route structure*). Consequently, controllers will have to be taught all of these new routes. Furthermore, controllers need to be trained in 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 as a 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 Knowledge of surveillance systems architecture, including all the associated Knowledge sub-categories (*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, the new curriculum will have to be added to teach controllers about specific onboard avionic capabilities that enable ADS-B Out (*K11.5-Avionics*), including the process whereby aircrafts' time and position data are disseminated via satellite.

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 TRACON 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 Out 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 position awareness as a result of ADS-B Out, this would increase the number of positively controlled aircraft being managed, thus influencing flows (*K18.17-Facility traffic flows*). 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 (*K18.19-Facility specific directives and procedures*).

Increases in accuracy regarding the identification and position of aircraft made possible by ADS-B Out could support the reduction of separation minima (*K21.2-Components of each type of communication*), 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 that they can substitute for radar coverage, which 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 assisting 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, four-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 utilize their Knowledge of geo-referencing more often (*K7.6-Geo-referencing*). Knowledge of position reporting requirements 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 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 interruptions in GPS outages or interference. 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 the Skill at identifying the appropriate order of work Tasks (*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 Out-equipped aircraft. TRACON 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 TRACON 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 the responsibility to the pilot or 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 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. The 10 potential risks associated with 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 accompanying policies and procedures that will govern its use. If this coordination is not handled effectively this 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 its limitations may result in poor controller performance, which could increase the possibility for 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 regarding aircraft equipage, this could increase cognitive workload and decrease efficiency.
- *Poor Computer-Human Interface Design*: If the Computer-Human Interface (CHI) that provides the line controller with information regarding 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. Controllers will therefore 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 the 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 at all (e.g., system outages) 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 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, they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

ADS-B Out provides highly accurate positional information that controllers can then access via their radar/traffic displays. This Driver otherwise has little direct impact on the controllers' job Tasks or KSAOs. However, 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.

Despite the fact that ADS-B Out does not directly influence many TRACON Tasks or KSAOs, it is one of the most important Drivers in terms of increasing capacity, and thus positively affects virtually every stakeholder. This Driver also embodies the notion of best equipped, best served. Aircraft that are ADS-B Out-equipped will have many opportunities and advantages, such as availability of more direct routes that result in fuel savings. Finally, controllers can be flexible in routing aircraft through airspace with little, no, or unreliable radar coverage and be less dependent on existing ground-based radar stations or NAVAIDs.

Driver 3: Flexible Airspace Management

FAM is a concept that supports the tactical reallocation of airspace and resources to alleviate airspace constraints, overloads, and system outages. It is supported by pre-defined inter- and intra-facility airspace configurations and bi-directional routes. TMU personnel or the supervisor will choose the appropriate configuration or adaption, and automation will support it by remapping flight and radar information to the appropriate control positions. The basic notion of FAM exists today. However, in the NextGen environment, FAM automation and policies will support many new configurations and routes, and will support the ability to keep air routes intact and move the boundaries and ownership of the airspace around air routes.

Overview of Changes From Implementing FAM

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

Table 11. Overview of the Impact of FAM

	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 options for procuring another controller's airspace (*New T*) Delete: • T295 • T299 • T302 • T305 • T309 • T313				Add: • Technology Acceptance (*New O*)	

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	Modify: • Identify that another controller's airspace is needed (*Modified T283*) • Evaluate options for temporarily releasing airspace (*Modified T291*)					
Driver otherwise affects existing Task or KSAO:	T42 T45 T46 T101 T105 T137 T194 T196 T205 T207 T281 T284 T285 T287 T292 T294 T297 T306 T307 T308 T310 T311 T312 T314 T315 T316 T319 T325 T331 T332 T336 T337 T344 T348 T351	K2.7 K7.1 K16.4 K17.4 K18.9 K18.10 K18.11 K18.17 K18.19 K18.20 K22.3 K22.4 K22.10 K22.11 K22.12 K24.3 K25.2 K26.2 K26.3 K27.5	Sk1 Sk3 Sk4 Sk6 Sk12 Sk20 Sk22 Sk23 Sk28 Sk49 Sk56	Ab1 Ab4 Ab5 Ab14 Ab24 Ab28 Ab30	O6 O7 O14	

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 the FAM concept in 2018 will produce changes to the current list of Tasks that TRACON line controllers perform in the following job Activity:

- Activity 9. Manage Airspace

Activity 9. Manage Airspace

One Task will need to be added to Activity 9. Controllers will need a new Task to *Evaluate the options for procuring another controller's airspace (New T).* Controllers will now have more than one method of obtaining another controller's airspace (i.e., FAM), so this extra step in the process of requesting temporary release of airspace is needed.

Several Tasks in Activity 9 will be deleted. To the extent that supervisors or traffic managers are making decisions about the new airspace configuration and will input these decisions directly into automation, AIR assumes that some of the Tasks associated with managing airspace will no longer be necessary. Supervisors or traffic managers will be changing the automation to reflect the change in airspace status instead of TRACON line controllers (*T295, T299*). The need to update status information areas will no longer be required because new airspace configurations will automatically show up on the radar/traffic display (*T302*). Additionally, controllers will no longer need visual aids and memory joggers to remind them of changes to airspace because the changes will be reflected on the radar/traffic display (*T305*). Note that controllers will not discontinue use of all memory aids but rather just the ones that reflect airspace and route configuration. Automation will configure communication and reflect airspace changes (*T309, T313*) for controllers, freeing up controllers to perform other Tasks.

In addition to deleting some of the Tasks associated with managing airspace, FAM will require the modification of and addition of Task statements. The Task of *Determine that another controller's airspace is needed* (*T283*) will be changed to *Identify that another controller's airspace is needed*. This change will occur because controllers will not determine this need independently. Controllers will work with TMU and supervisors if they want a more formal FAM change to take place. Similarly, the Task of *Evaluate feasibility of temporarily releasing airspace* (*T291*) will be changed to *Evaluate options for temporarily releasing airspace*. Controllers will not merely be evaluating the feasibility of temporarily releasing the space. FAM gives them more options on how to release airspace through a more formal method and possibly for a longer period of time.

Changes to How Tasks Are Performed

In addition to requiring changes to the existing list of TRACON job Tasks, the implementation of FAM will have an impact on *how* controllers will perform the Tasks in many Activities. Specifically, FAM will have a direct impact on seven of the 11 TRACON job Activities:

- Activity 3: Manage Flight Plan Data
- Activity 4: Manage Air Traffic
- Activity 6: Manage Traffic Flows and Sequences
- Activity 8: Assess Impact of Weather
- Activity 9: Manage Airspace
- Activity 10: Manage Resources
- Activity 11: Respond to Emergencies and Unusual Situations

Activity 3: Manage Flight Plan Data

FAM will add another piece of information that TRACON line controllers need to consider when evaluating flight plans (*T42*). If controllers know in advance that a route or airspace configuration is going to change, then flight plans affected by that change will need to be evaluated. Changing routes or configurations will need to be taken into consideration when making decisions about clearances. Clearances issued will need to include instructions about changing airspace configuration or route (e.g., route, altitude, frequency) when appropriate (*T45*). Also, the possibility that an airspace configuration or route may change will still need to be taken into consideration when determining the need for a flight plan amendment (*T46*).

Activity 4: Manage Air Traffic

FAM could be used as a potential method for responding to special operations; changing the direction of a route or the airspace configuration could be a plan of action or a part of the plan of action (*T101*). This plan would require less coordination on the landline because TRACON line controllers will be assigned a preplanned airspace or route configuration that works around the special operation (*T105*). Supervisors and traffic management will provide a new airspace or air route configuration to controllers rather than controllers having to determine the appropriate response to the special operation.

In addition to using FAM as a response to special operations, FAM will provide controllers with more information to consider when evaluating requests from pilots to deviate (*T137*). They will need to be aware whether a requested route is about to be changed or the airspace around the route changed. Controllers will also have to evaluate the number and pattern of pilot requests for deviation, because this information could be a prompt for the need for airspace or route reconfiguration (*T137*).

Activity 6: Manage Traffic Flows and Sequences

TRACON line controllers' decision-making process for determining and re-evaluating departure sequences (*T194*, *T196*) and arrival sequences (*T205*, *T207*) will change. That is, controllers will have to take dynamic information about airspace and direction of routes into consideration more often when sequencing and spacing aircraft because there are going to be more changes in airspace and air route structures.

Activity 8: Assess Impact of Weather

FAM will provide TRACON line controllers with more options for responding to severe weather. When controllers determine the altitude or route to avoid severe weather, it may involve implementing a FAM change. However, controllers will not make the final decision regarding what to change or when to implement it. They will just relay information and coordinate with TMU or the supervisor (*T281*), who will make the final decisions.

Activity 9: Manage Airspace

If FAM is selected as an option for providing temporary release of airspace, then the method for releasing the airspace will change. Controllers will request use of the airspace (*T284*) from the TMU or supervisor instead of another controller. Likewise, controllers will receive approval including any conditions (*T285*) from the TMU or supervisor instead of another controller. The TMU or supervisor will release the requested airspace (*T292*). Controllers will not return the airspace to the other controller, but instead will inform TMU or supervisor when it is no longer needed (*T287*). Then the TMU or supervisor will notify the appropriate controller that the airspace has been returned (*T294*). Overall, changes in airspace status as a result of FAM will require less coordination between controllers (*T297*). The affected controllers will see the airspace changes on their radar/traffic display, which means fewer landline/radio communications to other controllers within and outside of the facility.

Although FAM will remove some of the Tasks required of TRACON line controllers and shift some responsibility to TMU and supervisors, it will require controllers to do other Tasks more often. For example, as a result of FAM, Tasks associated with position/sector reconfigurations will occur more often because there will be more options for airspace and air route reconfigurations, and these options will be implemented more often in response to traffic demands. Therefore, all of the Tasks associated with transferring and receiving position/sector for reconfiguration, except those Tasks that have been removed by automation to automation communication (*T309, T313*), will be done more often (*T306-T308, T310-T312, T314-T316*).

Activity 10: Manage Resources

FAM will become an additional strategy for reducing TRACON line controllers' workload. Controllers will be able to identify airspace or air route reconfigurations as a possible workload reduction strategy (*T319*) and request the change from TMU or supervisor. As a result of the availability of FAM to reduce overloads, controllers will have to work harder to maintain facility awareness because more changes are occurring to airspace or air routes more often, which might be affecting controllers differentially (*T325*).

Activity 11: Respond to Emergencies and Unusual Situations

Finally, FAM will provide TRACON line controllers with more options for responding to emergencies or unusual situations. Controllers will be able to select changing airspace or air route as a plan of action for dealing with emergencies (*T331*) or unusual situations (*T344*). Being able to modify airspace to more closely fit an operation will help controllers to isolate small sections of airspace. Controllers will be better able to focus on the problem at hand (*T332*) without getting distracted managing other traffic surrounding the problem area or aircraft. If the plan of action involves changing the airspace configuration or air route, then the coordination of information among controllers will also be reduced (*T336*, *T351*). They will all see the changes on the radar/traffic display and will not need as many landline or radio communications to set up the changes, although they will likely still have to brief each other. After implementing the plan of action, controllers have to reevaluate the emergency or unusual situation; considering airspace and route changes would become part of this reevaluation (*T337, T348*).

Changes to Characteristics Required of TRACON Controllers

When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 FAM does not require adding new Knowledges, Skills, or Abilities, nor does it require deleting or modifying the language of these worker requirements. It does, however, require the addition of a new Other Personal Characteristic related to the need for controllers to have positive attitudes towards, perceived usefulness of, and perceived ease of use of technology (*New O-Technology Acceptance*). This is because FAM adds a new piece of functionality to the TRACON environment in terms of automation. In order for FAM to be used most effectively to help TRACON controllers perform their jobs, controllers must be comfortable using and trusting the automation.

Changes to Curriculum Required to Teach Knowledges

Any decisions regarding airspace and route reconfigurations will be the responsibility of the TMU and supervisors, but these decisions will have a direct impact on controllers. Consequently, TRACON line controllers will need to learn about expanded TMU roles and responsibilities (*K2.7-Traffic Management Unit responsibilities*). Controllers will also need to be taught new flight plan evaluation strategies (*K16.4-Evaluation strategies*) that will allow them to take into consideration information about possible future changes in route structure or airspace configuration. Additionally, controllers will have to be taught how the new routes/airspace configurations can be used as a strategy to balance workload when managing TMIs (*K17.4-Strategies for managing traffic management initiatives*). One of the main objectives for flexible airspace, and one of the main purposes of TMU, is to balance out traffic, and thus, workload among controllers.

FAM will also have a significant impact on the curriculum required to teach facility level Knowledges. Controllers will have to be taught new local sector configurations (*K18.11-Sector configurations*) resulting from airspace reconfigurations. They will also need to be taught any new facility traffic flows (*K18.17-Facility traffic flows*) resulting from the new configurations. Controllers will need to learn new LOAs/procedures/directives associated with managing new standardized and predefined air routes and airspace configurations (*K18.19-Facility specific directives and procedures*), and any procedures required to coordinate these changes with other controllers both within the same facility and with other facilities (*K18.20-Airspace coordination procedures*). To the extent that the switching of airspace configuration and route directions happens more often, this new coordination will also occur more frequently.

FAM will also have a significant impact on the curriculum to teach Knowledges associated with providing ATC services. Controllers will need to learn new scanning strategies to establish and maintain facility awareness (*K22.3-Scanning strategies*). For example, if controllers are aware that a route direction change in an adjacent sector is being discussed by supervisors, TMU personnel, or other controllers, they will need to attend to this discussion. In addition, controllers will need to learn new ways of communicating pending changes in airspace and route structure to others (*K22.4-Procedures for composing clearances and control instructions*). They will have to be taught how to use FAM as a new strategy for weather avoidance (*22.10-Strategies for severe weather avoidance*). For instance, there could be predefined airspace configurations or route configurations that can be used to avoid severe weather patterns. Furthermore, as airspace boundaries change, transfer of control points (*K22.11-Transfer of control requirements*) and transfer of communication points may change (*K22.12-Transfer of communication requirements*), requiring controllers to learn how different configurations will affect transfer of control and communication. Pointouts or handoffs could increase or decrease in frequency depending on the new sector configuration, how it interacts with the flow of traffic through space, and which controller is designated which responsibility.

Lastly, FAM will affect the curriculum for teaching approach/arrival and departure operations and for emergency operations. Controllers will need to be taught that there are new potential options, which include changing airspace, air routes, or both, when determining arrival (*K24.3-Arrival Routes*) or departure routes (*K25.2-Departure Routes*). Controllers will also have to learn how to use FAM for special operations (*K26.2-Required clearances and control instructions*) and as an emergency assistance technique (*K27.5-Emergency assistance techniques*). For instance, controllers may be able to use reconfigurations of airspace or air routes to isolate the emergency or special operations aircraft from others and shift the control of those aircraft to another controller as one possible technique.

Changes to Properties of Knowledges

FAM will result in changes in the air route and airspace structure—these will not be static in the same way they are today, but rather dynamic. Consequently, the level of proficiency and facility regarding Knowledge of air routes (*K7.1-Air route structure*) will increase and be used more often. Knowledge of facility specific airspace dimensions (*K18.9-Airspace dimensions*), adjacent airspace (*K18.10-Adjacent airspace*), and sector configurations (*K18.11-Sector configurations*) will also become more important. Controllers will have to understand these at a deeper level to manipulate the information about changes to airspace or air route configurations quickly; they will generally have to have greater proficiency and facility with this information.

For special operations that occur routinely enough that the FAA opts to build specific airspace configurations for them, FAM will give the facility the capability to enact this airspace configuration during these operations. This will reduce coordination and communications previously required because the plan for dealing with the special operation will now be understood by controllers and TMU. This will decrease the need for controllers to use Knowledge of clearances and instructions (*K26.2-Required clearances and control instructions*) and coordination requirements (*K26.3-Coordination requirements*) for special operations.

Changes to Curriculum Required to Teach Skills

FAM will affect the training curriculum needed to teach several Skills that are related to switching between different airspace and air route configurations. TRACON line controllers have to be taught and practice Skill at shifting between Tasks, specifically between managing traffic under one air route or airspace configuration and managing traffic under a different air route or airspace configuration (*Sk4-Task Switching*). Similarly, controllers need to be taught and will have to practice Skill at returning quickly to managing traffic after the air route or space configuration has changed (*Sk6-Interruption Recovery*). Skill at consistently applying the procedures even though they will be changing more often than today (*Sk12-Rule Application*) will need to be taught as well. Finally, controllers will have to learn and practice conducting position relief briefings (*Sk20-Position Relief Briefings*) that include FAM information, such as current airspace and air route configurations and any trend patterns of changes to these configurations that may be occurring.

FAM will also affect the training curriculum of several Skills associated with strategies controllers use to manage traffic. For example, controllers will need to be taught new Skills associated with using FAM as a new weather mitigation strategy (*Sk49-Weather Strategy Development*). FAM could be used to quickly and efficiently change an air route's direction or altitude to avoid severe weather, which would allow controllers to maintain traffic flow. Controllers will also need to be taught new Skills at using FAM as a new strategy to deal with emergencies and unusual situations (*Sk56-Emergency Response Development*). FAM configurations could be used to isolate airspace that contains the emergency/unusual situation, allowing controllers to focus on aircraft in that area and move the control of airspace with the non-involved aircraft to a different controller.

Changes to Properties of Skills

The implementation of FAM will increase the need for many of the communication and teamwork Skills. Skills associated with verbally communicating information (*Sk1-Oral Communication*), attending to what others are saying (*Sk3-Active Listening*), and working with others to accomplish air traffic Tasks (*Sk23-Coordination*) will be required more often. For example, controllers will have to coordinate with pilots every time there is a route or airspace change. In addition, they will have to engage in discussions with TMU personnel and supervisors regarding use of FAM as a strategy for dealing with multiple situations (e.g., emergencies, special operations, traffic congestion).

Controllers will have to use Skill at conducting position relief briefings more often (*Sk20-Position Relief Briefings*) because a briefing will be required every time there is a change in airspace or air route configuration. Skill at working collaboratively with other controllers within the same facility and in other facilities (*Sk22-Inter-position Teamwork*) will also be used more often because teamwork among controllers will be needed to make the airspace and air route changes in control. Controllers will need to be monitoring more actively what is happening in adjacent sectors (*Sk28-Facility Monitoring*) in case airspace will be combined with those sectors. Even though new airspace configurations will be standardized and will show up on the radar/traffic display automatically, these communication and teamwork Skills will still be required more often because the whole process of changing airspace will be occurring more frequently.

Changes to Properties of Abilities

FAM will increase the need for several 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 the Ability to listen to and understand information and ideas presented verbally (*Ab5-Oral Comprehension*) will increase in importance when discussing potential or actual configuration changes with supervisors and TMU and when conducting position relief briefings with other controllers. The Ability to remember information long enough to manage the current situation (*Ab14-working memory*) will also increase in importance because controllers will not only have to deal with and consider the current configuration, but also deal with a large number of potentially different configurations that could be pending.

Furthermore, controllers will need to use the Ability to imagine how an object will look after it is moved around or when its parts are moved or rearranged (*Ab30-Visualization*) more often, because this will allow controllers to consider how the airspace/route will look after the decision has been made to change it but before the change is implemented.

Finally, the Ability to adapt to changing situations (*Ab24-Flexibility*) will become more important for controllers because FAM requires that controllers change the operational context more frequently than today. Controllers will need to be able to adjust and adapt to using new airspace and air route reconfigurations. Controllers will also need to be able to learn the Knowledge and Skills associated with FAM and to apply lessons learned from experience using this new concept (*Ab28-Learning*).

Changes to Properties of Other Personal Characteristics

The increased coordination with TMU and supervisors and the flow of information between them resulting from FAM will increase the importance of two Other Personal Characteristics. It will increase the importance of being willing to work with others to achieve the common goal of balancing the flow of traffic (*O6-Cooperativeness*). It will also increase the importance of being willing to accommodate or deal with differences in personalities, criticisms, or interpersonal conflicts in the work environment (*O7-Interpersonal Tolerance*) because controllers will be coordinating more often with different people who have different roles and responsibilities.

As with most NextGen Drivers, the importance of controllers viewing themselves as being in control of automation and responsible for the outcomes instead of simply responding to it (*O14-Internal Locus of Control*) will increase for FAM. In this case, controllers will need to feel they are in control of the changes in route and airspace configurations that the automation is making on their radar/traffic display.

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 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. The five potential risks associated with implementing FAM are:

- *Improper Reliance on Automation or Procedures*: If controllers do not feel comfortable requesting changes to airspace or route structure, they may not utilize this option when such changes would have been appropriate. This will reduce efficiencies that FAM was designed to provide.

- *Lack of/Inadequate Training*: Lack of training or inadequate training in new procedures and intensive coordination required to achieve resectorization, resulting from the implementation of FAM, will result in poor controller performance and thus could potentially decrease efficiency and safety.
- *Mixed ATC Tools, Equipment, or Procedures*: If FAM is not implemented in all TRACONs, or if it is implemented on a significantly different schedule, then the resulting differences in resectorizations could create difficulty in transferring aircraft across airspace boundaries. This could reduce efficiency and increase the possibility for error.
- *More Dynamic Work Environment*: Allowing strategic adjustments to be made in airspace configurations and responsibility for operations will mean a more dynamic and less predictable work environment. If resectorizations happen too quickly, if controllers have little or no control over them, or if they are implemented in a non-standard manner, this could significantly increase the mental workload of controllers and thus increase the possibility for error.
- *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 FAM system 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

The FAM concept is expected to allow throughput to continue during system outages, severe weather, and other situations, thus creating the potential for increases in capacity, efficiency, and cost effectiveness. This dynamic reorganization of airspace seems like an intuitive way to reduce inefficiency and make better use of current workforce. However, the operationalization of the configurations (e.g., what configurations are given in the standardized playbook, whether they are intuitive, whether they get used) will determine whether maximum utility will be realized.

Although FAM will help balance workload, it could still create more work for controllers because of the additional coordination required with TMU and supervisors regarding whether and when to go to different airspace and air route configurations, and the coordination required with other controllers to make the switch in control of airspace. This increased coordination could be partially offset, however, by the fact that new airspace configurations and routes are standardized and changes will show up automatically on the traffic display.

FAM will make the work environment for TRACON controllers much more dynamic and will challenge controllers' Ability to conceptualize the "what if" scenarios. It increases the dynamic nature of the job for controllers. In this way it is the opposite of generic high altitude airspace, which decreases the dynamic nature of the job.

FAM balances controller workload by reducing spikes in flow and complexity, which has varying workflow implications. It introduces standardization in the procedures and the use of airspace and air route reconfigurations that will lead to overall system efficiency. Currently, the decision is up to each TMU on whether to use airspace reconfiguration or not. Implementing FAM will provide a standardized process that is not overly dependent on individual TMUs.

FAM balances controller workload by reducing spikes in volume and complexity, which has varying workflow implications. It introduces standardization in the procedures and the use of airspace reconfigurations that will lead to overall system efficiency. Currently, the decision is the responsibility of the TMU or Supervisor as to whether to implement airspace reconfigurations or not. Implementing FAM will provide standardization and offer methods of best practices instead of relying on disparate technique used by individual TMUs.

Driver 4: Integrated Arrival/Departure Air Traffic Control Service

The Integrated Arrival/Departure Air Traffic Control Service (known informally as "Big Airspace") is a concept designed to help overcome operational inefficiencies at airports serving major metropolitan areas. It proposes collocating TRACON and ARTCC controllers responsible for transition airspace in Super Density areas to promote effective communication and coordination. The Big Airspace concept will also support an expanded use of 3-mile separation standards and change current minima required for diverging courses in departure airspace; it will also expand the current use of visual separation standards above 18,000 feet.

For purposes of this report, and to reduce repetition for the reader, the changes discussed in this section pertain only to the ideas of collocating TRACON and ARTCC controllers and of the expanded use of 3-mile separation standards and visual separation standards. Although Flexible Airspace Management and PBN (RNAV/RNP) support the concept of Big Airspace, they are included in this report as separate NextGen Drivers. Consequently, changes to the TRACON line controller job produced by procedures and automation associated with Flexible Airspace Management and PBN will be discussed elsewhere in this report.

The collocation of TRACON and ARTCC controllers in the TRACON facility is a foundational concept for Big Airspace.[9] In addition, AIR assumes that the responsibility for the transition airspace into Super Density areas will be moved from ARTCC to TRACON (see Section IV). In the near term, AIR proposes that this airspace be managed by a TRACON-trained TRACON controller managing what was previously the TRACON portion of the transitional airspace into Super Density areas and an ARTCC-trained ARTCC controller managing what was previously the ARTCC portion of this transitional airspace. In this case, the primary impact on the job for either controller is that instead of having to coordinate over landline, they are coordinating in person. However, it follows that over time collocation may not be necessary. Instead, it is more likely that over time the TRACONs in metroplex areas would staff the positions working the

[9] Although earlier reports suggested that a new ATC facility would be built specifically to manage this airspace, it appears that at least in the mid-term this will not occur.

transition airspace into Super Density areas with their own controllers. These TRACON controllers will be required to demonstrate mastery in all of the TRACON sectors (i.e. both transition airspace into Super Density areas as well as all of the other TRACON sectors).

Although this is supposition, it seems reasonable for several reasons. First, it would be inefficient in the long run to staff a metroplex TRACON facility with ARTCC controllers. Much of what the ARTCC controllers are taught would not be utilized. In addition, the airspace will be simplified because responsibility for it resides within a TRACON facility (as opposed to across multiple TRACONs or a TRACON and an ARTCC), specific procedures will be implemented to assist controllers working this airspace (e.g., FAM and PBN), and the airspace will be converted to be more like TRACON airspace (e.g., 3-mile separation). However, because it is unknown how long it would take the FAA to train TRACON based controllers to manage this airspace, AIR does not describe this impact. Instead, AIR describes the impact of collocation. While this scenario does not create a substantive impact on the job of either controller, the impact on both the TRACON and the collocated ARTCC controller is described below.

Overview of Changes From Implementing Big Airspace

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

Table 12. Overview of the Impact of Big Airspace

	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 Task or KSAO:	T217 T227 T228 T231 T238 T244 T245	K2.2 K2.3 K2.4 K2.5 K7.1 K7.4 K11.4 K15.1 K17.3 K17.4 K18.9 K18.17 K18.19 K18.20 K22.11 K22.12 K24.3 K25.2	Sk1 Sk3 Sk18 Sk21 Sk22 Sk23 Sk24 Sk25 Sk26 Sk28 Sk34	Ab1 Ab4 Ab5 Ab24 Ab28	O6	

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 Big Airspace will not require changes to the list of Tasks that TRACON line controllers currently perform, it will have an impact on *how* controllers will perform Tasks associated with the following two of the 11 TRACON job Activities:

- Activity 6: Manage Traffic Flows and Sequences
- Activity 7: Transfer of Radar Identification

Activity 6: Manage Traffic Flows and Sequences
Because Big Airspace will collocate sector teams of TRACON and ARTCC controllers into TRACONs, the communications between these controllers will be made controller to controller. The ability to communicate in-person and to reach over and point out aircraft or areas on the radar/traffic display will likely ease coordination by reducing excessive voice communication (*T217*). Close physical proximity will have a positive effect on formal and informal communication and coordination.

Activity 7: Transfer of Radar Identification
Big Airspace will allow handoffs (*T227, T228*) and pointouts (*T244, T245*) between TRACON and ARTCC controllers that are collocated to be conducted in-person instead of over landlines or automation. The ability to communicate in-person will reduce the amount of coordination needed for coordinating restrictions (*T231, T238*). Collocated controllers will be able to coordinate better because they will be sitting next to each other; communications will be faster, controllers will have access to nonverbal cues and, finally, they will be able to view the same radar/traffic display or at least the same type of display.

Changes to Characteristics Required of TRACON Controllers

When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 Big Airspace does not require new KSAOs, it will require changes to the training curriculum. Since Big Airspace will be collocating sector teams of TRACON and ARTCC controllers in one facility, controllers will need to learn curriculum about this new type of integrated, collocated facility (*K2.2-Type of ATC facilities*). Controllers will need to learn about the new roles of each facility type (*K2.3-Roles of each facility type*). They will have to be taught about new positions associated with these new collocated positions (*K2.4-Types of ATCS positions in each facility type*) and the new responsibilities associated with them (*K2.5-ATCS responsibilities for each position in each facility type*).

Although, it is presumed that the TRACON controller will still be responsible for what was previously TRACON space and the ARTCC controller will still be responsible for what was previously ARTCC space, they will have to work closely together to blend traffic into and out of the transition airspace. Consequently, controllers will need to learn about new air route structure (*K7.1-Air route structure*). They will have to learn the new charts that reflect the new air route structure (*K7.4-Aeronautical charts*). Additionally, both controllers will have to learn more about the impact of altitude on aircraft (*K11.4-Performance characteristics*) because they will be managing more aircraft at higher or lower altitudes. There may be a new type of TMIs that controllers will have to be taught (*K17.3-Types of traffic management initiatives*) that go along with this new airspace and route structure. As a result, controllers may also need to be taught new strategies to handle these new types of TMIs (*K17.4-Strategies for managing traffic management initiatives*).

Big Airspace will affect several facility-specific Knowledges. Changes will be made to airspace sectors and as a result to the flows and conflict areas in the airspace. Controllers will have to be taught the new dimensions of this airspace (*K18.9-Airspace dimensions*) and the new facility traffic flows in this transition airspace (*K18.17-Facility traffic flows*). Further, collocation of TRACON and ARTCC controller teams at the TRACON facility will change airspace coordination procedures. Both controllers will need to learn new local procedures and directives (*K18.19-Facility specific directives and procedures*) required to support the new transition airspace. They will also need to learn new procedures for coordinating in this airspace with ARTCC controllers (*K18.20-Airspace coordination procedures*).

Big Airspace will change transfer of control points as a result of the new air space configurations and will also change coordination between collocated TRACON and ARTCC controllers. As a result, both controllers will have to be taught new transfer of control requirements (*K22.11-Transfer of control requirements*) and new transfer of communication requirements (*K22.12-Transfer of communication requirements*).

Finally, controllers will also need to learn new arrival routes (*K24.3-Arrival routes*) and departure routes (*K25.2-Departure routes*) due to changes to Big Airspace configurations.

Changes to Properties of Knowledges
Big Airspace will increase the importance of some general airspace Knowledges. Controllers will need to learn in more detail some of the other classes of airspace that they do not use often today because they will be managing airspace they are not responsible for today (*K15.1-Airspace classification*).

Changes to Curriculum Required to Teach Skills
None.

Changes to Properties of Skills
Although AIR does not anticipate that the implementation of Big Airspace will change the training curriculum required to teach Skills, it will require changes to the properties of Skills. Since TRACON and ARTCC line controllers will be collocated to improve efficiency, the need for Skill at working collaboratively when control responsibility is shared among two or more controllers (*Sk21-Shared Responsibility Position Teamwork*) will increase. Skill at working collaboratively with other controllers in the facility (*Sk22-Inter-position Teamwork*) will also increase in importance within the facility because of the additional coordination controllers will be performing. Consequently, controllers will be using 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 Skill at working with others to accomplish air traffic Tasks (*Sk23-Coordination*) more often. Coordination will be more efficient because controllers can coordinate aircraft further out with less compartmentalization and negotiation and more collaboration. Additionally, the collocated controllers will have the opportunity to take advantage of nonverbal cues, which was not an option before (*Sk24-Cue Recognition/Comprehension*), so their use of this Skill will increase.

Big Airspace will provide both controllers with different airspace to scan. Consequently, Skill at strategic scanning (*Sk25-Strategic Scanning*) will be more important because controllers have additional pieces of information to scan. Accordingly, controllers will have more traffic scenarios to comprehend and blend together (*Sk26-Operational Comprehension*) because they are now expanding airspace in their vicinity so more aircraft and a different type of sector/airspace will be in the mix now. Further, now that controllers are collocated it will be easier to look at the adjacent sector, so using Skill at monitoring in adjacent sectors while managing traffic in one's position/sector will increase (*Sk28-Facility Monitoring*).

Big Airspace will require both controllers to deal with less familiar altitudes more often. Consequently, controllers will have to achieve separation in a different manner due to the effects of higher or lower altitudes on aircraft performance. Certain separation strategies such as speed control might be used more frequently (*Sk34-Separation Strategy Implementation*), which will require increased Skill in timing tasks appropriately (*Sk18-Task Timing*).

Changes to Properties of 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 the Ability to listen to and understand information and ideas presented verbally (*Ab5-Oral Comprehension*) will increase in importance because of the increases in frequency and type (i.e., in-person) of coordination required.

The Ability for both controllers to adapt to changing situations (*Ab24-Flexibility*) will become more important because TRACON and ARTCC controllers will be working in the same facility. Controllers will also need to be able to learn the Knowledge and Skills associated with Big Airspace and to apply lessons learned from their 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
Big Airspace will collocate controllers in sector teams so controllers could have to coordinate more frequently. Being able to work with others to achieve a common goal (*O6-Cooperativeness*) will increase in importance.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of Big Airspace introduces the possibility of risks into the NAS. The three potential risks are:

- *Lack of/Inadequate Training*: Lack of training or inadequate training in new procedures associated with the implementation of Big Airspace, especially those related to the changes in the airspace boundaries and separation standards, will result in reductions in efficiency and increases in the possibility for error.
- *Mixed ATC Tools, Equipment, or Procedures*: Big Airspace will only be implemented at a small number of TRACONs and it will likely be implemented on significantly different schedules. This could make transferring controllers between facilities, or cross-training, more difficult as some will be trained and others not, which introduces system wide inefficiency.
- *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 Big Airspace will be implemented in 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 concepts and systems are fielded and are being used by controllers that they can be fully evaluated from a functional perspective. If controllers are not fully utilizing Big Airspace, then they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

Although Big Airspace is not a new tool or piece of equipment, it involves procedural changes in how airspace is utilized and will impact the workload and characteristics of controllers. The collocation of TRACON and ARTCC controllers managing transition airspace into Super Density areas in the same facility will change how coordination in this complex airspace is handled. Close physical proximity will allow controllers to coordinate better because they will be able to communicate in person. They will have access to nonverbal cues and will be able to view the same radar/traffic display or at least the same type of radar/traffic display. Workload in terms of sequencing/spacing and handoffs will be reduced. In addition, because the number of handoffs will be reduced, there should be fewer handoff errors. Skills at coordination and teamwork will increase and improve.

Controllers working in Big Airspace will also be exposed to some cross-training of TRACON and ARTCC Knowledges and Skills. TRACON controllers will have to become familiar with aircraft performance at higher altitudes farther from the airport, and collocated ARTCC controllers will have to become familiar with managing aircraft in airspace that looks much more like Terminal airspace.

Big Airspace is designed to alleviate a very specific problem at just a few airports. Nevertheless, to the extent that it alleviates significant problems in Super Density areas, it will have an overall positive effect on the NAS by increasing efficiency.

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 TRACON line controllers better plan for and execute arrival and departure Activities.

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 Task or KSAO:	T3 T10 T11 T12 T13 T15 T22 T194 T196 T205 T206 T207 T210 T213 T215	K18.5 K19.4 K22.3 K22.13 K24.5 K24.11 K25.5	Sk1 Sk3 Sk22 Sk23 Sk25 Sk35 Sk36 Sk37 Sk38 Sk39 Sk40	Ab1 Ab4 Ab5 Ab24 Ab28		

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 IADS will not require changes to the list of Tasks that TRACON line controllers currently perform, AIR proposes that this Driver will change *how* controllers perform certain Tasks, primarily in the following two of the 11 TRACON job Activities:

- Activity 1: Establish Situation Awareness
- Activity 6: Manage Traffic Flows and Sequences

Activity 1: Establish Situation Awareness

IADS will provide TRACON line controllers with new integrated information about the departures, arrivals, and taxiway scheduling 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 (*T10-T13*). 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 or conducting the position relief briefing (*T3, T22*).

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 (*T10, T15*). The integrated information may increase the efficiency of controllers by reducing information redundancy.

Activity 6: Manage Traffic Flows and Sequences

The primary effect IADS will have on managing traffic flows and sequences is the new shared situation awareness between terminal controllers of the interaction between arrivals, departures, and surface operations. More up-to-date predicted and actual departure and arrival times will augment the process of determining sequences (*T194*, *T205*). It will mean less guess work on the part of TRACON line controllers and less vectoring to accommodate new entries into the flow. This will enable controllers to fill in more slots in the flow, which will reduce delays and conserve NAS resources. This new integrated information will also help controllers improve the process of re-evaluating the traffic situation (*T196, T207*).

The number of communications will be reduced because controllers will have to make fewer adjustments (*T206*) to the flow and will have to coordinate with other controllers less frequently

(*T210*), resulting in a reduced workload for controllers and a conservation of controller resources. It will change the coordination not just between controllers within the TRACON facility but between ATCT and TRACON line controllers as well. 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.

When responding to TMIs, IADS-provided information regarding predicted departure times will help controllers to evaluate the impact of TMIs on traffic flow (*T213*). Additionally, this information will help controllers to determine the appropriate action to bring aircraft in conformance with TMIs (*T215*). For example, predicted information about departures and arrivals would assist controllers in determining which aircraft should be given priority for landing.

Changes to Characteristics Required of TRACON Controllers

When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 TRACON line controllers, it will have an impact on training. First, TRACON 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 TRACON controllers. This Knowledge will be taught as part of the existing facility Tools and Equipment Knowledge category, 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 about this new information and how to use it to enhance the provision of approach control service (*K22.13-Approach control service*) and for arrival sequencing (*K24.11- 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 TRACON 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 route, fixes, and other information from paper or electronic flight strips. The implementation of IADS will allow arrival and departure optimization by TRACON controllers by providing them with more comprehensive information about all the flights in arrival and departure phases in a single source. New training curricula will be required to teach controllers how to use this new IADS-provided information to develop, select, and implement appropriate 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 the curriculum required 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, and 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.

IADS will increase how often controllers use one Skill. Since IADS is providing controllers new and more information regarding scheduling and sequencing, controllers will need to use Skill to quickly and accurately search for relevant information (*Sk25-Strategic Scanning*) more often.

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 Knowledges 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 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. The six potential risks associated with 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 as well as any limitations could result in poor controller decision-making with regard to sequencing and prioritization. This will lead to underutilization of the tool's capabilities.
- *Mixed ATC Tools, Equipment, or Procedures*: If IADS is not implemented in the TRACON and its associated ATCT, or if it is implemented in different ways or on significantly 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 TRACON controller. If the Computer-Human Interface (CHI) does not 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.
- *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 arrival 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 be not 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 arrivals and departures, which increases throughput and conserves controllers' cognitive resources. It accomplishes this by providing TRACON line controllers with shared access to information—increasing their shared situation awareness with ATCT line controllers—and by introducing standardization of information between TRACON and ATCT 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: Optimized Profile Descent

Optimized Profile Descent (OPD) is a process that starts at an aircraft's top of descent (TOD) and requires the aircraft to descend continuously before reaching the final approach fix. The main benefits of OPD are (a) increased fuel savings for NextGen equipped aircraft, (b) reduced carbon dioxide emissions, and (c) reduced frequency congestion due to reduced controller to pilot communications once the approach has commenced.

Overview of Changes From Implementing OPD

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

Table 14. Overview of the Impact of OPDs

	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: • Service Orientation (*New Sk*)		Add: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T10 T42 T79 T145 T156 T201 T205 T206 T208	K4.1 K4.3 K7.1 K11.2 K11.4 K11.5 K16.2 K16.4 K18.9 K18.17 K18.19 K19.4	K21.3 K22.4 K22.8 K22.11 K22.12 K22.13 K24.3 K24.4 K24.5 K24.9 K24.11	Sk1 Sk3 Sk18 Sk23 Sk25 Sk27 Sk32 Sk35 Sk38 Sk42	Ab1 Ab4 Ab5 Ab21 Ab22 Ab24 Ab28 Ab29	O4 O14	

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 an analysis of the impact of OPD on the job of the line controller working in the TRACON environment reveals that it will not likely require adding to, deleting from, or modifying any of the current job Tasks, to the extent that OPD reduces controller to pilot communications when aircraft are NextGen-equipped, it will have a direct impact on *how* Tasks are performed. Specifically, OPD will have a direct impact on five of the 11 TRACON 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 Traffic Flows and Sequences

Activity 1. Establish Situation Awareness

In order for aircraft to fly OPD routes, they must be properly equipped. Assuming that equipage information is encoded in some way into the data block, controllers will require more time for scanning to gather information on whether aircraft are RNP-equipped (*T10*).

Activity 3. Manage Flight Plan Data

OPDs can only be performed by aircraft that are RNP-equipped. Consequently, the information about aircraft equipage is a new piece of information that controllers need to take into consideration when evaluating the flight plan (*T42*).

Activity 4. Manage Air Traffic

In order for aircraft to fly an OPD, they must be RNP-equipped, which means at a minimum they are capable of monitoring their own conformance to the OPD path and that they are Data Comm equipped. Consequently, controllers will have to verify that aircraft flying OPDs are in conformance with flight plans (*T79*) less often because the aircraft will be doing this.

In the case where NextGen-equipped aircraft cannot meet the specified arrival time at the top of descent, controllers will have to determine the appropriate action to resolve nonconformance (*T145*). Furthermore, this process may include controllers identifying or using new strategies that are seldom used. For example, providing angled vectors to aircraft or making aircraft perform step-down descents.

Activity 5. Resolve Conflicts
With the implementation of OPDs, RNP-equipped aircraft will be following pre-defined OPD procedures; consequently, there will be a decrease in controller to pilot communications. Hence, controllers will be issuing fewer control instructions to achieve separation (*T156*).

Activity 6. Manage Traffic Flows and Sequences
With the advent of OPDs, controllers will still ensure coordinated arrival routings as they do today. However, controllers will have to balance the needs of aircraft with mixed equipage during coordinated arrival routing (*T201*). Similarly, controllers will also have to take mixed equipage (e.g., aircraft with and without Future Air Navigation System or FANS technology) into account when determining arrival sequences (*T205*). Furthermore, TRACON controllers need to project closure rates in order to develop and issue any necessary speed restrictions to equipped aircraft following OPDs (*T206*). Due to predefined OPD paths and equipped aircraft flying OPD paths, controllers may not need to use speed control as a way of ensuring separation (*T206*).

The control instructions required to implement approach sequence for OPDs will contain fewer components because OPD paths are predefined (*T206*). For example, controllers will not issue as many instructions for vectoring and speed control as they currently do. OPDs also have the potential to reduce the number of communications needed between controllers and pilots flying on OPD paths. Assuming the aircraft are meeting OPD times, controllers are not likely to make adjustments to their routes to optimize the benefits. However, controllers may have to increase the number of communications with pilots during the initial or setup phase of getting aircraft to top of descent to begin initiating their OPD. They may have to issue instructions with restrictions, especially time restrictions, more often. More specifically, restrictions might be based on whether pilots can arrive at specified points (i.e., top of descent) before routes or airspace changes (*T208*).

Changes to Characteristics Required of TRACON Controllers
When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 implementation of OPDs does not require adding to, deleting from, or modifying the language in the existing list of Knowledges, Skills or Abilities. However, OPDs will add one new Other Personal Characteristic to capture the necessity for TRACON controllers to adopt positive attitudes toward technology (*New O-Technology Acceptance*). The implementation of OPDs will also require the addition of a new Skill. Controllers will need to be responsive and

helpful when working with an increasingly large number of aircraft with varying levels of equipage and capability (*New Sk-Service Orientation).*

Changes to Curriculum Required to Teach Knowledges
Controllers need to be taught new Knowledges about aircraft aerodynamics (*K4.1-Aircraft aerodynamics*) so they will know how to manage high-altitude aircraft. Controllers will also need new Knowledges about speed regimes (*K4.3-Speed regimes*) as well as new routes and route structures (*K7.1-Air route structure*). Furthermore, controllers need to be taught weight classes (*K11.2-Weight classes*) and performance characteristics (*K11.4-Performance characteristics*) of aircraft as they apply to aircraft flying an OPD, especially in terms of descent rates. Additionally, controllers need to be taught about the new avionics (*K11.5-Avionics*) that are required onboard the aircraft to support OPDs including FANS.

Because aircraft must be RNP-equipped to fly OPD routes, controllers will 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, including aircraft equipage and crew certification and how to evaluate the impact of RNP equipage on providing ATC services (*K16.4-Evaluation Strategies*). Assuming this information is contained in the data block, then recognizing/understanding this information must be taught as part of Knowledge interpretation (*K19.4-Interpretation of information provided*). It is currently unknown whether OPDs will require changes in ownership of airspace. However, if ownership changes are required, controllers will need to be taught new airspace boundaries (*K18.9-Airspace dimensions*). Controllers will also have to learn the impact of OPD routes to traffic flows (*18.17-Facility traffic flows*) as well as new LOAs/SOPs/procedures (*K18.19-Facility specific directives and procedures*) that will be required among the ATCT, TRACON, and ARTCC facilities.

Since OPD aircraft must continue along their route once they begin descent, controllers will need to learn about new separation/conflict resolution strategies (*K21.3-Conflict resolution strategies*). If OPDs require special clearances or control instructions, then controllers will need to be taught new procedures for formatting and issuing restrictions associated with clearances or control instructions (*K22.4-Procedures for composing clearances and control instructions*). When aircraft cannot meet time requirements, controllers will need to learn new procedures for how to coordinate, mitigate, or prevent nonconformance (*K22.8-Conformance assurance*), including new strategies/control actions that likely do not exist currently to get aircraft back in conformance. The specific procedures regarding the progression of aircraft along OPD through what could be potentially two facilities' airspace have not been specified. However, if the implementation of OPDs changes the responsibility of aircraft based on their trajectory along OPDs instead of along very specific facility boundaries the way it is done today, then controllers will need to learn new transfer of control requirements (*K22.11-Transfer of control requirements*) associated with these descents and new transfer of communication requirements (*K22.12-Transfer of communication requirements*) associated with these procedures.

Additionally, controllers will need to be taught about new procedures for providing approach control service to OPD aircraft (*K22.13-Approach control service*), new OPD arrival routes (*K24.3-Arrival routes*), and how to sequence OPD and non-OPD aircraft appropriately (*K24.11-Arrival sequence*).

Changes to Properties of Knowledge
Knowledge of continual descent approaches, including optimized profile descents (*K24.9-Continual descent approach, or CDA), and/or Optimized Profile Descent, or OPD*) will become important to more TRACON controllers and facilities. Furthermore, Knowledge of conventional STARs (*K24.4-Conventional standard terminal arrival routes, or STARs*) and RNAV-enabled arrival routes (*K24.5-Area navigation, or RNAV-enabled, arrival routes*) will gain importance because these routes enable OPDs.

Changes to Curriculum Required to Teach Skills
Because OPD aircraft cannot be routed in the same way other non-OPD aircraft can, one variable in the arrival flow process is the fixed path that OPD-enabled aircraft traverse. Consequently, controllers will need to learn several new technical Skills such as new separation strategy development (*Sk32-Separation Strategy Development*). Similarly, controllers will need new Skills at sequencing strategy development (*Sk35-Sequencing Strategy Development*), new spacing strategy development (*Sk38-Spacing Strategy Development*) Skills, and conflict strategy development (*Sk42-Conflict Resolution Strategy Development*) Skills.

Training and proficiency will be required for monitoring descent rates, especially in terms of knowing what the descent profiles look like for specific types of aircraft on an OPD path. This includes Skill at projecting an aircraft's projected descent path (*Sk27-Object Projection*). Skill at task timing (*Sk18-Task Timing*) will change as controllers need to know how to release aircraft behind OPD aircraft and move other non-OPD aircraft around OPD aircraft.

Changes to Properties of Skills
Because of the speed requirements for OPD aircraft, Skill at task timing (*Sk18-Task Timing*) becomes more important. Timing of initiating an aircraft on an OPD and segregating other non-OPD aircraft around the OPD aircraft on their descent will be very important. Because OPDs are predefined and are known in advance to the pilots, fewer control instructions will be required for these procedures, and instructions will consist of fewer components. Consequently, the implementation of OPDs will reduce the time controllers have to engage in oral communication Skills (*Sk1-Oral Communication*) as well as reduce the amount of active listening Skills that are required (*Sk3-Active Listening*). OPDs will reduce the use of coordination Skills (*Sk23-Coordination*), but only for communication associated with OPD aircraft. On the other hand, OPDs will increase the number of times controllers have to use oral communication Skills (*Sk1-Oral Communication*), active listening Skills (*Sk3-Active Listening*), and Skill at coordination requirements (*Sk23-Coordination*) for all other non-OPD aircraft around OPD-enabled aircraft. Because OPDs are pilot-directed activities, controllers are monitoring more and actively managing less for these OPD aircraft. Consequently, strategic scanning will become more important (*Sk25-Strategic Scanning*) and controllers will have to force themselves to monitor even without specific cause, whereas before they were generally prompted by an event(s) or by a detected anomaly.

Changes to Properties of Abilities
Oral expression (*Ab1-Oral Expression*), verbal reasoning (*Ab4-Verbal Reasoning*), and oral comprehension (*Ab5-Oral Comprehension*) abilities will be less important when managing OPD aircraft due to decreased communication. Conversely, oral expression (*Ab1-Oral Expression*), verbal reasoning (*Ab4-Verbal Reasoning*), and oral comprehension (*Ab5-Oral Comprehension*)

will be more important for all non-OPD aircraft around OPD aircraft because of the increased coordination required to keep them separated from OPD aircraft. Because controllers monitor instead of actively manage OPD aircraft, abilities associated with monitoring—sustained attention (*Ab21-Sustained Attention*) and concentration (*Ab22-Concentration*)—will become more important. Furthermore, visuospatial reasoning (*Ab29-Visuospatial Reasoning*) will become more important because controllers will have to determine closure rates more accurately on the final approach course. Finally, because OPDs are new procedures that change how things are done today, controllers' ability to learn (*Ab28-Learning*) and adapt to new situations (*Ab24-Flexibility*) will become more important.

Changes to Properties of Other Personal Characteristics

Being careful, thorough, responsible, organized, proactive, hardworking, achievement-oriented, and persevering (*O4-Conscientiousness*) will become more important because now aircraft that are flying an OPD route will not be managed actively but rather monitored passively. Controllers will have to maintain their vigilance even when they are not actively involved in communicating with pilots.

As with most NextGen Drivers, the importance of controllers viewing themselves as being in control of automation and responsible for the outcomes instead of simply responding to it (*O14-Internal Locus of Control*) will increase for OPD. In this case, controllers will need to feel they are still responsible even if the aircraft's on-board monitoring equipment (i.e., RNP) is monitoring conformance to the OPD route.

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 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. The nine potential risks associated with OPDs are:

- *Best equipped, Best Served*: Only properly equipped aircraft can fly OPDs. This creates a best equipped, best served environment for controllers, the impact of which is complex. In order for controllers to support aircraft flying time-constrained OPDs, controllers may need to spend more time formulating and issuing control instructions for non-participating aircraft to allow simultaneous operations of both participating and non-participating aircraft. The net effect on efficiency is currently unknown.
- *Degradation or Failure of Equipment or Systems*: The implementation of OPDs is dependent on aircraft being PBN-enabled. If there is a degradation or failure of the systems that support PBN-enabled routes, OPDs will not be a viable route option. Consequently, the efficiencies associated with OPDs will not be realized.
- *Improper Allocation of Tasks to Automation*: The implementation of OPDs requires the allocation of certain Tasks that were previously the line controllers' responsibility to aircraft and facility automation. The result is that once controllers issue the clearance to the pilot to fly the OPD, from that point on controllers are monitoring the aircraft instead of actively managing it. 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 utilizing OPDs, they may not approve their use in situations where they

would have been appropriate, or they may issue OPDs with unnecessary restrictions. This will reduce efficiencies that OPDs were designed to support.

- *Lack of/Inadequate Training*: Lack of training or inadequate training in the implementation of OPD procedures and how to follow them in an operational context may result in controllers being inefficient, and therefore not allow for full realization of the benefits of the technology. For example, controllers may be unable to direct aircraft to arrive at the beginning of the OPD at the appropriate time. This will affect not only the participating aircraft but also the non-participating aircraft, which will create inefficiencies.
- *Mixed Aircraft Equipage*: OPDs are implemented by controllers in a mixed equipage environment (i.e., not all aircraft are PBN enabled). If controllers do not have quick access to near real-time and current information on their displays regarding aircraft equipage, this could increase cognitive workload and decrease efficiency. In addition, to the extent that controllers have to determine which type of route is appropriate (i.e., OPD or non-OPD) based on aircraft equipage, this could potentially further increase cognitive workload and decrease efficiency.
- *More Dynamic Work Environment*: Because not all aircraft can fly OPD routes, the result is an increase in the dynamic nature of the job of controllers as they work to support both participating and non-participating aircraft. This could increase mental workload and thus increase the possibility for error. Note that although an increase in the dynamic nature of the job implies an increase in cognitive workload, the net effect of OPDs on workload is unknown due to the fact that some OPD procedures could increase workload (e.g., time critical nature of these routes; balance between participating and non-participating aircraft) and some could decrease workload (e.g., elimination of requirement for active management after the aircraft begins the OPD).
- *Skill Decay*: Because aircraft flying OPDs self-monitor conformance to their routes, implementation of OPDs has the potential for decay of the Skills required for active management of aircraft. The resulting lack of preparedness by line controllers to actively manage aircraft could make them less efficient. Note that although there are few OPDs today, it is anticipated that additional OPDs will exist by 2018. Consequently, although this represents a minor impact today, this risk will likely increase over time.
- *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 OPDs will be released into the NAS with known deficiencies, the full impact of using them in an operational context may be not realized until the system goes "live." For example, OPDs may not have reliable interoperability with other air traffic concepts. In addition, it is not until OPDs 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

OPDs are one of the few 2018 Drivers for which the element of time will become highly relevant, because if the OPD-enabled aircraft do not meet the contract (i.e., cannot arrive at the top of descent point on time), then controllers' workloads increase substantially. The primary impetus for OPD is fuel savings and reduced carbon dioxide emissions. Hence, its strongest benefit is for air carriers. However, it does have some direct impact on the jobs of line controllers, such as reduced controller to pilot communication. Additionally, OPDs will help environmental impact concerns by reducing fuel consumption and noise without substantively burdening controllers.

OPDs may increase controller workload as they work to accommodate all the other aircraft that cannot perform these types of descents. However, in coming years, OPDs will become more beneficial to NAS operations. Controllers will be able to accommodate these new operational requirements more efficiently after gaining experience and more aircraft will be equipped to benefit from the increased capabilities of technology.

DRIVER 7: PERFORMANCE-BASED NAVIGATION

Performance-Based Navigation (PBN) is a concept that describes performance requirements for aircraft (i.e., navigation specifications) and the associated infrastructure (i.e., navigation aid infrastructure) required to fly more optimized routes. Navigation specifications refer to a set of aircraft and aircrew performance requirements that support navigation in a particular defined airspace. The specifications provide better consistency and predictability, which allow TRACON controllers to manage air traffic similar to ARTCC controllers. For example, instead of issuing a series of instructions for four or five turns, TRACON controllers might issue a single clearance. Consequently, these RNAV/RNP specifications will substantively reduce voice communications.

Overview of Changes From Implementing PBN

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

Table 15. Overview of the Impact of PBN

	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: • Service Orientation (*New Sk*)		Add: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T10 T42 T65 T66 T67 T79 T87 T138 T145 T155 T194 T195 T201 T205 T206 T279 T319 T335 T344	K7.1 K7.3 K7.4 K11.5 K16.2 K16.4 K16.5 K18.19 K19.4 K21.1 K21.3 K22.4 K22.8 K22.10 K22.13 K24.3 K24.5 K24.11 K25.1 K25.5 K27.5	Sk1 Sk3 Sk17 Sk18 Sk23 Sk25 Sk27 Sk32 Sk35 Sk38 Sk42 Sk49	Ab1 Ab4 Ab5 Ab21 Ab22 Ab24 Ab28 Ab29 Ab33	O4 O14	

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 impact of PBN on the job of the line controller working in the TRACON environment will not likely require adding to, deleting from, or modifying any of the current job

Tasks, PBN will have an important impact on *how* the job is performed. PBN will have a direct impact on eight of the 11 TRACON 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 Traffic Flows and Sequences
- Activity 8. Assess Impact of Weather
- Activity 10. Manage Resources
- Activity 11. Respond to Emergencies and Unusual Situations

Activity 1. Establish Situation Awareness
In order for aircraft to fly RNP routes, they must be properly equipped. Assuming that equipage information is encoded in some way into the data block, controllers will require more time scanning to gather information regarding whether aircraft are RNP equipped (*T10*).

Activity 3. Manage Flight Plan Data
Because only certain aircraft will be equipped with the technology to use RNAV or RNP routes, this means that controllers will have another piece of information to attend to (i.e., that individual aircraft's equipage) when evaluating the flight plans (*T42*). The route of the flight must match the aircraft equipage. Time parameters are required for using RNAV or RNP routes; hence, the time component of departure and en route time messages will become more important. However, it is currently unclear how this information will be incorporated into the NAS. If departure and en route time information is entered via automation, then the TRACON controllers will not be actively involved and the Tasks will not change. However, if the automation does perform this function then controllers will be entering a decreased number of departures or en route time messages (*T65-T67*).

Activity 4. Manage Air Traffic
RNP provides the capability for pilots of properly equipped aircraft to self-monitor their own route conformance. Although controllers will still have to monitor conformance, they will likely have to issue fewer instructions due to nonconformance (*T79*).

RNAV/RNP routes are very specific, detailed routes. Although controllers will still instruct pilots to fly the route, they will not be required to provide little (if any) additional control instructions (*T87*). In cases of pilot nonconformance with RNAV/RNP routes (regardless of whether the nonconformance was known to the pilot or not), controllers must still respond to nonconformance to ensure separation from other aircraft and return aircraft to the original or a modified route. However, controllers will have different potential resolutions (*T145*) for PBN-enabled aircraft, including the possibility of transitioning from the automated route to a manually flown or vectored route, such as a visual approach/manual departure route versus returning to the PBN-enabled route. In this case, the shift for controllers will be from an automated to manual environment. When controllers are considering potential flight path deviations in response to pilot requests, they must consider that PBN-enabled aircraft can fly optimized routes (*T138*).

Activity 5. Resolve Conflicts
PBN-enabled aircraft are the most flexible aircraft because they can fly the most specific and efficient routes (e.g., within the confines of weather and other factors, they can fly point-to-point routes). The capabilities of PBN-enabled aircraft can aid controllers when determining actions required in resolving conflicts (*T155*) because PBN routes are more flexible than traditional ground-based NAVAID routes and provide controllers with more options.

Activity 6. Manage Traffic Flows and Sequences
Because RNAV-enabled arrival and departure routes are pre-defined routes, it will be unnecessary for controllers to give detailed step-by-step navigational instructions to pilots. The control instructions to PBN-enabled aircraft for departure (*T195*) and arrival sequences (*T206*) will be different in two ways. First, the control instructions will have fewer components in them. And second, there will be fewer messages/instructions to be relayed to the aircraft, which will ease controller workload and reduce radio frequency congestion. Lastly, because only some aircraft will be PBN-enabled and not all routes are PBN-enabled, controllers will have additional information to consider (e.g., aircraft equipage, presence/availability of RNAV/RNP route) when determining a sequence within the departure flow (*T194*), when ensuring coordinated arrival routing (*T201*), and when determining arrival sequence (*T205*).

Activity 8. Assess Impact of Weather
Aircraft that are PBN-enabled are more flexible in their routing and holding options; these aircraft can utilize more optimized routes and controllers may use this capability as a potential strategy when determining ways to avoid severe weather (*T279*). More specifically, controllers may direct an aircraft to a fix that enables flexibility with other aircraft that are not PBN equipped.

Activity 10. Manage Resources
The PBN-enabled aircraft will provide flexibility in flying optimized routes and curved flight path trajectories. This capability may become a new work overload reduction strategy that controllers can use in the future (*T319*).

Activity 11. Respond to Emergencies and Unusual Situations
PBN-enabled aircraft are more flexible in their routing and holding options because of their reduced reliance on ground-based navigational aids. This flexibility is particularly advantageous during emergency situations because it allows controllers to hold non-emergency aircraft safely while still providing expeditious handling to emergency aircraft, to aircraft in distress, or to aircraft experiencing unusual situations. Controllers can maneuver the PBN-aircraft virtually anywhere as necessary (*T335*).

The flexibility that PBN-enabled aircraft provide can be used by controllers when determining a plan of action to handle unusual situations (*T344*). Lastly, PBN-enabled aircraft are less likely to be affected by NAVAID outages because they are enabled by satellite-based navigation aids. Consequently, PBN-enabled aircraft will mitigate any additional workload issues for controllers created by such ground-based NAVAID outages.

Changes to Characteristics Required of TRACON Controllers

When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 PBN into the TRACON environment will not require deleting or modifying the language of currently required Knowledges, Skills, and Abilities. However, it will require the addition of a new Other Personal Characteristic. Controllers will need to have positive attitudes towards, perceive the usefulness of, and to perceive ease of use of technology (*New O-Technology Acceptance*). That is, in order for controllers to fully utilize the capabilities associated with PBN, they must be comfortable using automation.

Second, the implementation of PBN prompts the need for a new Skill that allows TRACON controllers to be 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

Controllers will need to learn new route structure (*K7.1-Air route structure*) as well as new types of navigation (*K7.3-Types of navigation*). For example, based on the aircraft's capabilities, navigation may be ground-based, satellite-based, or some combination of the two. Additionally, PBN enables many RNAV and RNP air routes. Consequently, aeronautical charts will look different (*K7.4-Aeronautical charts*) and controllers will need to be taught about the new charts, their components, and what they mean. Controllers will also need to be taught about the new avionics (*K11.5-Avionics*) that are required onboard aircraft to support PBN operations. These avionics are based on satellite-based technology and, therefore, aircraft do not have to depend on ground-based equipment.

Because aircraft must be properly equipped to fly RNAV/RNP routes, controllers will 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, including aircraft equipage and crew certification, and how to evaluate the impact of RNP equipage on providing ATC services (*K16.4-Evaluation Strategies*). Assuming information regarding aircraft equipage is contained in the data block, then recognizing/understanding this information must be taught as part of Knowledge interpretation (*K19.4-Interpretation of information provided*). Controllers will have to use Knowledge of RNAV/RNP routes to build new flight plans or to introduce new segments into existing flight plans (*K16.5-Flight plan processing*). Furthermore, controllers will need to be taught new local LOAs/SOPs/procedures (*K18.19-Facility specific directives and procedures*) that are required to support the new routes.

PBN operations could also be used as a conflict resolution strategy (*K21.3-Conflict resolution strategies*) because these operations provide controllers with additional flexibility in routing. Hence, controllers need to learn new Knowledge related to these strategies. If RNAV/RNP routes require special clearances, then controllers will need to be taught new procedures for composing both the instructions and any restrictions (*K22.4-Procedures for composing clearances and control instructions*). Aircraft may be unable to meet the time constraints associated with these routes, and consequently controllers may need to learn new procedures for dealing with these nonconforming aircraft (*K22.8-Conformance assurance*), including learning new strategies or control actions that may not currently exist to ensure route conformance. For example, this may include circling the aircraft to re-initiate a continuous descent approach that is enabled by RNP-equipped aircraft. Additionally, controllers will need to be taught how to use the fact that PBN capable aircraft can fly optimized routes as a strategy for severe weather mitigation (*K22.10-Strategies for severe weather avoidance*). To the extent that PBN enables more flexible routing (i.e., the ability to fly direct or to fly curved paths and not having to fly from one ground-based NAVAID to the other), it reduces the impact of weather on operations and flight. Moreover, controllers will need new Knowledge for approach control service (*K22.13-Approach control service*) if aircraft are RNP-capable and can do their own conformance monitoring.

PBN capable aircraft are flexible because they can fly optimized paths that will offer controllers a wide range of arrival route options and arrival strategies (*K24.3-Arrival routes*). Therefore, controllers need to be taught about these options and strategies. Furthermore, controllers will need to be trained in new local RNAV-enabled routes (*K24.5-Area navigation (RNAV-enabled) arrival routes*). Controllers will have to learn how to take new information into account when developing arrival sequences (*K24.11-Arrival sequence*) including aircraft equipage and availability of routes. This is especially important in low visibility situations because only some aircraft will be able to initiate an approach under low visibility conditions. Additionally, controllers will need to take more information into consideration when developing departure sequences (*K25.1-Departure sequence*) such as whether aircraft are equipped, as well as which routes are available and usable. Controllers will also need to be taught new local RNAV-enabled routes (*K25.5-Area navigation—RNAV-enabled—departure routes*). Finally, controllers need to be taught how to use PBN routes as emergency techniques (*K27.5-Emergency assistance techniques*) because PBN aircraft are more flexible in routing and holding options and in their flight path creations. More specifically, in case of an emergency situation, controllers can move PBN-enabled aircraft on any of the PBN routes (satellite-based) as well as other more conventional NAVAID routes.

Changes to Properties of Knowledge

Knowledge of terrain separation standards and separation standards from unapproved airspace will be less important, as pilots of RNP-equipped aircraft will take on some responsibility for conformance to routes (*K21.1-Types of separation standards*). Conversely, there are two Knowledges that increase in importance. These are Knowledge of local RNAV-enabled arrival routes (*K24.5-Area navigation—RNAV-enabled—arrival routes*) and Knowledge of local RNAV-enabled departure routes (*K25.5-Area navigation (RNAV-enabled) departure routes*).

Changes to Curriculum Required to Teach Skills

Because NextGen represents a shift from a “first come, first served” system to a “best equipped,, best served” system, controllers have to be taught aircraft capability to fly PBN routes both in terms of equipage and workload availability for pilots when identifying the appropriate order of work Tasks (*Sk17-Task Prioritization*). Controllers will have to mentally project flight trajectories that are much more variable in nature than they are today (e.g., curved flight paths, climb then descend to get over airspace). Therefore, controllers need to be trained in and need practice on how to mentally project these routes (*Sk27-Object Projection*).

Because aircraft flying RNAV/RNP routes are not constrained in the same way other non-equipped aircraft are, controllers will need to be taught to utilize these choices when developing separation strategies (*Sk32-Separation Strategy Development*). For example, equipped aircraft do not have to fly from one ground-based NAVAID to the other and, hence, controllers will have more routing choices. Similarly, controllers will need new sequencing strategy development (*Sk35-Sequencing Strategy Development*), new spacing strategy development (*Sk38-Spacing Strategy Development*), new conflict strategy development (*Sk42-Conflict Resolution Strategy Development*), and new weather strategy development (*Sk49-Weather Strategy Development*) Skills that allow controllers to make the best use of the new routing options.

Changes to Properties of Skills

Because RNAV/RNP arrival and departure routes are pre-defined and are known in advance to pilots, fewer control instructions will be required for these procedures and instructions will consist of fewer components. Consequently, the implementation of PBN routes will reduce the frequency with which controllers have to engage in oral communication Skills for this procedure (*Sk1-Oral Communication*), reduce the number of times active listening Skills are required (*Sk3-Active Listening*), and reduce coordination requirements (*Sk23-Coordination*).

Because aircraft flying RNAV/RNP arrival and departure routes must proceed along their routes once they begin their descent or climb, fewer changes can be made to the course direction or speed. Movement of aircraft into, out of, or around these routes must be performed in a timely manner to optimize airspace. In addition, assuming pilots have to enter data by hand into the Flight Management System, controllers need to take this lag time into account when issuing control instructions. Taken together, this means that Skills at task timing will be vital (*Sk18-Task Timing*). Because RNAV/RNP arrival and departure routes are pilot-directed activities, controllers will be monitoring more and actively managing less for these aircraft. Consequently, strategic scanning will become more important (*Sk25-Strategic Scanning*) and controllers will have to force themselves to monitor even without specific cause, whereas before they were generally prompted by an event(s) or by a detected anomaly.

Changes to Properties of Abilities

Because RNAV/RNP-enabled arrival and departure routes are pre-defined and are known in advance to the pilots, then fewer control instructions will be required for these routes and instructions will consist of fewer components. Consequently, RNAV/RNP route implementation will reduce the times controllers have to communicate information and ideas verbally to pilots (*Ab1-Oral Expression*), perceive and understand principles governing the use of concepts and symbols (*Ab4-Verbal Reasoning*), and listen to and understand information from pilots in spoken words and sentences (*Ab5-Oral Comprehension*).

Because controllers will monitor instead of actively manage aircraft flying RNP routes, Abilities associated with monitoring, including sustained attention (*Ab21-Sustained Attention*), and concentration, (*Ab22-Concentration*) will become more important. Furthermore, controllers' Ability to learn (*Ab28-Learning*) will become more important because PBN operations are new procedures that change how things are done today. Additionally, controllers will need to be flexible and adapt to new situations (*Ab24-Flexibility*). For example, they may have to work to meet the needs of pilots who may have time constraints if they have to hand enter data into the FMS.

Additionally, the Ability to perceive and understand principles (*Ab29-Visuospatial Reasoning*) will be more important because objects will have different relationships to each other in 4-D due to the addition of the time element that was absent before. The Ability to recall a deferred or interrupted action (*Ab33-Recall from Interruption*) will be more important because aircraft will not always be able to follow their RNAV/RNP routes. In this case, controllers will need to have the Ability to jump quickly back into the aircraft's situation, understand the situation, and direct them accordingly.

Changes to Properties of Other Personal Characteristics

There are two Other Personal Characteristics that will gain in importance as a result of PBN operations. First, RNAV/RNP aircraft can self-monitor for conformance to their routes so controllers will not be managing these aircraft actively, but instead monitoring. Consequently, being vigilant, and maintaining this vigilance even when they are not actively involved, will be a more important quality for controllers to have (*O4- Conscientiousness*). Second, internal locus of control (*O14-Internal Locus of Control*) will be more important because it is vital for controllers to believe that maintaining conformance to the route is under their control, instead of shifting the responsibility to the aircraft.

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 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. The 10 potential risks associated with PBN are:

- *Best equipped, Best Served*: Only some aircraft will be equipped to fly PBN routes or to monitor their conformance to routes in the mid-term. This creates a best equipped, best served environment for controllers, the impact of which is complex. Although controllers will spend less time actually managing aircraft on a PBN route, they may be spending more time managing non-PBN equipped aircraft. The net effect on efficiency is currently unknown.
- *Deficiencies in Technology*: While PBN technology remedies some of the vulnerabilities in existing technologies, to the extent that it relies on satellites, it is 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*: The implementation of PBN operations is dependent upon 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, which may include monitoring adherence of PBN aircraft to their routes and using ground-based aids for navigation. These backup procedures rely on older, 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 Allocation of Tasks to Automation*: The implementation of PBN requires the allocation of certain tasks that were previously the line controllers' responsibility to aircraft and facility automation. The result is that controllers are monitoring the aircraft flying PBN-enabled routes 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 utilizing PBN-enabled routes, they may not utilize them when they would have been appropriate. This will reduce efficiencies that PBN-enabled routes were designed to provide.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities (and any relevant limitations) of the new procedures may result in poor controller performance (i.e., poor decision-making) and thus decrease safety. Additionally, unexpected nonconformance by participating aircraft could have severe consequences, with controllers needing to shift back to actively managing aircraft. For example, with parallel runway approaches that have two aircraft turning toward each other—this is a critical time for controllers to know whether the aircraft are in conformance. There are some approach paths being built to account for these risks.
- *Mixed Aircraft Equipage*: Avionics required for aircraft to monitor their conformance to a route or fly a PBN-enabled route will not be installed on all aircraft. In the mid-term, controllers will need to spend more time formulating different clearances based on equipage, which increases workload and decreases efficiency for controllers. In addition, if controllers are not provided with immediate access to current information on aircraft equipage, this could also increase cognitive workload and decrease efficiency.
- *More Dynamic Work Environment*: Because only some aircraft will be equipped to fly PBN-enabled routes or monitor their own conformance to routes, the result is an increase in the dynamic nature of the job of controllers. This could increase their mental workload and thus increase the possibility for error. Note that this increase in workload may be offset by a simultaneous reduction in workload resulting from the predictable nature of PBN aircraft performance and reductions in communications required to manage them.
- *Skill Decay*: Because RNP aircraft self-monitor conformance to their routes, this has the potential to decay the Skills required for active management of aircraft. The

resulting lack of preparedness by line controllers to actively manage aircraft could make them less efficient (e.g., increase in the time required to respond).

- *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 PBN system 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 the feedback that is vital to system evolution.

Driver Impact Summary

PBN is primarily a benefit to the air carrier that will save time and money by using optimized routes. Although PBN is not automation for TRACON controllers, its implementation does impact line controllers. From a Task perspective, PBN operations reduce reliance on ATC for navigation assistance, as well as decreasing reliance on traffic management for route optimization. PBN reduces ATC communications and provides additional alternatives for route adjustments.

From a KSAO perspective, the implementation of PBN and the fact that only certain aircraft can perform them will have significant impact on controllers' KSAOs. To the extent that procedures are running smoothly, an outcome of PBN is that controllers' workloads will be reduced because they have to less actively manage PBN-enabled aircraft. More specifically, PBN operations reduce workload because there is less communication and coordination required between controllers and pilots of PBN-equipped aircraft. However, this places additional burden on controllers to be more vigilant in their monitoring and—when considered alone—may make the job less challenging and perhaps less interesting.

Finally, PBN-equipped aircraft allow system capacity improvements that are unmatched anywhere else in TRACON NextGen Drivers, because it will affect every type of airspace and every type of aircraft operation. This Driver will have a significant impact on the efficiency of the NAS because aircraft will now be able to self-navigate and self-monitor their performance while flying Oceanic and domestic routes. Additionally, this Driver also has environmental benefits, as routes will use less fuel and emit less carbon emissions.

Driver 8: Terminal Automation Modernization and Replacement Program, Phase 3

TAMR 3 is an FAA initiative to replace or upgrade the primary terminal automation systems at TRACONs and associated ATCT facilities. Enhancements include addressing capacity limitations and creating an improved Computer Human Interface (CHI). Additionally, the new display and processor is compatible with NextGen technologies. More specifically, the TAMR 3 program may incorporate the Electronic Flight Strip Transfer System (EFSTS) that transmits flight information between ATCT and TRACON facilities. However, the Data Comm component will not be implemented in TRACON facilities by mid-term 2018.

Overview of Changes From Implementing TAMR 3
The following table provides a visual summary of the changes that will occur as a result of implementing TAMR 3. Additional details regarding these changes can be found in the sections that follow.

Table 16. Overview of the Impact of TAMR 3

	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: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T41 T52 T42 T53 T43 T54 T44 T55 T45 T56 T46 T57 T47 T58 T48 T59 T49 T60 T50 T62 T51 T63	K16.3 K16.5 K16.6 K19.1 K19.2 K19.3 K19.4 K19.5 K19.6 K19.7 K19.8 K22.3	Sk2 Sk29 Sk52 Sk53 Sk54	Ab2 Ab3 Ab24 Ab28 Ab35	O14	

Changes to TRACON Job Tasks
When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 impact of TAMR 3 on the job of the line controller working in the TRACON environment will not likely require adding to, deleting from, or modifying any of the current job Tasks, TAMR 3 provides controllers with standardized information regarding flight plans and will most directly impact how Tasks associated with managing flight plan data are performed.

Activity 3. Manage Flight Plan Data
Line controllers may enter and amend flight plan data less often if access to the EFSTS is available to traffic managers and supervisors as well as line controllers. Consequently, due to wide accessibility and standardization of the EFSTS between and within facilities, traffic managers will be primarily responsible for entering or amending flight plan information (*T41-T54*). Furthermore, flight plan information will be more standardized between facilities than it is today, which will reduce the frequency with which line controllers enter and amend flight plan information, because they will not be communicating flight plan information as frequently between facilities.

EFSTS will change the processing of flight progress strips, in that controllers will not mark strips by hand (*T55-T60*), assuming that the facility is using paper flight progress strips. Instead of writing on paper strips with pen and pencil, controllers will enter data into the electronic system. Note that it is not currently known how data entry will be accomplished (e.g., touch screen, keyboard entry). Furthermore, controllers will not be required to release paper strips to the next controller, as flight progress strips will be transferred electronically. Finally, controllers will not have to file flight progress strips as data will be stored electronically (*T62*, *T63*).

Changes to Characteristics Required of TRACON Controllers
When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 PBN into the TRACON environment will not require deleting or modifying the language of currently required Knowledges, Skills, and Abilities. However, it will require the addition of a new Other Personal Characteristics. Controllers will need to have positive attitudes towards, perceive the usefulness of, and perceive ease of use of technology (*New O-Technology Acceptance*). That is, in order for controllers to fully utilize the capabilities associated with TAMR 3, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges
Controllers will need to be trained in new methods for flight plan filing (*K16.3-Filing process*) because TAMR 3 includes EFSTS. Also, controllers will need to learn new procedures for processing flight plans (*K16.5-Flight plan processing*). Additionally, controllers will also need to learn a new flight plan data display method (i.e., EFSTS) (*K16.6-Flight plan data display methods*). Controllers need to be taught Knowledge of an additional type of tool (*K19.1-Types of tools and equipment*), functionality (*K19.2-Functionality of tools and equipment*), operation (*K19.3-Operation of tools and equipment*), interpretation (*K19.4-Interpretation of information provided*), limitations (*K19.5-Limitations*), degradation indicators (*K19.6-Degradation indicators*), troubleshooting (*K19.7-Minor troubleshooting*), and backup systems (*K19.8-Backup systems*). Finally, controllers will need new scanning strategies for the new tool (*K22.3-*

Scanning strategies), such as where to look for flight plan information as well as intra- and inter-tool scanning strategies.

Changes to Properties of Knowledge
None.

Changes to Curriculum Required to Teach Skills
Controllers will need to be taught how to use the new EFSTS to manage air traffic instead of paper flight progress strips (*Sk29-Flight strip utilization*).

Changes to Properties of Skills
Because controllers will no longer be hand writing on paper flight progress strips, Skill at written communication (*Sk2-Written Communication*) will become less important. Instead, because controllers will have to enter flight process data into a computer, Skill at effectively using tools and equipment including input devices and peripherals (*Sk52-Tool and Equipment Operation*) will become more important. Finally, because the EFSTS is a computerized tool, Skill at recognizing equipment degradation or failure (*Sk53-Tool and Equipment Status Recognition*), Skill at responding to tool/equipment degradation or failure including minor troubleshooting, and Skill at executing backup procedures (*Sk54-Tool and Equipment Degradation/Failure Response*) will become more important when managing flight plan data.

Changes to Properties of Abilities
Controllers' ability to communicate information in writing (*Ab2-Written Expression*) will become less important because information will be entered electronically. Instead, ability to make fast, simple, and repeated movements of the fingers, hands, and wrists (*Ab35-Wrist/Finger Speed*), which is required for data entry using a keyboard/mouse/touch screen, will become more important. Additionally, the Ability to read and understand information in writing will still be important. However, to the extent information is presented electronically instead of in paper form, this could have an impact on controllers' understanding of information and ideas presented in writing (*Ab3-Written Comprehension*). Finally, because TAMR 3 is a program to replace or upgrade the primary automation systems in TRACON, controllers' Ability to adapt to new systems (*Ab24-Flexibility*) and apply lessons learned from experience (*Ab28-Learning*) will become more important.

Changes to Properties of Other Personal Characteristics
As with most NextGen Drivers, the importance of controllers viewing themselves as being in control of automation and responsible for the outcomes instead of simply responding to it (*O14-Internal Locus of Control*) will increase for the TAMR 3 program (specifically, EFSTS). In this case, controllers will need to feel they are in control of the changes in managing flight plan data.

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 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. Although TAMR 3 primarily involves an automation upgrade, it does introduce the possibility of five risks into the NAS. These are:

- *Degradation or Failure of Equipment or Systems*: If STARs fails or degrades, then controllers will have to revert to nonradar separation of aircraft. These procedures require greater separation between aircraft and, consequently, the implementation of these as a backup procedure will reduce efficiency and will increase the possibility for error, especially during the transition.

- *Lack of/Inadequate Training*: Lack of training or inadequate training in the capabilities of the new platform and its new functionalities (e.g., EFSTS) as well as any limitations may result in poor controller performance (e.g., delayed decision-making as a result of having to access printed materials such as procedures guides). When combined with increases in the probability of the user being distracted, these delays reduce efficiency and increase the possibility for error.
- *Poor Design of Computer-Human Interface Design*: If the Computer-Human Interface (CHI) that is being designed for this NextGen capable version of STARS is not designed to present the information in a meaningful way (e.g., does not distract the user from other more critical information; can be retrieved quickly; is easily distinguishable from other related information), this could increase the possibility of error, thus reducing efficiency and safety.
- *Skill Decay*: Implementation of EFSTS has the potential for the decay of the Skills required for managing paper flight strips. The result is lack of preparedness by line controllers and reduction in safety during unusual situations, when the automation is either not functioning at all (e.g., system outages), 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 STARS 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

TAMR 3 program is an upgrade of the TRACON controllers' primary radar display, which will ultimately enable integration with other NextGen products. Standardization of equipment between TRACON facilities should help support shared situation awareness among controllers and traffic managers.

Furthermore, the TAMR 3 program will have a fairly substantive impact because many TRACONs are expected to either get an upgrade or full replacement with new technology. This is the continuing platform for NextGen tools and other Drivers to exist, but in the mid-term the main change is EFSTS.

DRIVER 9: WAKE TURBULENCE MITIGATION FOR ARRIVALS

Wake Turbulence Mitigation for Arrivals is a system that will allow for reduced separation minima on parallel approach courses when there are favorable crosswind conditions. Specifically, TRACON line controllers will see an indicator light on their radar/traffics, indicating that crosswinds are stable and strong enough to dissipate wake turbulence. Automated Terminal Proximity Alert (ATPA) Phase II will incorporate a larger matrix of wake turbulence separation standards, and will monitor and alert controllers to potential loss of separation between aircraft on CSPRs. As a result, controllers will not have to know whether specific pairs of aircraft create potential wake turbulence problems.

Overview of Changes From Implementing WTMA

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

Table 17. Overview of the Impact of WTMA

	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 WTMA indicator status (*New T*)	Add: • ATC Automation (*New K)* • Interoperability (*New K*)			Add: • Technology Acceptance (*New O)*	Add: • WTMA Indicator (*New TE*)
Driver otherwise affects existing Task or KSAO:	T3 T12 T22 T85 T86 T154 T158 T205 T206	K8.6 K18.19 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 K24.3 K24.11	Sk1 Sk3 Sk6 Sk12 Sk15 Sk17 Sk18 Sk23 Sk25 Sk38 Sk39 Sk40 Sk53 Sk54	Ab1 Ab4 Ab5 Ab8 Ab11 Ab14 Ab23 Ab24 Ab28 Ab33	O4 O12 O14	

Changes to TRACON Job Tasks

When determining the impact of a NextGen Driver on the job of TRACON line controllers, 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 WTMA will produce changes to the current list of Tasks that TRACON line controllers perform in the following job Activity:

- Activity 6: Manage Traffic Flows and Sequences

Activity 6: Manage Traffic Flows and Sequences

The introduction of WTMA to the TRACON work environment will require adding Tasks associated with implementing new wake turbulence separation standards. More specifically, 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: checking the WTMA indicator status light when wake turbulence is an issue (*New T*).

Changes to How Tasks Are Performed

In addition, AIR proposes that WTMA will have an impact on *how* controllers in major airports with parallel approach courses will perform Tasks. Specifically, WTMA will have a direct impact on three of the 11 TRACON job Activities:

- Activity 1: Establish Situation Awareness
- Activity 4: Manage Air Traffic
- Activity 6: Manage Traffic Flows and Sequences

Activity 1: Establish Situation Awareness

WTMA will affect situation awareness by providing TRACON line controllers with information on when conditions are favorable for reducing separation minima for operation 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 the time required for controllers to scan for temporary changes to the NAS (*T12*). It could also increase the time it takes to receive and conduct a position briefing (*T3, T22*). For example, WTMA will add a new parameter (i.e., current separation minima) to be discussed during the briefing. In addition, the briefing may also require discussion about the pattern of shifting between two different sets of separation rules.

Activity 4: Manage Air Traffic

The WTMA algorithm will give controllers a new piece of information to take into consideration when providing separation services. Having information on whether the conditions are favorable or not for reduced wake turbulence separation will change the control actions that are available to controllers (*T85*) when performing radar separation. For example, controllers will have to choose different routes based on the current wake separation minima (i.e., standard or reduced). Information on whether the conditions are favorable or not for reduced wake turbulence separation will have to be taken into account when controllers are prioritizing their control actions (*T86*).

Activity 5: Resolve Conflicts
WTMA may have an effect on conflicts depending on how the alerts for loss of separation on tools like TAMR 3 are calibrated. If wake turbulence separation standards are less than what the current conflict alerts are designed to accept and if these conflict detection algorithms are not adjusted to account for reduced wake turbulence separation standards, then controllers may have to spend more time evaluating (*T154*) and responding to alerts (*T158*).

Activity 6: Manage Traffic Flows and Sequences
Instead of applying a single set of wake turbulence separation standards, controllers will be required to switch back and forth 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 arrival sequence (*T205*) and issuing the appropriate control instructions to implement the approach sequence (*T206*).

Changes to Characteristics Required of TRACON Controllers
When determining the impact of a NextGen Driver on the characteristics required of TRACON 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 WTMA 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 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 WTMA also requires the addition of one new Other Personal Characteristic—the need for positive attitudes towards, perceived usefulness of, and perceived ease of use of technology (*New O-Technology Acceptance*). WTMA adds a new piece of automation to the TRACON environment, so controllers must be comfortable using and trusting the automation.

Changes to Curriculum Required to Teach Knowledges

The introduction of WTMA will require that TRACON line controllers learn new training material to support existing 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 controllers and to machines; and concepts associated with decision support tools (DSTs), including the decision support versus decision-making continuum, evaluation strategies, and the concept of automation-based algorithms and the importance of understanding them.

WTMA will also require controllers to learn new course curriculum regarding how weather—and wind in particular—can impact operations (*K8.6-Impact on operations*). In particular, controllers will need to be taught about wake turbulence mitigation and its effect on operations, since they do not currently have the capability that WTMA provides. The implementation of WTMA allows TRACON controllers to take advantage of reduced wake turbulence separation minima. However, ATCTs have a corresponding tool for departures (i.e., Wake Turbulence Mitigation for Departures or WTMD). The coordination between controllers in these two facilities will be driven in part by new intra- and inter-facility specific agreements (*K18.19-Facility specific directives and procedures*).

Controllers will 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 of 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 on the WTMA system 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*). In addition, controllers will need to be taught new curriculum for the new Knowledge about how the new facility Tools and Equipment work in conjunction *(New K-Interoperability)*. For example, in the case of WTMA, the curriculum would include information regarding how the ATPA information will be depicted on the radar/traffic display, how the system as a whole interacts with other alerts and the existing automation including ARTS/CARTS/STARS.

Although the exact details of the new WTMA procedures have not yet been determined, controllers will likely need to be taught a new communication process related to informing others of the change from standard to reduced separation minima. This will involve teaching all of the Knowledge sub-categories under K20 (*K20.1-Types of 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 WTMA will allow controllers to reduce wake turbulence separation minima in favorable wind conditions, controllers will need to be taught new content with regard to separation. More specifically, they will need to be taught the new separation minima (*K21.2-Separation minima*) that will be used on parallel approach courses when wake turbulence is being appropriately mitigated by the wind.

Controllers will need to be taught new curriculum regarding the provision of air traffic services, including new scanning strategies (*K22.3-Scanning strategies*) for ATPA, which will alert controllers to potential losses of separation on CSPRs. Controllers need to be taught how to incorporate this new WTMA alert into their scan of the operational environment. In addition, controllers will likely need to be taught procedures for creating clearances and other instructions (*K22.4-Procedures for composing clearances and control instructions*). For instance, the introduction of WTMA may mean that controllers will have to include verbiage specific to the wake turbulence mitigation and the application of the reduced separation standard in the control instruction when using reduced wake turbulence separation minima.

Changes to Properties of Knowledges

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

Since WTMA is designed for use of aircraft arrivals on parallel approach courses, controllers may also need Knowledge of how to release aircraft for arrival on parallel runways more often than they do today. The number of arrivals on parallel approach courses should increase with WTMA. Consequently, controllers will need to apply their Knowledge of certain arrival routes (*K24.3-Arrival routes*) and arrival sequences (*K24.11-Arrival sequence*) more frequently.

Changes to Curriculum Required to Teach Skills

Although controllers will not directly interact with WTMA equipment other than monitoring the alert, they may still need to learn new Skills on recognizing and responding to degradation/failure of WTMA (*Sk53-Tool and Equipment Status Recognition and 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

WTMA will increase the importance of several Skills. Although the procedures associated with WTMA have not yet been specified, controllers will certainly be required to communicate their intention to use reduced separation minima to pilots and to other controllers. As a result, Skills in verbally communicating information (*Sk1-Oral Communication*), Skill in attending closely to what others are saying (*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 in maintaining awareness after being interrupted by the temporarily reduced separation standard may also become more important (*Sk6-Interruption Recovery*). Skill in recognizing high workload may also become more important (*Sk15-High Workload Recognition*). WTMA will allow controllers to space departing aircraft closer together and to increase departure throughput. However, that does not mean controllers should do this in every case just because they have the capability.

Skill in identifying the appropriate order of work tasks will become more important (*Sk17-Task Prioritization*) as WTMA 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 WTMA 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 in developing viable spacing strategies (*Sk38-Spacing Strategy Development*), selecting the most appropriate strategy (*Sk39-Spacing Strategy Selection*), and implementing these strategies (*Sk40-Spacing Strategy Implementation*).

The importance of rule application Skills (*Sk12-Rule Application*) will not necessarily increase, but it may become more difficult because the rules will not be consistent. Sometimes controllers will have to use one standard, and at other times they will have to use another. This increases the possibility of error.

Changes to Properties of Abilities

WTMA 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. WTMA will also increase the importance of visual abilities. Since ATPA has a lighting component that is in color, the Ability to match and detect differences between colors, including shades of color and brightness (*Ab8-Visual Color Discrimination*) becomes even more important.

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*). Further, the Ability to remember information (e.g., which separation standard applies, which aircraft are separated by that standard) long enough to manage the situation (*Ab14-Working Memory*) will also become more important because the changes in separation standards are only temporary. Controllers will have to retain at any given time which separation standard is in place for parallel approach courses. Recognizing and attending to detail will increase in importance as the consequence of missing something is greater when aircraft are closer together (*Ab23- Attention to Detail*)—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 become more important (*Ab33-Recall from Interruption*).

Finally, 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 need to be able to adjust and adapt to using reduced separation standards of WTMA. Controllers will also need to be able to learn the Knowledges and Skills associated with WTMA 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

Being thorough will be even more important as a result of WTMA, again, because the aircraft are closer together and controllers will have to less time to make a correction (*O4-Conscientiousness*). WTMA will increase the importance of controllers accepting risks associated with the job while embracing the requirements of the job (*O12-Risk Tolerance*). As controllers reduce separation between aircraft and put more planes closer together during conditions that they cannot verify visually, they are trusting that the automation is correctly interpreting the wind conditions. At the same time, spacing planes closer together increases the risk of a potentially high consequence of error if the planes do experience impacts of wake turbulence.

Additionally, WTMA will increase the importance of controllers viewing themselves as being in control of automation and responsible for the outcomes (*O14-Internal Locus of Control*) instead of simply responding to it. This is especially the case with WTMA, 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. A comprehensive list of the 17 risks associated with TRACON NextGen Drivers is presented in Appendix B. The 10 potential risks associated with the implementation of WTMA are:

- *Change in Culture*: Developmental and CPC-level line controllers will need to demonstrate willingness to learn to use WTMA and its DSTs when managing air traffic. An inability to learn to use, or lack of interest in learning and using, the new automation and DSTs 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 DST that determines when conditions are favorable or if the DST that provides the minimum separation standard that is supported do not provide reliable or valid information, 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 WTMA 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 WTMA or the DST associated with it 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 WTMA's wake turbulence mitigation guidance, they may not implement the reduced separation minima in cases when it was available. This will reduce efficiencies that WTMA was designed to support.
- *Lack of/Inadequate Training*: Lack of training or inadequate training in the functions of WTMA and the DST, its alerts, and the algorithms that will assist controllers in achieving minimum separation—as well as their limitations—may result in poor controller performance with regard to aircraft separation. This could increase the possibility for error, thus reducing safety and efficiency.
- *More Dynamic Work Environment*: WTMA 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 controllers, and may increase mental workload and thus the possibility of error.
- *Poor Computer-Human Interface Design*: If the Computer-Human Interface (CHI) that presents critical ATPA-provided information such as the minimum separation allowed, as well as the alerts associated with its use, 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 of error, thus reducing efficiency and safety.
- *Reduced Separation Minima*: Reducing separation minima through the use of WTMA 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.
- *Skill Decay*: Because ATPA estimates the minimum distance required between aircraft, this may result in decay in controllers' Skill at mentally evaluating wind conditions and determining how they will affect closure rates on final approach. Any resulting lack of preparedness by line controllers to detect closure rates and final approach speeds could negatively affect efficiency and increase the possibility of errors when WTMA is not available.
- *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 WTMA 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

WTMA will provide controllers with the opportunity to maximize the use of airspace by informing them when wake turbulence separation minima for aircraft on parallel approach courses can be reduced. The ATPA DST also informs controllers which separation standard to apply to aircraft pairs. WTMA will allow controllers to make more efficient sequencing decisions and to increase throughput at major airports with parallel approach courses by taking advantage of favorable crosswind conditions. However, this shifting between two different wake turbulence separation standards, perhaps multiple times during a shift, will increase controller workload and the possibility of errors. When combined with the likely increase in throughput, these risks become even more pronounced.

The WTMA tool itself does not require much input from controllers. The tool gathers and evaluates the wind data and the supervisor decides whether to enable the reduced separation or not and then informs the controller. However, the implementation of WTMA will result in a cultural change for controllers. Current wake turbulence mitigation standards are based on historical accidents, so the potential for accidents does exist. The use of wind data (which cannot be seen) to reduce separation standards that have likely changed little in many years may prove to be a substantive change for controllers and for pilots. Controllers may be reluctant to instruct aircraft on parallel approach courses to land so close together.

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, if so, how they can be mitigated.

The Job of the NextGen TRACON Controller

This report describes the job of the Air Traffic Control Specialist (ATCS) working in the Federal Aviation Administration's (FAA's) Terminal Radar Approach Control (TRACON) 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 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 TRACON 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 affect 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; 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 TRACON controller contained in this report is based on NextGen documentation as of January 2011[10] 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

[10] 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 15 potential risks associated with the implementation of NextGen Drivers (see Appendix B for the full list) in the TRACON environment. These risks range from challenges associated with technology, new policies and procedures, the new work environment, and individual controller job performance. The impact of the risks varies, with some risks being associated with only one or two Drivers, and others being associated with all ten. A high level summary of the risks and AIR's recommendations are provided below.[11] A more comprehensive discussion of each risk can be found in the Technical Report that details the research conducted to support the development of this and other Job Descriptions (AIR, 2011b).

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 TRACON 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.

[11] Much of the research suggested here is in progress.

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. Existing research should be continued and perhaps additional research could be conducted to determine how to address deficiencies in technology. The research could address the problem from both an engineering standpoint (e.g., how to eliminate interruptions in satellite communications) and a human performance standpoint (e.g., how to ensure success using the technology despite the deficiency). 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 the 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 the CHI 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 (HITLs) 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, to determine the impact of this policy on controllers.

The only NextGen Driver for TRACON that specifically and directly reduces separation minima is WTMA (although ADS-B out theoretically supports this notion as well). 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: (a) 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, or (b) controllers could be assigned to work in facilities based on their proficiency in the required aptitudes.

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

- Change in Culture
- More Dynamic Work Environment

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

To ensure adoption of the new NextGen technologies, automaton, and procedures by all controllers, training will need to include specific information regarding both the benefits and limitations of the new tools. The increase in the dynamic nature of the work will mean a less predictable work environment for controllers. In addition to conducting research on the effects of individual Drivers (e.g., whether controllers can adjust to changing airspace boundaries), controllers will need training on the new tools and procedures. Research could also be conducted 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, this may mean that new KSAOs need to be added or that 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 based on 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 TRACON NextGen Drivers creates four 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

To the extent that 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 a controller 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 being 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 the human operators, where controllers are working together with the automation to identify critical errors in the system when they occur. 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 of the NextGen Drivers require that developmental and CPC-level air traffic control specialists (ATCSs) receive training and practice on Knowledges and Skills. Training should include how to operate the new automation as well as information 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., its algorithms). Teaching controllers the limitations of the automation should reduce both over- and under-reliance on the automation. Feedback presented to the line controller by the automation—if properly designed and appropriately delivered—may also assist controllers' performance.

In sum, the most important steps in addressing the 15 potential risks that were identified as part of this research are research and training. Given the number of Drivers and the number of individuals to be trained, this 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 ATCS Job Analysis Data

TRACON 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 briefing 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
S2	*Assessing position/sector data*	
	T10	Scan control environment to gather information about aircraft
	T11	Scan control environment to gather current and trend weather data
	T12	Scan control environment for information regarding temporary and permanent changes to the NAS
	T13	Scan control environment for information about traffic outside your sector
	T14	Request pilot position reports
	T15	Interpret data gathered above to identify patterns and irregularities
	T16	Project the current situation into the future to identify potential threats to safe and efficient flow of air traffic
S3	*Monitoring equipment and automation system status*	
	T17	Monitor equipment and automation system status
	T18	Receive information regarding equipment and automation status from status information areas, verbal notices, pilots, and relief briefings
S4	*Relinquishing position responsibility*	
	T19	Review system status information for comprehensiveness and accuracy
	T20	Review briefing checklist and/or notes to assure comprehensiveness of briefing coverage
	T21	Initiate mandated recording of briefing
	T22	Brief relieving controller
	T23	Sign off position log if required
A2	**Manage Communications**	
S5	*Establishing and terminating radio communications*	
	T24	Receive initial radio communication from pilot
	T25	Establish two way radio communications
	T26	Issue most current automatic terminal information service (ATIS) information
	T27	Determine frequency in use by receiving sector
	T28	Issue change of frequency to pilot
S6	*Issuing clearances, instructions, or other messages*	
	T29	Identify need for communication
	T30	Receive request requiring response
	T31	Determine appropriate recipient(s)

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T32	Construct clearance, instruction, or message with proper phraseology
	T33	Issue clearance, instruction, or message
	T34	Listen for read back
	T35	Verify correct read back
	T36	Restate clearance, instruction, or message if required
	T37	Listen for read back
	T38	Verify correct read back
	T39	Evaluate situation to determine need for additional communications
	T40	Issue additional clearance, instruction, or message if required
A3	**Manage Flight Plan Data**	
S7	*Entering flight plan data*	
	T41	Receive request for flight plan
	T42	Evaluate flight plan request
	T43	Enter flight plan locally or into NAS as required
	T44	Evaluate flight plan for accuracy
	T45	Issue clearance as appropriate
S8	*Amending flight plan data*	
	T46	Determine the need for an amendment
	T47	Receive request for flight plan amendment
	T48	Enter flight plan changes locally or into NAS
	T49	Review amended flight plan for accuracy
	T50	Update information locally or in the NAS if required
	T51	Ensure other controllers are advised of amendment status
	T52	Request a flight plan amendment
	T53	Receive notice of flight plan amendment status
	T54	Coordinate with others as required
S9	*Managing flight progress strips*	
	T55	Receive flight progress strip
	T56	Request flight progress strip from other facilities
	T57	Evaluate flight progress strip information for accuracy
	T58	Ensure flight progress strip is most current amendment
	T59	Utilize appropriate strip marking
	T60	Resequence flight progress strips
	T61	Update traffic count/status manually
	T62	File flight progress strips when necessary
	T63	File records (e.g., facility log)
	T64	Drop flight plan and track from the NAS
S10	*Processing departure or en route time information*	
	T65	Enter departure or en route time message
	T66	Receive departure or en route time notices
	T67	Monitor departure or en route time notices
A4	**Manage Air Traffic**	
S11	*Establishing and maintaining positive aircraft identification and position*	

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T68	Observe aircraft entering radar coverage area
	T69	Receive request from pilot to verify radar identification
	T70	Observe loss of radar contact
	T71	Inform pilot that radar contact is lost if appropriate
	T72	Identify appropriate radar identification procedure(s)
	T73	Perform appropriate radar identification procedure(s)
	T74	Verify aircraft identification by observing procedure results
	T75	Inform pilot that radar contact has been re-established
	T76	Transfer radar identification
	T77	Verify aircraft leaving sector
S12	*Performing radar separation of aircraft*	
	T78	Review flight plan data
	T79	Verify aircraft is in conformance with flight plan
	T80	Monitor aircraft progress through radar coverage area
	T81	Project mentally an aircraft's trajectory
	T82	Identify potential or actual conflicts
	T83	Establish required separation of aircraft
	T84	Maintain required separation of aircraft
	T85	Determine potential control actions
	T86	Prioritize control actions
	T87	Issue appropriate control instructions
	T88	Verify pilot conformance to instructions
S13	*Performing nonradar separation of aircraft*	
	T89	Request current pilot position report
	T90	Record flight information on flight progress strip
	T91	Track aircraft movement on flight progress strip
	T92	Identify potential or actual conflicts
	T93	Establish required separation of aircraft
	T94	Maintain required separation of aircraft
	T95	Determine potential control actions
	T96	Prioritize control actions
	T97	Issue appropriate control instructions
	T98	Verify pilot conformance to instructions
S14	*Responding to special operations*	
	T99	Receive notice of special operation
	T100	Evaluate impact of the special operation
	T101	Determine appropriate plan of action
	T102	Implement plan of action as required
	T103	Re-evaluate plan of action
	T104	Revise plan of action if required
	T105	Coordinate special operation with others
	T106	Receive notice of termination of special operation
S15	*Processing requests for VFR flight following*	
	T107	Receive request for flight following

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T108	Evaluate conditions for providing flight following
	T109	Approve or deny flight following request
	T110	Enter flight information into the automation locally and the NAS if required
	T111	Ensure correct data entry for flight following requests
	T112	Issue beacon code to aircraft if applicable
	T113	Radar identify the aircraft
	T114	Issue appropriate clearance or control instructions as required
	T115	Ensure compliance with clearance or control instructions as necessary
	T116	Receive request for cancellation of air traffic services
	T117	Acknowledge request
S16	*Providing radar assistance to VFR aircraft*	
	T118	Determine if pilot and aircraft are qualified and capable of IFR flight if appropriate
	T119	Request that the pilot file an IFR flight plan if appropriate
	T120	Receive clearance request from pilot
	T121	Acknowledge pilot request for flight plan
	T122	Query pilot regarding existence of IFR flight plan
	T123	Receive pilot response
	T124	Determine potential control actions
	T125	Prioritize control actions
	T126	Issue the appropriate clearance
	T127	Coordinate with adjacent/affected facilities if applicable
	T128	Receive request for cancellation of air traffic services
	T129	Acknowledge request
S17	*Monitoring uncontrolled objects/aircraft*	
	T130	Observe uncontrolled object/aircraft
	T131	Receive information of uncontrolled object/aircraft
	T132	Initiate track on uncontrolled object/aircraft if appropriate
	T133	Flight-follow uncontrolled object/aircraft if appropriate
	T134	Coordinate with others if appropriate
	T135	Delete track on uncontrolled object/aircraft if appropriate
S18	*Responding to pilot requests for flight path deviation*	
	T136	Receive pilot request to deviate
	T137	Evaluate pilot request for deviation
	T138	Determine alternative clearance if required
	T139	Issue appropriate control instructions if required
	T140	Coordinate deviation with the next controller if required
S19	*Responding to aircraft nonconformance*	
	T141	Observe aircraft nonconformance
	T142	Receive notice of aircraft nonconformance from others
	T143	Inform other controller of nonconformance in that controller's position or sector
	T144	Query pilot operator about intentions
	T145	Determine appropriate action to resolve nonconformance
	T146	Issue appropriate control instructions to correct aircraft nonconformance
	T147	Issue advisory or alert if required

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T148	Verify compliance with instructions
	T149	Inform supervisor of nonconformance and if necessary of violation
A5	**Resolve Conflicts**	
S20	*Performing aircraft conflict resolutions*	
	T150	Identify potential or actual loss of separation
	T151	Receive notice of potential or actual conflict
	T152	Inform other controller of potential or actual conflict in that controller's position or sector
	T153	Observe aircraft conflict alert indication
	T154	Evaluate validity of the potential or actual aircraft conflict
	T155	Determine appropriate action to resolve conflict situation
	T156	Issue appropriate control instructions to ensure separation
	T157	Verify pilot conformance with instructions
	T158	Suppress conflict alert if appropriate in accordance with procedures and directives
	T159	Issue advisory or safety alert as appropriate
	T160	Inform pilot when traffic no longer a factor
	T161	Report loss of separation as appropriate
	T162	Restore conflict alert function to normal
S21	*Performing unsafe altitude resolutions*	
	T163	Identify potential or actual unsafe altitude situation
	T164	Detect MSAW indication/alarm
	T165	Receive notice of potential or actual unsafe altitude situation
	T166	Inform other controller of unsafe altitude situation in that controller's position or sector
	T167	Determine validity of unsafe altitude/MSAW notice or indication
	T168	Determine appropriate action to resolve unsafe altitude situation
	T169	Issue appropriate control instructions to resolve unsafe altitude situation
	T170	Suppress MSAW function if appropriate in accordance with procedures and directives
	T171	Issue advisory or safety alert as appropriate
	T172	Restore MSAW function to normal
S22	*Performing airspace violation resolutions*	
	T173	Identify potential or actual airspace violation
	T174	Receive notice of potential or actual airspace violation
	T175	Inform other controller of airspace violation in that controller's position or sector
	T176	Determine the validity of airspace violation
	T177	Determine appropriate action to resolve airspace violation
	T178	Issue appropriate control instructions to ensure separation
	T179	Issue advisory or alert as appropriate
	T180	Report airspace violation as appropriate
S23	*Issuing unsafe condition advisories*	
	T181	Determine need for advisory or alert
	T182	Generate advisory or alert appropriate for situation
	T183	Issue advisory or alert as appropriate
	T184	Monitor response to advisory or alert
	T185	Cancel advisory or alert when situation returns to normal

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
A6	**Manage Traffic Flows and Sequences**	
S24	*Managing departure flows and sequences*	
	T186	Receive request for release of departure aircraft
	T187	Receive notice of missed approach/go around
	T188	Verify departure route via automation and/or flight progress strip
	T189	Issue appropriate clearance with restrictions if required to establish departure flow
	T190	Approve departure release with restrictions if required
	T191	Radar identify the aircraft
	T192	Ensure that the correct flight plan information is in the NAS
	T193	Perform the action required to associate data block with the aircraft if required
	T194	Determine sequence within departure flow
	T195	Issue appropriate control instructions to establish or maintain departure sequence
	T196	Re-evaluate traffic sequence
	T197	Issue appropriate revised control instructions if required
S25	*Managing arrival flows and approach sequences*	
	T198	Observe radar target/data block/flight progress strip of arrival aircraft
	T199	Receive notification of scheduled arrival
	T200	Receive pilot request for unscheduled Class D, B, C and E operations
	T201	Ensure coordinated arrival routing
	T202	Accept transfer of radar identification
	T203	Verify pilot has current arrival information
	T204	Issue current arrival information if required
	T205	Determine arrival sequence
	T206	Issue appropriate control instructions to implement approach sequence
	T207	Re-evaluate traffic sequence
	T208	Issue appropriate revised control instructions if required
	T209	Update automation and/or flight progress strip
	T210	Coordinate with adjacent sectors as required
S26	*Responding to traffic management initiatives*	
	T211	Receive information regarding traffic management initiative
	T212	Discuss impact of traffic management initiative with supervisor
	T213	Evaluate traffic management initiative for effect on traffic flow
	T214	Develop options for bringing the aircraft into conformance with traffic management initiative
	T215	Determine appropriate action to bring aircraft into conformance with traffic management initiative
	T216	Advise pilot of a traffic management initiative if necessary
	T217	Coordinate with local Traffic Management Unit (TMU) and/or Air Route Traffic Control Center (ARTCC) as necessary
	T218	Issue appropriate control instructions to comply with traffic management initiative
	T219	Verify compliance with instructions by pilot and other facilities
	T220	Revise plan if necessary
	T221	Receive notice of cancellation of traffic management initiative
	T222	Coordinate cancellation of traffic management initiative with others

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
A7	**Transfer of Radar Identification**	
S27	*Initiating handoffs*	
	T223	Receive request for transfer of radar identification
	T224	Determine need for transfer of radar identification
	T225	Ensure all conflicts are resolved
	T226	Initiate automated handoff
	T227	Initiate manual handoff
	T228	Receive manual handoff acceptance
	T229	Receive automated handoff rejection message
	T230	Retract handoff if required
	T231	Coordinate restrictions with receiving controller as necessary
	T232	Issue appropriate control instructions as required
	T233	Observe handoff acceptance
	T234	Issue appropriate control instructions to redirect aircraft from airspace as required
S28	*Accepting handoffs*	
	T235	Observe automated handoff request
	T236	Receive a request for manual handoff
	T237	Determine response to handoff request
	T238	Coordinate restrictions with initiating controller as necessary
	T239	Accept handoff
	T240	Deny handoff
	T241	Receive control of aircraft according to Letter(s) of Agreement (LOAs) and Standard Operating Procedures (SOPs)
S29	*Issuing pointouts*	
	T242	Identify need for pointout
	T243	Initiate automated pointout
	T244	Initiate manual pointout
	T245	Receive approval of pointout with restrictions if required
	T246	Adhere to restrictions if required
	T247	Receive rejection of pointout
	T248	Issue appropriate control instructions to remain clear of airspace if rejected
	T249	Initiate handoff if rejected
S30	*Responding to pointouts*	
	T250	Receive automated pointout request
	T251	Receive manual pointout request
	T252	Initiate automated track of aircraft as necessary
	T253	Ensure target data block correlation
	T254	Determine response to pointout
	T255	Approve pointout with restrictions
	T256	Deny pointout
	T257	Declare radar contact
	T258	Suppress automated track after pointout is no longer a factor
A8	**Assess the Impact of Weather**	
S31	*Processing weather information*	

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T259	Review graphical weather information
	T260	Review text based weather information
	T261	Determine whether airport is IFR or VFR
	T262	Receive notice of runway or airport condition changes
	T263	Receive runway condition/use data
	T264	Forward runway condition/use data
	T265	Monitor available airport-related equipment malfunctions (RVR wind and altimeter)
	T266	Receive weather reports
	T267	Request weather reports
	T268	Forward weather reports
	T269	Receive notice of faulty airport environmental sensor
	T270	Forward reported outages of airport environmental sensor
	T271	Review displayed weather information
S32	*Responding to severe weather information*	
	T272	Observe radar or satellite display of severe weather intensity and trend
	T273	Solicit PIREPS as required
	T274	Request weather information from others
	T275	Receive request for weather information
	T276	Receive weather information (e.g., SIGMETs)
	T277	Disseminate weather information as appropriate
	T278	Evaluate severe weather impact on routes or flow
	T279	Determine altitude or route change to avoid severe weather
	T280	Issue appropriate control instructions to bypass severe weather
	T281	Inform supervisor or traffic management coordinator of weather impact on routes or flow
	T282	Receive new routing for weather avoidance from supervisor or traffic management coordinator
A9	**Manage Airspace**	
S33	*Requesting temporary release of airspace*	
	T283	Determine that the use of another controller's airspace is needed
	T284	Request the use of airspace
	T285	Receive approval including conditions if any for the use of airspace
	T286	Issue appropriate control instructions
	T287	Return airspace when no longer needed
	T288	Receive rejection
S34	*Responding to requests for temporary release of airspace*	
	T289	Receive request for temporary use of airspace
	T290	Observe affected traffic
	T291	Evaluate feasibility of temporarily releasing airspace
	T292	Release airspace with conditions as appropriate
	T293	Issue appropriate control instructions
	T294	Receive notification that released airspace is returned
	T295	Change automation associated with temporary use of airspace
S35	*Responding to changes in airspace status*	
	T296	Receive notice of the change in status of airspace

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T297	Coordinate change in status of airspace with others
	T298	Coordinate airspace restrictions with others
	T299	Change automation to reflect the change in airspace status
	T300	Determine appropriate actions to ensure separation from airspace
	T301	Issue appropriate control instructions
	T302	Ensure status information areas are updated
	T303	Receive notice that restriction is terminated
	T304	Inform others that restriction is terminated
	T305	Discontinue use of visual aids/memory joggers
S36	*Transferring position/sector for reconfiguration*	
	T306	Advise receiving controller to prepare for position/sector reconfiguration
	T307	Give briefing to the receiving controller taking the airspace
	T308	Verify that the receiving controller has necessary settings for communication system and automation system
	T309	Configure communication and automation system to reflect changes
	T310	Adjust display for the new configuration
S37	*Receiving position/sector for reconfiguration*	
	T311	Receive notice to prepare for sector or position reconfiguration
	T312	Adjust display for the new configuration
	T313	Configure communication and automation system to reflect changes
	T314	Receive briefing from the controller relinquishing the airspace
	T315	Determine if ready to accept position responsibility
	T316	Assume control of position/sector
A10	**Manage Resources**	
S38	*Managing personal and position workload*	
	T317	Ensure fitness for duty
	T318	Identify current or potential overload situations
	T319	Identify potential overload reduction strategies
	T320	Inform supervisor of current or potential overload
	T321	Request assistance if required
	T322	Implement overload reduction strategy as appropriate
	T323	Receive supervisor notice of implementation of overload reduction strategy
S39	*Supporting teamwork environment*	
	T324	Participate in training and other professional development activities
	T325	Maintain TRACON facility awareness
	T326	Inform supervisor of important situations
	T327	Offer assistance if required
A11	**Respond to Emergencies and Unusual Situations**	
S40	*Responding to emergencies*	
	T328	Receive notice of emergency
	T329	Detect an emergency
	T330	Evaluate the situation
	T331	Determine appropriate plan of action

TRACON Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-Activity (S-italics)* Task (T)		
	T332	Respond to emergency as required
	T333	Review emergency checklist
	T334	Declare emergency if necessary
	T335	Amend traffic flow and sequence to expedite emergency aircraft
	T336	Coordinate emergency information with others
	T337	Re-evaluate plan of action
	T338	Revise plan of action if required
	T339	Report emergency declared and action taken to supervisor
S41	*Responding to unusual situations*	
	T340	Detect unusual situation
	T341	Receive notice of unusual situation
	T342	Evaluate situation
	T343	Report situation to supervisor
	T344	Determine the appropriate plan of action
	T345	Issue required security notifications immediately if necessary
	T346	Comply with security notifications and/or coordination as required
	T347	Implement plan of action
	T348	Re-evaluate situation
	T349	Revise plan if appropriate
	T350	Implement revised plan
	T351	Coordinate information with others as appropriate
S42	*Responding to system/equipment degradation or failure*	
	T352	Detect degradation or failure
	T353	Receive notice of degradation or failure
	T354	Coordinate degradation or failure information with others
	T355	Initiate backup system if appropriate
	T356	Implement backup procedures
	T357	Initiate nonradar separation procedures if required
	T358	Coordinate with others regarding repair if required
	T359	Receive notice of return to service
	T360	Verify accuracy of system data
	T361	Resume normal operations
	T362	Notify others of return to normal operations

TRACON ATCS Knowledges

ATCS Knowledges for TRACON		
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
K8	Knowledge of Basic Weather Concepts	
	K8.1	Atmospheric properties
	K8.2	Sources of weather information
	K8.3	Weather terminology

ATCS Knowledges for TRACON		
	K8.4	Weather features
	K8.5	Weather data interpretation
	K8.6	Impact on operations
	K8.7	Impact on flight/aircraft
	K8.8	Pilot Report (PIREP) solicitation requirements
	K8.9	Weather information recording
	K8.10	Weather information dissemination requirements
	K8.11	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	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	Services and equipment
	K13.3	Types of airport lighting
	K13.4	Noise abatement concepts
	K13.5	Types of obstructions/obstacles
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	

ATCS Knowledges for TRACON		
	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 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	Facility traffic flows
	K18.18	Areas with high potential for confliction (hot spots)
	K18.19	Facility specific directives and procedures
	K18.20	Airspace coordination procedures
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 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

ATCS Knowledges for TRACON		
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	Nonparticipating aircraft
	K23.7	Tower en route control service
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	Continual descent approach (CDA)/Optimized Profile Descent(OPD)
	K24.10	Practice approaches
	K24.11	Arrival sequence
K25	Knowledge of Departure Operations	
	K25.1	Departure sequence
	K25.2	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

ATCS Knowledges for TRACON		
	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.

TRACON Tools and Equipment

No	Category	Full Name	Acronym	Description
TE1	Automation	Automated Radar Tracking System/Common Automated Radar Tracking System/Standard Terminal Automation Replacement System	ARTS/CARTS/STARS	▪ ARTS/CARTS/STARS is the primary radar automation system for TRACON controllers. These systems consist of both hardware and software components. Depending on facility type these systems pull primary and secondary radar information from airport surveillance radar and flight plan data from the Host computer, which resides at the ARTCC facility. ▪ Controllers use the system to track airborne aircraft. It provides critical operational information about aircraft positions, flight data, and weather. It detects unsafe proximities between tracked aircraft pairs and provides warning if tracked aircraft are detected at a dangerously low altitude. Some facilities may have an additional function called the converging runway display aid (CRDA). CRDA is a software-based potential conflict resolution tool that enables approach controllers to run two final approaches that intersect to identify potential conflicts. These features display "ghost" targets as an aid to controllers attempting to tightly space aircraft in the terminal environment. ▪ The controller monitors the radar display for aircraft information. Depending on the facility and the type of system, controllers will have ARTS Color Display (ACD), Fully Digitized Automated Display (FDAD), or Terminal Controller Workstation display. Controllers may input data or change references via a keyboard or trackball. ▪ ARTS is the oldest version of the automation system and STARS is the newest version. CARTS has replaced ARTS in some facilities, and STARS has replaced CARTS or ARTS at other facilities. Current plans are for ARTS and CARTS to all be replaced with a new and improved version of STARS.
TE2	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.

No	Category	Full Name	Acronym	Description
TE3	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.
TE4	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 TRACON 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, TRACONS 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 ETVS/RDVS 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.
TE5	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 sector (airspace for tower). 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
TE6	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. The controller is 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/ETVS. 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.
TE7	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 TRACON controllers' situation awareness by providing information regarding many relevant parameters in a single display. The display is located in the vicinity of the controller's workstation 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.
TE8	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
TE9	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.
TE10	Information Management	Overhead Charts	Charts	▪ Overhead charts are aeronautical charts that are positioned above the controller's workstation to show the boundaries of that facility's airspace, individual sector boundaries, NAVAIDS, routes, waypoints, reporting points, and points of interest in that airspace. This information may be contained in IDS and not displayed as an overhead chart. These charts are updated every 56 days. ▪ These charts provide basic information about the airspace and operations to the controller. ▪ Controllers periodically view the overhead charts for information.
TE11	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 NAVAID 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.

Appendix B: Potential Risks

Potential Risk to TRACON Driver Matrix

	TRACON Drivers									
Potential Risks	4-D Wx Data Cube	ADS-B Out	FAM	Big Airspace	IADS	OPD	PBN	TAMR 3	WTMA	**# of Drivers Affected**
Best Equipped, Best Served		●				●	●			**3**
Change in Culture									●	**1**
Coordination of Multiple Stakeholders		●								**1**
Deficiencies in Technology		●					●		●	**3**
Degradation or Failure of Equipment or Systems	●	●			●	●	●	●	●	**7**
Improper Allocation of Tasks to Automation						●	●			**2**
Improper Reliance on Automation or Procedures	●		●			●	●		●	**5**
Lack of/Inadequate Training	●	●	●	●	●	●	●	●	●	**9**
Mixed Aircraft Equipage		●				●	●			**3**
Mixed ATC Tools, Equipment, or Procedures	●		●	●	●					**4**
More Dynamic Work Environment			●			●	●		●	**4**
Poor Computer-Human Interface Design	●	●			●			●	●	**5**
Reduced Separation Minima		●							●	**2**
Skill Decay	●	●			●	●	●	●	●	**7**
Technology Development and Maturation	●	●	●	●	●	●	●	●	●	**9**
# of Risks Cited per Driver	**7**	**10**	**5**	**3**	**6**	**9**	**10**	**5**	**10**	

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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