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JOB DESCRIPTION FOR THE NEXTGEN MID-TERM ARTCC CONTROLLER

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

30 SEPTEMBER 2011

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Acknowledgements

The American Institutes for Research (AIR) thanks Dino Piccione, Technical Lead for Human Factors Air Traffic/Technical Operations Research, and Barbara L. Wilper, Scientific and Technical Advisor for Human Factors, both of the Federal Aviation Administration's (FAA) Human Factors Research and Engineering Group. In addition to sponsoring this research, they provided significant technical guidance and support.

Managers from the FAA's Air Traffic Technical Training and Oversight group also assisted. Greta Ballard, Daniel Lacroix, Gregory Sanders, and Mark Marchese procured both information and access to subject matter experts (SMEs) and participated in focus groups and other reviews.

Numerous other individuals made significant contributions. In particular, NextGen and air traffic control SMEs from the FAA, the National Air Traffic Controllers Association (NATCA), and numerous contracting organizations participated in interviews that informed the ideas presented.

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 Air Route Traffic Control Center (ARTCC) 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 ARTCC-specific NextGen technologies, automation, and procedures (i.e., Drivers) that are proposed to exist in 2018. The result is this description for the ARTCC 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 an ARTCC 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 ARTCC environment is based on the NextGen technologies, automation, and procedures (i.e., NextGen ARTCC Drivers) that will have an impact on the job responsibilities, KSAOs, and the work environment more generally.

NextGen ARTCC Drivers

AIR identified 10 primary NextGen technologies, automation, and procedures—or NextGen Drivers—that will influence the ARTCC work environment in 2018:

- 4-Dimensional Weather Data Cube (4-D Wx Data Cube)
- Automatic Dependent Surveillance-Broadcast Out (ADS-B Out)
- Conflict Resolution Advisories (CRAs)
- Data Communications (Data Comm)
- Flexible Airspace Management (FAM)
- High Altitude Airspace
- Integrated Arrival/Departure Air Traffic Control Service (also known as Big Airspace)
- Initial Tailored Arrivals (ITAs)
- Performance-Based Navigation (PBN)
- Time-Based Flow Management (TBFM)

Although at least some of these Drivers do not require satellite-based technology, they are in many cases more recently being supported directly or indirectly by satellite technology. However, they will not affect all ARTCC facilities equally. For example, ITAs are performed only in oceanic airspace and will affect the job of controllers working in facilities that manage this type of airspace. Note that AIR was compelled—*by necessity*—to make certain assumptions regarding these Drivers to determine their impact on the job. These assumptions are described in detail in this report.

New NextGen ATCS Role

The impact of the implementation of ARTCC Drivers includes the creation of a new ATCS role. High Altitude Airspace creates generic high altitude airspace sectors that will be managed by controllers who will have substantively different roles and responsibilities than ARTCC line controllers working more traditional ARTCC sectors. This new role will require a controller with a different set of KSAOs.

NextGen ARTCC Tasks

AIR's analysis suggests that the 10 ARTCC 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 352 current ARTCC job Tasks (see Appendix A for a full list). These changes include the following:

- Addition of 13 Tasks across three Drivers.
- Deletion of 97 Tasks across two Drivers. However, 91 of those deletions will be the result of the implementation of High Altitude Airspace and will apply only to controllers working in the new ATCS managing generic high altitude airspace.
- Modification of 15 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.

The 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 ARTCC Task list, there will be a number of changes regarding *how* the job Tasks in that list are performed. The 10 Drivers influence between 4 and 98 Tasks each, with many Tasks being affected by more than 1 Driver. Based on the number of Tasks affected, the implementation of 4-D Wx Data Cube, Data Comm, and High Altitude Airspace—which affect 53 or more Tasks each—will arguably effect the most change: 4-D Wx Data Cube will affect 70 Tasks in 9 out of 11 ARTCC job Activities; Data Comm will affect 53 Tasks across 10 out of 11 Activities; and High Altitude Airspace will affect 98 Tasks across all 11 Activities. However, recall that the implementation of High Altitude Airspace creates a new ATCS role associated with managing the generic high altitude portion of this airspace; these changes will occur because controllers in this role will have fewer responsibilities.

Net Impact of NextGen on ARTCC Tasks

A summative evaluation of the detailed impacts by Driver as described in Section V of this report suggests that there are several net effects of the NextGen technologies, automation, and procedures on the Tasks of the ARTCC controller. First, controllers will use more automation than ever before. They will use new procedures to perform their work. These new tools and procedures will give them access to more information, and also to more accurate information, which will improve their situation awareness and decision making. For example, the implementation of 4-D Wx Data Cube will give controllers 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 ARTCC Drivers, but the net effect will be an increase in efficiency for controllers. This will lead to improvements in the efficiency of operations throughout the National Airspace System (NAS). 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 change 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 ARTCC KSAOs

In addition to having an impact on job Tasks, the 10 ARTCC NextGen Drivers will also affect the requirements of individuals who perform the ATCS job. However, as with the job Tasks, the list of currently required KSAOs will change relatively little (see Appendix A). The following changes will occur:

- Addition of
  - two new Knowledges across multiple Drivers;
  - one new Skill across multiple Drivers; and
  - one new Other Personal Characteristic across multiple Drivers.
- Deletion of 37 Knowledges in one Driver. Note that this deletion applies only to controllers managing generic high altitude airspace; because they are still required for all other controllers, they will be deleted from the Knowledge list for the Generic High Altitude Airspace (GHAA) controllers but retained on the ATCS Knowledge list.
- Modification of one Knowledge in one Driver and one Skill in two Drivers.

As with the Tasks, part of the reason for the lack of impact of the Drivers on the KSAOs is due partly to the characteristics of the Drivers themselves and partly to how the KSAOs are written. For example, the 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 10 ARTCC Drivers do have a significant impact on various properties of existing KSAOs. More specifically, the training curriculum required to teach the Knowledges and Skills associated with the Drivers will need to change. In addition, some KSAOs will be used more or less often or will otherwise become more or less important as a result of the implementation of a NextGen Driver(s).

The 10 Drivers influence the properties of between 20 and 70 KSAOs each, with many KSAOs being affected by more than 1 Driver. Based on the number of KSAOs affected, Data Comm, High Altitude Airspace, and PBN—which affect 44 or more KSAOs each—will arguably effect the most change. Data Comm affects 59 KSAOs, High Altitude Airspace affects 70 KSAOs, and PBN affects 44 KSAOs. For example, the implementation of Data Comm means that controllers will need to be taught new course content regarding the new communication system architecture. The implementation of High Altitude Airspace creates a new role for an ATCS working the generic high altitude portion of this airspace. These controllers will be responsible for fewer air traffic services. For example, controllers managing GHAA will not need to know procedures associated with visual flight rules (VFR) flight, and they will not need to be skilled in providing these services because VFR operations will not take place in this airspace. Finally, the implementation of PBN operations reduces the use of abilities associated with verbal communication and coordination because aircraft engaged in these operations can self-monitor their conformance to highly prescribed routes and thus require less interaction with controllers.

Net Impact of NextGen on KSAOs Required of ARTCC Controllers

A summative evaluation of the detailed impacts by Driver as described in Section V of this report suggests that there are several net effects of the NextGen technologies, automation, and procedures on the KSAOs required of ARTCC 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.

ARTCC Drivers will have a more limited net impact on the Abilities and Other Personal Characteristics required of ARTCC controllers. No new Abilities are required, and only one new Other Personal Characteristic is required (i.e., being comfortable using technology). Instead, the Drivers increase or decrease the frequency of use or importance of Abilities and Other Personal Characteristics. 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 ARTCC NextGen Drivers. More specifically, several Drivers either reduce the need for communications directly (i.e., Data Comm) or otherwise create shared situation awareness through the sharing of information (i.e., 4-D Wx Data Cube; FAM, ITAs, PBN), thus reducing the need for abilities that support verbal communication.

Another net impact is that the job of the ARTCC 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 and to mixed aircraft equipage. The change will also occur because some ARTCC 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. Data Comm requires controllers to switch between using voice and data communications. ADS-B Out and Data Comm are implemented onboard only some aircraft, and PBN operations and ITAs can be performed only 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 that they are in control, not the automation.

Potential Risks

NextGen adds new technologies, automation, and procedures to the 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 ARTCC Drivers in the mid-term 2018 (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), and new work environment (e.g., more dynamic work environment) to 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 range is 3 to 12, with Big Airspace having only 3 identified risks. Data Comm has the most associated risks, with 12. Similarly, the 19 risks have a differential impact, with some being associated with only a few Drivers and others with many Drivers. The number of Drivers ranges from 1 to 10; Loss of Party Line Information is associated with only 1 Driver (i.e., Data Comm) and Lack of/Inadequate Training and Technology Development and Maturation is associated with all 10 ARTCC Drivers.

Net Impact of ARTCC NextGen Drivers
In summary, although 19 is a substantial number of risks, 3 represent the primary potential threats to safety and efficiency of the NAS: (a) lack of/inadequate training, (b) improper design or implementation of technologies, and (c) mixed aircraft equipage. All NextGen Drivers require that developmental and Certified Professional Controller (CPC)–level ATCSs receive training and practice on Knowledges and Skills. Even though the impact of some ARTCC Drivers is very limited (e.g., ITAs apply only to facilities that manage Oceanic airspace; Big Airspace applies only to ARTCCs that overlie metroxplex airspace), this will still create a substantive impact on the FAA overall. In addition, if controllers do not receive, or do not implement the training they do receive, they will perform less efficiently, they will be more likely to make errors, and the benefits the Drivers were intended to create will not be realized.

The improper design of technology includes both the design of the hardware and software components that must work reliably and in concert with other NAS components and the design of the human interface. If either 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 on, 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

The implementation of ARTCC NextGen Drivers will result in several outcomes. First, the lines between controllers working at different facilities will be blurred in 2018 owing to the implementation of Drivers such as Big Airspace and TBFM. 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 the controllers' workload. Similarly, trajectory-based operations, such as those that will result from TBFM, require controllers to work to ensure that aircraft meet more arrival times along their route, thus requiring controllers to be more precise and timely in their judgments and actions. While increasing efficiency in the NAS overall, these changes may increase the 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 CRA and TBFM. 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 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 that 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 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 the recurrent training that will be required to support NextGen in 2018; enhancing the current job analysis by conducting research to identify ATCS training, supervisory, and Oceanic responsibilities; and developing 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. 108-176) establishing and empowering the Joint Planning and Development Office (JPDO) to lead a combined public-private initiative titled the Next Generation Air Transportation System (NextGen). By leveraging existing and new technology, including satellite-based surveillance and navigation, NextGen is intended to support significant increases in capacity and 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 Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs) required of line controllers to perform the job will help inform whether and how the pre-employment selection process should be modified. Similarly, identifying potential changes to the job will help identify whether and how training should be changed. This vision of the NextGen mid-term job is being developed in advance of the implementation of the NextGen technologies, automation, and procedures that will be the impetus for the job changes. This timing 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 (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. For example, AIR reviewed the NextGen Concept of Operations (U.S. Department of Transportation, 2010a) and Operational Improvements (U.S. Department of Transportation (2010b). AIR also conducted 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 technologies, automation, and procedures is complex and ongoing. In addition, the work requires the coordination and cooperation of a large and diverse group of stakeholders and a substantial financial investment. Consequently, the information in deliverables must be based on information available at the time. It is fully expected that the information in any given report or deliverable will need to be modified as the NextGen technologies, automation, and procedures mature and are implemented.

STRUCTURE OF THE REPORT

This report captures the job description of ATCSs working in 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 ARTCC 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 ARTCC 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 ARTCC. The Drivers are critical in that they provide the

[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.

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

- *Characteristics of NextGen ARTCC 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) approach to developing a description of the line controller job for the Next Generation Air Transportation System (NextGen) mid-term Air Route Traffic Control Center (ARTCC) environment was to conduct a strategic job analysis. Whereas a traditional job analysis involves gathering information from job incumbents, a strategic job analysis requires a different process because job incumbents do not yet exist (Schippmann, 1999). Instead, the strategic job analysis typically involves gathering information from policy experts and other subject matter experts (SMEs) to develop a concept of the job (Schneider & Konz, 1989). For this analysis, AIR collected, reviewed, and synthesized data and then used the resulting knowledge to project the impact of the changes to the job.

DATA COLLECTION

AIR began by evaluating four primary sources of information:

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

Each source 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 lists of Knowledges and Abilities. However, those lists were simply reproduced as a courtesy to the reader from their original sources, which were the Computer Technologies Associates (CTA) assessment (Ammerman, Fairhurst, Hostetler, & Jones, 1989) and the Separation and Control Hiring assessment (SACHA; Nickels, Bobko, Blair, Sands & Tartak, 1995), respectively; they were not vetted by SMEs as part of the 2007 research. Neither a full list of Skills nor a list of Tools and Equipment existed. To complete the current research, AIR needed comprehensive, current, vetted, and separate lists of Activities, Sub-Activities, Tasks; Knowledges, Skills, Abilities, and Other Personal Characteristics (KSAOs); and Tools and Equipment. Consequently, AIR developed drafts of these documents (if draft versions did not exist) and worked with SMEs to edit them.

AIR gathered input from SMEs who are experts in the job to ensure that 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, who is also a human factors researcher and a pilot.

The edits to the job Activities, Sub-Activities, and Task lists did not result in substantive changes to the core ATCS job responsibilities. However, the lists were reorganized to be more logical; reordered where appropriate to more closely follow the temporal sequence of the job; reworded to be more consistent with today's air traffic control culture; and edited to follow the proper format. The edits to the KSAO and Tool and Equipment lists were more substantive. The existing Knowledge list had not been updated since the late 1980s. There was no list of Tools and Equipment, and the existing Abilities list combined 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 among the lists. That is, AIR ensured 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 Air Traffic Control Specialist (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 to develop the vision for the job as it will exist in 2018. This substantive research process comprised several steps. First, AIR reviewed the available NextGen documentation, including the Federal Aviation Administration's (FAA) 2009 and 2010 NextGen Concept of Operations; multiple iterations of the Operational Improvements (OIs); the FAA's 2009 and 2010 NextGen Implementation Plans; RTCA's 2009 NextGen Mid-Term Implementation Task Force Report and the FAA's Response to it; and many others as identified in Appendix C. These documents helped AIR understand the FAA's goals and priorities for the implementation of NextGen automation systems, the benefits associated with each, and the implementation timeline of the technologies, automation, and procedures.

Despite the informative nature of the NextGen documentation, these documents captured NextGen at a high level and did not contain the detailed information needed to build a vision for how the job of the ATCS would change. For example, AIR needed information 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 included senior NextGen engineers and policymakers. The job titles of the SMEs who participated can be found in Table 1.

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

Job Title
Chief System Engineer of Terminal
Air Traffic Control Subject Matter Expert, FAA Contractor
Director NextGen Facilities, NextGen & Operations Planning
NextGen Automation Integration Manager, NextGen & Operations Planning
National Air Traffic Controllers Association (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 staff traveled to the FAA's William J. Hughes Technical Center in Atlantic City. The goals of the site visit were to interview additional NextGen automation experts and air traffic controllers and to view demonstrations of ongoing human factors evaluations of air traffic control (ATC) equipment. AIR's first visit took place in May 2010 and included interviews with five human factors and air traffic control experts. AIR's second visit occurred in July 2010 and included interviews with two additional SMEs. The job titles of these seven SMEs are shown in Table 2.

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

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

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

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 and the effects of the loss of party line information associated with the use of Data Communications (Data Comm).

Data Synthesis and Projection

The analysis of the current job, NextGen documents, SME interviews, and academic literature yielded a large volume of information regarding NextGen and the job of the ATCS. Once these data collection steps were completed, the next step was to synthesize and consolidate 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, including questions concerning the

- mapping of NextGen information to facility type;
- comprehensiveness of the draft list of Drivers;
- differences in ARTCC facilities;
- conceptualization of the future job; and

- presentation of job changes.

AIR addressed these challenges with the solutions described next.

Map NextGen Information to Facility Type

First, it was unknown how the NextGen information collected mapped onto the three facility types: ATCT, TRACON, and ARTCC. That is, not every concept discussed in the NextGen Concept of Operations (ConOps) or the OIs or identified in the SME interviews is relevant to every facility type. Unfortunately, with one exception, the NextGen documents reviewed by AIR job analysts did not specify which facility types 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 a release of the OIs older than the November 2010 version being used by AIR. Given the highly evolving nature of NextGen, AIR conducted an internal exercise in January 2011 to map the OIs to facility type.

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

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

OI No.	OI Name
102108	Oceanic In-trail Climb and Descent
102114	Initial Conflict Resolution Advisories
102118	Delegated Responsibility for In-Trail Separation
102137	Automation Support for Separation Management
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
104102	Flexible Entry Times for Oceanic Tracks
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
105208	Traffic Management Initiatives with Flight Specific Trajectories

OI No.	OI Name
106202	Enhance Emergency Alerting
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

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 ARTCC environment. This list of ten NextGen Drivers included the following:

- 4-Dimensional Weather Data Cube (4-D Wx Data Cube)
- Automatic Dependent Surveillance-Broadcast (ADS-B)
- Conflict Resolution Advisories (CRA)
- Data Communications (Data Comm)
- Flexible Airspace Management (FAM)
- High Altitude Airspace
- Initial Tailored Arrivals (ITAs)
- Integrated Arrival/Departure Air Traffic Control Service (Big Airspace)
- Performance-Based Navigation (PBN)
- Time-Based Flow Management Program (TBFM)

To ensure that this list of Drivers was comprehensive, AIR researchers independently assigned these Drivers to the OIs identified for the ARTCC environment and then reconvened and discussed them to reach consensus. With one exception, the results suggested that the list of Drivers was complete (i.e., AIR's ARTCC Drivers were mapped onto at least one OI) with one exception. The High Altitude Airspace concept did not have an OI associated with it as of November 2010, most likely because the concept does not require the addition of new tools or automation. Note that one OI, OI #102118 (*Delegated Responsibility for In-Trail Separation*), will require Automatic Dependent Surveillance-Broadcast In (ADS-B In), but this system will not be widely available by 2018. Finally, OI #105302 (*Continuous Flight Day Evaluation*) does not have an ARTCC Driver associated with it. AIR assumes that this is because the analysis required to support strategic *Continuous Flight Day Evaluation* will be the responsibility of FAA system engineers, not line controllers. However, if controllers will be required to contribute to this improvement, this responsibility needs to be defined.

Account for Differences in ARTCC Facilities

As discussed in Section I, the primary impetus for the NextGen initiative is to increase the capacity and efficiency of the National Airspace System (NAS). Additional benefits include reduced environmental impact and noise. Although these benefits are relevant for all ARTCCs, ARTCCs will be affected differentially. Some Drivers will have an impact on only a subset of ARTCCs. For example, Initial Tailored Arrivals are planned only for ARTCC sectors that manage Oceanic air traffic because these specialty continuous descent paths are confined to sectors where incoming aircraft and the responsible line controller must both have equipment that is not standard. Consequently, AIR presumed at this stage that NextGen mid-term Drivers would affect the work environment at ARTCC facilities—and hence controllers working in those facilities—disproportionately. On the basis of this observation, AIR decided to, where appropriate, describe in the report which facility types (e.g., ARTCCs responsible for Oceanic airspace) would most likely be affected by the NextGen technologies, automation, and procedures. Note that this differential impact is less pronounced than it is for ATCTs and TRACONs, which are more numerous and more diverse.

Conceptualize the Future Job

AIR's research plan for developing the concept of the future job involved combining the newly gathered NextGen information 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 ARTCC 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 ARTCC NextGen Driver would require adding to, deleting, 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, a Sub-Activity, or a 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 independent rating exercises, they met to discuss their 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 ARTCC NextGen Job Description.

Present the Job Changes

A final concern surfaced regarding the presentation of the synthesized data. AIR researchers had originally planned to describe the future job by following the hierarchy used for describing the current ARTCC 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 ARTCC 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., *A5-Resolve Conflicts*). Consequently, the team decided 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 November 2010, much of the documentation was still written in very high level terms. AIR's data collection, review, and synthesis processes described above were designed to operationalize those ideas. This process ultimately resulted in a list of NextGen Drivers that are likely to affect the job of the ARTCC 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 in Section III to help readers familiarize themselves with the structure because it is also used to organize information about the job as it will exist in the NextGen mid-term.

Section III. Characteristics of Current ARTCC Work and Workers

In this section of the report, the American Institutes for Research (AIR) describes the job of the Air Route Traffic Control Center (ARTCC) 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 job analytic data). Understanding this organizational structure is essential for interpreting the NextGen 2018 Job Description (see Section V) because the description is organized similarly.

CURRENT ARTCC JOB CHARACTERISTICS

As previously stated, ATCS work that is currently performed in the ARTCC environment is captured in a 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 ARTCC 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 ARTCC Activity 1: Establish Situation Awareness

Activity 1 for ARTCC line controllers describes the responsibility to achieve and maintain optimal situation awareness about activities that either are taking place or will take place in their assigned area(s) of responsibility. Situation awareness begins before controllers accept responsibility for the control position, is maintained throughout their position assignment, and ends when they are relieved by another controller.

As ARTCC line controllers begin working their assigned positions, they must relieve other controllers who are responsible for positions. During this period, the relieving controller must become thoroughly familiar with the current status of the airspace for which he or she will be responsible. Controllers will access current and predicted operational information by using status and information areas (SIAs), position relief checklists, sign-in logs, and information contained on alphanumerical data blocks. During their working period, controllers will continue to monitor the airspace surveillance radar system flight strips and weather data systems. This information will also be passed along to the relieving controller during the relief briefing. The relieving controller will then use the previously gathered/updated information and incorporate it into his or her position relief briefing using recorded lines, position checklists, and logs.

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

Current ARTCC Activity 2: Manage Communications

ARTCC 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 ARTCC 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. ARTCC controllers use the Voice Switching and Control System (VSCS) for their communications system.

The quality and accuracy of this information are 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 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 to effect a smooth and safe flow of air traffic and flight plan information.

Current ARTCC 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 the NAS system architecture.

ARTCC line controllers access flight plan data electronically via the Host computer system (i.e., Host and Oceanic Computer System Replacement or HOCSR) or the En Route Automation Modernization (ERAM) system, the User Request Evaluation Tool (URET), and the Flight Data Input Output (FDIO) system. Flight data controllers 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 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. They access critical flight information from two key sources: (1) the flight data block located on the primary radar/traffic display to determine the aircraft's current position and speed and (2) flight progress strips to evaluate the impact of amendments to the flight plan.

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

Current ARTCC Activity 4: Manage Air Traffic

ARTCC 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. Consequently, medical, rescue, and security operations are given priority status over normal operations.

To provide radar separation, ARTCC controllers must first make positive radar identification and establish two-way radio contact with the pilot. Using procedures outlined in controller handbooks, Standard Operating Procedures (SOPs), and Letters of Agreement (LOAs), they will properly identify each target by using information available on their radar/traffic display (i.e., Host or ERAM, URET). Each radar system includes associated automation capabilities that allow controllers to follow near real-time and accurate flight data information. Controllers may also employ nonradar 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 ARTCC line controllers involve special and preplanned flight movements, such as VIP, national security, presidential or foreign dignitary operations. These evolutions are pre-coordinated by ARTCC supervisors and/or traffic managers who advise ARTCC line controllers of the beginning, end, and expected duration of each event. Another additional service provided by ARTCC controllers is 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 provide traffic information accordingly. Other additional services provided regularly by ARTCC controllers include monitoring uncontrolled objects, responding to pilot requests for weather deviations, and responding to nonconformance issues. In each case, information is obtained and verified, and a control plan is formulated and executed by ARTCC line controllers who then act in accordance with established procedures, make required notifications, and perform necessary coordination.

The management of traffic flows and associated additional services that are provided by ARTCC line controllers is crucial to system efficiency and allows 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 preplanning capabilities for different phases of flight; however, conflicts are also inherently a part of this system owing to the number and complexity of flight path trajectories that occur within this airspace. ARTCC line controllers are responsible for detecting and resolving those conflicts (as outlined below).

Current ARTCC Activity 5: Resolve Conflicts

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

For ARTCC line controllers to resolve a conflict, they must first identify a potential or actual loss of separation. They can be assisted in this task by using the conflict detection capabilities of Host or ERAM and URET. 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 to determine the most appropriate course of action. Issuing safety alerts and conflict advisories and warning pilots of terrain are the first priority of ARTCC line controllers. These actions are similar because controllers must first identify, validate, and then formulate a resolution, which involves issuing an appropriate instruction to the pilot involved so he or she can take evasive action, if necessary. These alerts must be accurate and timely and must be performed thoroughly to achieve a complete resolution. 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. However, by using proper established procedures, ARTCC 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 overflights 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 ARTCC Activity 6: Manage Traffic Flows and Sequences

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

ARTCC line controllers must be in constant communication with controllers who are located at Terminal Radar Approach Control (TRACON) facilities that underlie their areas of jurisdiction. They also direct and assist pilots as they transition to and from airports, feeding the departures into en route traffic streams and blending and sequencing the arrivals. Because the ARTCC is responsible for airspace that overlies approach controls and remote airports, controllers working at Airport Traffic Control Towers (ATCTs) must request departure releases for all aircraft flying in Instrument Flight Rule (IFR) conditions that depart their airports. ARTCC line controllers receive, verify, correct, and amend these requests if necessary to adhere to a flow or sequence that optimizes the use of their airspace. They then allow the departure aircraft to enter their airspace, establish radar contact, provide radar separation, and oversee the flight as it completes the outbound transition. The arrival phase is similar but in reverse; ARTCC line controllers receive inbound aircraft from an adjacent sector controller and coordinate with either the TRACON or ATCT controller to ensure the most effective use of the arrival stream of traffic.

To maximize efficiency in operations, ARTCC controllers must also work within the constraints of air traffic management initiatives (TMIs). To ensure that these programs are followed closely, controllers must coordinate in real time with pilots, other controllers, and traffic managers. Although TMIs ensure a more even flow to traffic for downstream controllers, the limiting nature of traffic restrictions means that the workload usually increases and becomes more complex for the originating facility's controllers because they determine which course of action is most appropriate to achieve the program goals. Because implementation can vary widely depending on 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 ARTCC line controllers. 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 provided by Host or ERAM and URET embedded in the radar systems helps them do their work seamlessly and is a key component of overall effectiveness. These automated data transfer systems will be covered in the next activity.

Current ARTCC 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 ARTCC line controller responsible for that aircraft must make a positive transfer of control. This requirement ensures flight data integrity, allows continuous surveillance of the flight, and uses minimal voice communications, which reduces workload and conserves controllers' resources for other air traffic management tasks.

ARTCC 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/traffic displays (i.e., Host or ERAM, URET) to change and maintain information contained in data blocks. These displays give controllers the ability to silently communicate with other controllers and facilities. ARTCC 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 whether 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 (which is a complete transfer of control) 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 to provide system users with a seamless transition along their route of flight. Controllers continue to update and modify this information in a manner that results in less frequency congestion, more situation awareness, and better overall system performance. Subsystems in Host or ERAM and URET allow controllers to devote time and attention to other important issues critical to system operation, such as assessing the impact of weather.

Current ARTCC 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 crucial because it gives aircraft operators the ability to avoid potentially unsafe conditions during critical phases of flight.

To respond appropriately to rapidly changing conditions, ARTCC line controllers actively monitor information that is displayed on weather system displays and observe information that is derived from sensors located at various airports underlying their areas of jurisdiction. These weather data are communicated via graphical or textual displays that include Weather and Radar Processing System (WARP); Integrated Terminal Weather System (ITWS); Automated Surface Observation System (ASOS); Automated Airport Weather Stations (AWOS); and Automatic Terminal Information System (ATIS), all of which are located on system status areas at the control positions. ARTCC line controllers also receive direct weather information from the Center Weather Service Unit (CWSU), which incorporates existing and forecasted weather conditions and provides critical information concerning areas of severe weather. Other sources of weather information can be derived from weather products such as Terminal Doppler Weather Radar and Next Generation Weather Radar (NEXRAD). Specialized weather information and products can also be accessed from the National Lightning Detection Network, the National Weather Service (NWS) Rapid Update Cycle data, and the Meteorological Data Collection and Reporting System. Controllers are required and must solicit and disseminate pilot reports (PIREPs), significant weather reports (SIGMETs), and/or airmen's meteorological information (AIRMETs). This information is broadcast to pilots or to other control facilities using ATIS or the VSCS and enables a real-time synopsis of weather throughout the NAS.

As ARTCC controllers determine strategies to help pilots avoid significant weather conditions, they will determine whether altitude or route changes are necessary and also coordinate with other control facilities 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 ARTCC line controllers can greatly enhance overall system performance and allow other duties to be performed, such as the management of airspace, which is covered in the next section.

Current ARTCC 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 en route and adjacent terminal facility and is influenced directly by how effective ARTCC line controllers are at airspace utilization. Because airspace is not static and can dynamically change as a result of operational requirements, controllers must be extremely adept at the efficient use of airspace.

The management of ARTCC airspace is especially challenging because of the changing boundaries that result from runway configurations that can change regularly at some airports. As a result of these demands, ARTCC line controllers may require additional airspace. As controllers determine their need to use other airspace, they request approval and provide additional instructions to the pilot that are based on existing conditions. Line controllers now assume 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/traffic display (i.e., Host or ERAM and URET). These methods are also used when ARTCC controllers transfer their own separation authority to others during sector reconfigurations when positions are combined and decombined. 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 ARTCC line controllers use proper procedures to make decisions quickly and efficiently. Also important is the management of controller workload, which is accomplished in several ways, as detailed below.

Current ARTCC Activity 10: Manage Resources

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

ARTCC line controllers must first determine whether they are fit for duty. This means recognizing fatigue, sickness, or any other condition that could impair their 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. Controllers must be aware of potential or actual work overload situations, which often occur as a result of an overload of traffic volume or an increase in traffic complexity, and they must respond to these situations by requesting assistance from controllers, supervisors, or traffic managers. Finally, in addition to recognizing overload situations at their own station, ARTCC controllers must also recognize and respond to these situations when they affect other controllers.

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

Current ARTCC Activity 11: Respond to Emergencies and Unusual Situations

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

ARTCC 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, ARTCC line controllers must detect system or equipment degradation or failure and respond to alarms. They must then forward the notice of 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 computer failures, controllers must revert to the Enhanced Back-Up Surveillance (EBUS) system and a possible manual writing of flight progress strip information; for sensor or tracking failures, they will revert to nonradar 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 that safety is not compromised during these emergency situations.

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

CURRENT KSAOS

The sections above describe in detail the work performed by ARTCC controllers. However, in addition to describing the work of the ARTCC controller, a job analysis identifies the characteristics required of workers to perform the work, usually 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 or 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 to a person before he or she can do the job. 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 a person before he or she is 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 staff, who worked closely with technical subject matter experts (SMEs).

Current Knowledges

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

Current Skills

ARTCC controllers must not only possess factual information about the work but also be skilled in doing the work. That is, it is not enough to simply know the rules of separation; it is critical that controllers also be skilled in applying the rules in the context of separating air craft. The 58

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

Skills required of ATCSs are captured in 12 categories, which are provided in Table 5. The list of Skills with their definitions can be found in Appendix A.[4]

Table 5. Current ATCS Skills

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

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

Skill Category	No.	Skill Label
	Sk36	Sequencing Strategy Selection
	Sk37	Sequencing Strategy Implementation
	Sk38	Spacing Strategy Development
	Sk39	Spacing Strategy Selection
	Sk40	Spacing Strategy Implementation
Conflicts	Sk41	Conflict Identification
	Sk42	Conflict Resolution Strategy Development
	Sk43	Conflict Resolution Strategy Selection
	Sk44	Conflict Resolution Strategy Implementation
	Sk45	Advisories/Alerts Utilization
Weather	Sk46	Weather Data Interpretation
	Sk47	Current Weather Assessment
	Sk48	Weather Projection
	Sk49	Weather Strategy Development
	Sk50	Weather Strategy Selection
	Sk51	Weather Strategy Implementation
Tools and Equipment	Sk52	Tool & Equipment Operation
	Sk53	Tool & Equipment Status Recognition
	Sk54	Tool & Equipment Degradation/Failure Response
Emergencies	Sk55	Emergency Recognition
	Sk56	Emergency Response Development
	Sk57	Emergency Response Selection
	Sk58	Emergency Response Implementation

Current Abilities

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

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

[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).

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

Section IV. Drivers of the NextGen ARTCC Work Environment

INTRODUCTION

By 2018, new technology, automation, and procedures will change the environment in which Air Route Traffic Control Center (ARTCC) 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 ARTCC 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 ten Drivers to consider their impact on the job, in some situations, there was so little information that AIR opted not to include the technology, automation, or procedure as a Driver. For example, research conducted early in the project suggested that SWIM may have an important influence on the NextGen mid-term work environment for the ARTCC line controller. However, subsequent research did not result in enough evidence that SWIM would be operational by 2018 to warrant its inclusion as a primary NextGen Driver for ARTCC. 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 10 specific NextGen Drivers that are presumed to influence the job of the ARTCC controller by 2018. For simplicity and convenience, Drivers in this section of the report are presented in alphabetical order, as shown in Table 8.

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

No.	ARTCC NextGen Drivers
1	4-Dimensional Weather Data Cube
2	Automatic Dependent Surveillance-Broadcast
3	Conflict Resolution Advisories
4	Data Communications
5	Flexible Airspace Management
6	High Altitude Airspace
7	Initial Tailored Arrival
8	Integrated Arrival/Departure Air Traffic Control Service
9	Performance-Based Navigation
10	Time-Based Flow Management Program

However, before these 10 Drivers are discussed, it must be stated that NextGen—and consequently many of these Drivers—are possible only because of the foundational nature of satellite technology and related components that enhance those data. More specifically, satellite-based positioning, navigation, and timing services provide aviation industry stakeholders with highly accurate information regarding the location of aircraft and other objects, such as aids to navigation and ground vehicles in four-dimensional space. Although widely available to the public, the availability, accuracy, and integrity of the Global Positioning System (GPS) data are further enhanced in aviation through the use of supplemental systems such as the Wide Area Augmentation System (WAAS) and the Ground-based Augmentation System (GBAS).

The increases in accuracy, reliability, and integrity of these data, when compared with traditional radar surveillance and ground-based navigation services, have a profound impact on what is possible in the National Airspace System (NAS). For example, GPS technology is not influenced by weather in the same way that ground-based technologies are. Thus, operations can continue in weather that once would have grounded aircraft, which improves efficiency and throughput. Properly equipped aircraft are no longer required to fly from one ground-based navigation aid to the other. Aircraft can now navigate between predefined points in space. This allows more direct and flexible routes to be flown, thus increasing efficiency in the NAS and savings for the user. Having highly accurate data regarding aircraft allows the Federal Aviation Administration (FAA) to build—and for aircraft to fly—highly prescribed performance-based routes. 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.

In sum, satellite-based surveillance and navigation enable many specific technologies, automation, and procedures and will in turn assist ATCSs to work more efficiently in the future. More specifically, this technology supports and enables the 10 NextGen Drivers identified above, which are most likely to affect the ARTCC work environment by NextGen 2018 and are of particular interest for the purpose of building a description of the 2018 ARTCC 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. It is currently unknown on which platform in ARTCC 4-D Wx Data Cube information will exist.

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

These data will be accessible as 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.

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.

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

The 4-D Wx Data Cube implementation is proposed to be completed in three phases: Initial Operating Capability (IOC), Intermediate Capability (IC), and Full Operational Capability (FOC). IOC is projected to provide information on parameters relevant to air traffic management, including turbulence, icing, convection, ceiling, visibility, and wake vortex displacement. 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. On the basis of this information, it is anticipated that IOC and IC will be implemented by 2018 and will influence the job of mid-term ARTCC line controllers. However, given that the completion date for FOC is 2020, and given that the integration of weather information into DSTs (i.e., finding the best fit between weather information and the DST to host that information) will be an iterative process and may take longer than expected, AIR assumes that FOC will not significantly influence the job of controllers in 2018.

Driver 2: Automatic Dependent Surveillance-Broadcast

Automatic Dependent Surveillance Broadcast (ADS-B) is a surveillance technology on board aircraft that transmits the aircraft's GPS-identified position to ground stations, which in turn broadcast the information to controller screens and cockpit displays. ADS-B consists of two components: ADS-B In and ADS-B Out. ADS-B In consists of equipage and services that allow aircraft to receive traffic and weather broadcast services information in the cockpit and is expected to help improve pilot situation awareness. ADS-B Out refers to the broadcast of aircraft location information via ADS-B transmissions from equipment on board the aircraft to ADS-B ground stations and to other aircraft if they are appropriately equipped. It is projected to provide more up-to-date and 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 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 with 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 nonradar 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 with the 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) refer to ADS-B but not to the specific components of ADS-B-In and ADS-B Out. Given the dearth of available information, AIR assumes that ADS-B In will not have a substantial impact on the work performed by ARTCC line controllers in 2018. Although ADS-B In has not been mandated, federal regulations require that ADS-B Out be installed on aircraft flying in the busiest airspace by 2020. Approximately 60% of commercial aircraft will be equipped with ADS-B Out by 2018 because the cost and technology challenges, such as changing equipage standards, will prevent a portion of certificate holders from adopting ADS-B early.

Driver 3: Conflict Resolution Advisories

Increased air traffic and eased airspace restrictions in NextGen mid-term may lead to an increase in controller workload and to more complex traffic patterns. ARTCC line controllers currently have aircraft-to-aircraft problem prediction capability and trial planning tools that allow them to create resolutions and to submit them to the automation, which will probe the viability of the resolutions for them. However, in 2018, trial planning enhancements will be made to the automation in the form of Conflict Resolution Advisories (CRA). CRA is a set of DSTs that will include menus of probed options with automation-developed resolutions—as opposed to a single controller–developed resolution—for predicted aircraft-to-aircraft conflicts.

In the mid-term, CRA will consist of three main menus on the radar and radar associate consoles. The CRA Altitude Menu will replace the Probed Altitude Menu. The CRA Altitude Menu will still display a list of altitudes including the aircraft's flight plan altitude, but it will also show several alternate altitudes above and below it that are color coded to indicate the problem status. In addition, the CRA Altitude Menu will highlight an altitude resolution advisory when there is a potential aircraft-to-aircraft conflict, and it will consider the current and requested altitude of an aircraft when exploring altitude options. The CRA Heading Menu provides a resolution advisory when the aircraft has a potential aircraft-to-aircraft conflict and allows controllers to create a two-leg vector that can be modeled on a graphic display of the trajectory. Further, it will send a reminder to the appropriate controller when it is time for the aircraft to be put back on its original trajectory (i.e., at the turn-back point). The CRA Search All Menu allows controllers to search for resolutions to potential aircraft-to-aircraft conflicts in different dimensions and directions. The resolution can be modeled on the trajectory, and a reminder can be sent to the appropriate controller for a future maneuver.

The potential benefits of CRA include improved efficiency and increased safety. Improved intent information entry and more strategic control actions resulting from the CRA menus could lead to reduced maneuvering of aircraft and more direct routing. Also, better controller decision making and more strategic conflict resolutions provided by probed menus could lead to fewer operational errors. Two mini-evaluations conducted in November 2010 and February 2011 showed additional potential benefits that include reducing the need for a climbing aircraft to only be cleared to the ceiling of the current controller's airspace, reducing the need for multiple time-critical actions thereby increasing the amount of traffic that can be managed by controllers, and improving preplanning and expeditious traffic flow. Although these mini-evaluations were conducted on the radar associate controller console, the CRA menus are being developed with the radar controller in mind. CRA could be beneficial to both the radar controller and the radar associate controller, but whether both or just one will get the automation depends on which piece(s) of equipment the strategic probe tool is located during the 2018 NextGen time frame.

CRA as described above assumes that many other NextGen capabilities will also be operational, including Area Navigation/Required Navigation Performance (RNAV/RNP), ADS-B, Data Communications (Data Comm), Flexible Airspace, and Big Airspace. Because AIR presumes that these enabling tools and concepts will be in place, it presumes that CRA will also be in place. The original time frame for CRA to be field tested was 2013. However, there has been some slippage. Despite the delay, as noted above, two mini-evaluations of CRA have been conducted and a third one is being planned along with two human-in-the-loop (HITL) experiments. As a result, AIR anticipates that the three CRA menus planned for the mid-term will be operational as scheduled.

Driver 4: Data Communications

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

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

Note that there are latency challenges associated with Data Comm messaging, and the length of the message may vary depending on whether the situation is time sensitive. Specifically, delivery of Data Comm messages may take up to 8 seconds or less for time-critical data messages and 30 seconds or less for all other data messages. In addition, there will likely be delays associated with controllers and pilots recognizing the receipt of Data Comm messages and crafting and sending a response. Owing to these latency challenges, it is anticipated that radio transmissions will continue to be used for time-sensitive messages, and Data Comm messaging will be reserved for issues that are less time sensitive. Despite this challenge, which will persist into 2018, the benefits of data communications are significant.

Data Comm is proposed to be implemented in three phases: (a) Segment One, 2012 through 2017; (b) Segment Two, 2017 through 2022; and (c) Segment Three, 2022 and beyond. Consequently, the ARTCC line controllers' job in the mid-term will be affected primarily by

Segment One and marginally by Segment Two. These two segments are presented in detail below:

- *Segment One (2012–2017):* Segment One functionalities shall enable ARTCC line controllers to meet many of their data communications requirements. For example, in Segment One, Data Comm will allow controllers to compose messages, will provide predefined messages for controllers, and will allow these messages to be transmitted. In this segment, the FAA will add the ability to broadcast messages in mass format. Further, in terms of ARTCC-specific requirements, Data Comm will be used for transmitting Automated Terminal Information Service (ATIS) messages and other functions. For example, Data Comm will process requests for current ATIS and enable NAS users to manage the contents of the ATIS.
- *Segment Two (2017–2022):* Segment Two will extend the use of Data Comm to other types of messages, such as aircraft-generated information necessary for conformance management of future trajectories and sending hazardous weather information to the aircraft. It may further support the expansion of NextGen Trajectory Based Operations (TBOs) into other portions of the airspace. To accomplish this, Data Comm shall acquire aircraft-generated trajectory information from ADS-B-equipped aircraft and disseminate aircraft-generated contract data to NAS users.

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

Driver 5: Flexible Airspace Management

Flexible Airspace Management (FAM) is a concept that supports the tactical reallocation of airspace and resources to match traffic demand and alleviate choke points. The FAM concept is supported by predefined inter- and intra-facility airspace configurations and bidirectional routes.[7] 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 be the ability to keep air routes intact and move the

[7] Note that the bidirectional routes component of FAM will have limited impact in the ARTCC.

boundaries and ownership of the airspace around air routes. This will mean that the control of an air route and any aircraft flying it can be moved to a different control position.

Important potential benefits of FAM as it will exist in the 2018 NextGen environment include improved efficiency and increased flexibility. Predefined airspace configurations and bidirectional routes will allow strategic adjustments to be made to better manage traffic demand and to handle other constraints such as weather, Special Activity Airspace (SAA) activations and deactivations, and runway configuration changes. In addition, the reallocation of the control of aircraft to different radar ARTCC line controllers will allow tactical changes to be made to handle constraints such as controller workload and equipment outages. An initial HITL 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, SA, airspace designs, and boundary change procedures implemented in the study.

The FAM concept as it will exist in NextGen is still in the preliminary stages of development. Although 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 developing how this concept will work and are exploring the tools needed for this concept. In addition, the FAA's automation road map and other sources indicate that the concept will be operational by 2018. Although no documentation is currently available that lists what components of the FAM concept will be in existence by 2018, for the purpose of this report AIR presumes that new inter-facility airspace configurations will be in place and that new bidirectional arrival/departure routes will also be in place in the busier ARTCC environments.

Driver 6: High Altitude Airspace

High Altitude Airspace in NextGen mid-term is designated as airspace between FL 340 and FL 590 that will be restricted to high-performance aircraft (i.e., aircraft equipped with Data Comm and Area Navigation [RNAV]/Required Navigation Performance [RNP] capability). This airspace will be broken down into two types: generic and nongeneric. Generic High Altitude Airspace (GHAA) will exist where traffic is mainly in level flight, the level of complexity is low with regard to crossing patterns, and traffic density is low to moderate. Non-Generic High Altitude Airspace (NGHAA) will exist where there are climb and descent profiles, the level of complexity is greater with regard to crossing patterns, and there are unique local features (e.g., SAA).

Both generic and nongeneric sectors will implement TBOs (see section on Performance-Based Navigation) and FAM techniques (see section on Flexible Airspace Management). In addition, both will require automation for conflict detection and resolutions for controllers (see section on CRA). GHAA will allow greater staffing flexibility. Controllers will be interchangeable intra-facility and to a limited extent, control of GHAA can be moved to other facilities. Further, GHAA is adaptable to allow reconfigurations of sector size and/or shape and can be combined. All of these will allow better response to fluctuations in traffic demand.

The implementation of high altitude airspace also provides important potential benefits to air carriers. Both GHAA and NGHAA airspace will experience improved efficiency and increased flexibility. TBOs will allow properly equipped aircraft to fly optimized and other user-preferred routes. In addition, the airspace will be designed to be flexible and to require fewer trajectory adjustments. As stated above, GHAA has additional benefits regarding controller staffing and training. Because GHAA is less complex and because fewer services will be offered, controllers managing this airspace will need fewer Knowledges and Skills. Foundational air traffic control Knowledge (e.g., basic weather concepts, concept of separation) will still be required, but GHAA controllers will not need as much sector-specific Knowledge (e.g., runway configurations, local obstructions/obstacles) because automation will provide much of this information. The remaining local knowledge that is required (e.g., hot spots) will not create a substantive training requirement. Thus, controller training time will be accelerated. Further, because generic sectors do not require sector-specific Knowledge, control of this airspace can be moved among controllers and among facilities to meet any fluctuations in traffic flow, demand, or controller workload.

Although no documentation exists to suggest that high altitude airspace will be rolled out in phases, the assignment of airspace as high altitude airspace in 2018 will depend on many other NextGen technologies, automation, and procedures being in place, including Data Comm, RNAV/RNP, Time-Based Flow Management (TBFM), and FAM. Because AIR presumes that these enabling tools and concepts will be operational by the mid-term in the busier metropolitan areas, and because this requirement does not appear to require significant additional training as many of the other Drivers will, it presumes that high altitude airspace will be implemented as described above in airspace surrounding the major metropolitan facilities.

Driver 7: Initial Tailored Arrivals

Initial Tailored Arrivals (ITAs) are arrival paths that support continuous descent operations for Future Air Navigation System (FANS)–equipped aircraft. ITAs are currently prenegotiated long before the flight takes place and are created jointly by the air carrier, aircraft manufacturer, and the FAA. ITAs are built on a published approach procedure (e.g., ILS28L), which ensures that the path meets existing regulations regarding hazards, such as obstacles, and an arrival route (either a “tailored” arrival route or an existing route). Pilots will request an ITA from ARTCC Oceanic sector controllers while the aircraft is still in cruise phase. Controllers will assess the operational context and if appropriate will create a clearance for the aircraft to fly the ITA that will ensure that the aircraft reaches the fixes at the time required to maintain spacing. The clearance will typically include one or more waypoints for the cruise portion of the route, the descent profile, any restrictions regarding speed and altitude, an approach procedure, and an arrival runway. The clearance will be sent directly to the onboard flight management system (FMS) through the Advanced Technology and Oceanic Procedures (ATOP) system. Note that ITAs currently being developed for the mid-term are not supported by DSTs. However, in the future, Tailored Arrivals (TAs) will be supported by DSTs, which will be part of ground-based automation that will create options that optimize the time component of the ITA.

ITA is one of two methods of performing Continuous Descent Operations (CDO). The other method is Optimized Profile Descent (OPD), which is an important NextGen 2018 concept for the Terminal Radar Approach Control (TRACON) environment (see AIR’s TRACON Job Description for additional information). However, ITA differs from OPD in several important ways. First, ITAs are available to only a small number of users (i.e., aircraft that are FANS equipped and that can thus receive data communications). In contrast, OPDs are published for all users and support operations to a large number of aircraft types that are not FANS equipped. Second, ITAs do not need to begin at Top of Descent (TOD) because the pilot can request an ITA well before the aircraft reaches TOD and hence do not require a strict adherence to time. Third, these routes are limited to Oceanic approaches because ATOP is currently the only automated air traffic control system capable of sending data messages. Finally, ITAs, unlike OPDs, are not "published" in the formal sense of the word but rather are made available to only those air carriers who have appropriately equipped aircraft.

ITA demonstrations began at coastal airports of San Francisco, Los Angeles, and Miami (associated with the respective ARTCCs issuing ITA clearances) in 2007 and are continuing. The results suggest that ITAs will provide a number of potential benefits to controllers and other users of the NAS:

- Reduced fuel consumption
- Reduced emissions of carbon dioxide and other harmful gases
- Reduced noise pollution near metropolitan areas
- Reduced radio frequency congestion

For example, these demonstrations led to an average fuel savings of 176 gallons per arrival for Boeing 747s and 99 gallons per arrival for Boeing 777s during full ITAs. Note that traffic constraints and severe weather may result in ARTCC controllers discontinuing an ITA clearance while in progress. Nevertheless, data show that even ITA paths that are discontinued owing to unfavorable weather or other factors (i.e., partially completed ITAs) are still beneficial to the operators of the NAS and to the environment. Demonstration ITAs that were only partially completed also recorded savings of 78 gallons and 43 gallons per flight for 747s and 777s, respectively.

Beginning in 2011, ITAs will be fully operational at the three aforementioned coastal airports that are served by ARTCCs managing Oceanic airspace for FANS-equipped aircraft. Implementation at additional coastal airports that are served by ARTCCs equipped with ATOP (e.g., Oakland Center, New York Center, Anchorage Center) is possible. For ITAs to be operational at additional domestic airports, more aircraft must be equipped with FANS technology and the associated ARTCC facilities must have ATOP or some similar data communications system to uplink the data to the aircraft's flight management system. With the increase in data communications in the en route environment in the mid-term (see Data Communications section for more information) and the continuing progress of installing FANS on Oceanic and non-Oceanic aircraft, it is projected that ITAs will be operational at additional coastal and domestic airports by mid-term 2018. Although detailed information on which or how many airports will have ITA operations is lacking, the most likely candidates are Core 30 (see Appendix D) airports with international gateways located along the coast of the continental United States.

Driver 8: 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, ARTCC and TRACON 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 use Area Navigation–enabled routes (see section on Performance-Based Navigation) and dynamic resectorization capabilities (see 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 task 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, because the TRACON airspace is small and easily congested, often the result is "no notice holding" in ARTCC airspace. This means that ARTCC controllers are given no prior notice that they will have to hold an aircraft in their space before they attempt to hand it off to TRACON. This leads to extreme inefficiencies, operational complexities, and increased workload.

Big Airspace operations are intended to reduce operational inefficiencies that occur when coordinating ARTCC and TRACON 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 eight potential areas for Big Airspace facilities: New York, Philadelphia, Baltimore/Washington, Chicago, Atlanta, central Florida, northern California, and southern California. However, early analyses show that because 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 its initial implementation. 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 9: Performance-Based Navigation

Performance-Based Navigation (PBN) 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 navigation specifications and 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 describe the ability of the aircraft and aircrew to conduct curved paths (with direct routes) as opposed to conventional zig-zag paths based on ground-based navigational aids (NAVAIDs). 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 both the ground-based and 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 (see Appendix D) but are projected to expand to the remaining Core 30 airports by mid-term 2018.

There are two types of navigation specifications: Area Navigation (RNAV) and Required Navigation Performance (RNP). These navigation specifications are discussed in greater detail below.

Area Navigation

RNAV is a navigation specification that removes the requirement for a direct association between aircraft navigation and a 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-enabled routes) to their destination instead of conventional routes from one ground navigation station to the other.

Two examples of RNAV-based procedures are Standard Instrument Arrivals (STARs) and Standard Instrument Departures (SIDs). A STAR is a published designated arrival procedure for IFR aircraft that links a specific ARTCC route to a specific airport and/or runway. A SID is a designated published departure procedure for Instrument Flight Rule (IFR) aircraft that follows aircraft during transition from the airport through terminal airspace and connects with specified ARTCC routes.

RNAV-enabled routes 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 and ARTCC airspace owing 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-enabled routes at 118 airports (both Core 30 and non-Core 30 airports) in 30 states and territories. Further, 27 of the nation's Core 30 airports are projected to have RNAV-enabled routes by the NextGen near term. According to the PBN road map, the FAA intends to mandate RNAV for arrival and departures at most Core 30 airports by 2018. Consequently, AIR proposes that RNAV-enabled routes will be operational at all or most of the Core 30 airports in the continental United States by 2018. AIR also anticipates that RNAV-enabled routes 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 using the NAS more efficiently.

RNP-enabled routes provide several potential benefits to users of the NAS:

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

Currently, approximately 30% of the U.S. fleet is capable of using RNP-enabled routes. 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-enabled routes around the airspace at 63 airports in 31 states, two U.S. territories, and one country. Finally, 20 of the nation's Core 30 airports are projected to have RNP-enabled routes by the NextGen near term. Consequently, for purposes of building the ARTCC Job Description, AIR assumes that 50% of the U.S. fleet will be equipped with necessary technology to fly RNP-enabled routes by 2018. Further, based on the current and projected number of RNP-enabled routes, AIR anticipates that RNP-enabled routes will be operational by 2018 at least 90% of Core 30 airports.

Driver 10: Time-Based Flow Management Program

The Time-Based Flow Management (TBFM) Program is a plan to upgrade and enhance the Traffic Management Advisor (TMA). TMA, which is currently being used by Traffic Management Coordinators (TMCs) in ARTCCs, identifies trajectories and times that aircraft must reach or cross specific points in space on the arrival and departure paths. This arrival and departure information (obtained via TMA En Route Departure Capability) is then provided to line controllers (via the radar/traffic display), who ensure that aircraft arrive at these required time of arrivals (RTAs) by using various control methods (e.g., speed control, spinning, rerouting). Known as Time-Based Metering (TBM), this concept is used today to manage the flow of aircraft through congested airspace more efficiently than with traditional miles-in-trail spacing. However, TMA needs to be upgraded to TBFM because TMA does not support extended metering and other key functionalities that will provide benefits to NAS stakeholders. TBFM will add TBM functionalities, which will address current TMA shortcomings and increase the role of TBM in operations and extend its benefits, thus advancing air traffic management toward TBOs.[8]

Several new functionalities are planned. Three will most directly affect ARTCC line controllers:

- *Extended metering (also known as adjacent center metering):* Although multiple metering fixes are available today via TMA, the fixes are confined to a single center's airspace. Extended metering will allow multiple metering fixes to be identified anywhere in en route airspace, even extending past any individual center's boundaries instead of being confined to a single center's airspace as it is today. The net effect of sharing fix information across center boundaries will be a reduction in the frequency and size of aircraft deviations from fixes in any given controller's airspace because the deviations will be absorbed across more airspace.
- *3-D Path Arrival Manager:* Although TMA DSTs currently generate trajectories and RTAs, the system is largely passive; it does not provide options to the line controllers regarding how to maneuver aircraft to meet the required arrival times. TBFM's new DST, called 3-D Path Arrival Manager (3-D PAM), will provide control options that could be used to absorb aircraft deviations from the RTAs.
- *Airborne rerouting:* TBFM will also send DST-generated reroutes, when required, directly to the line controller as opposed to the Enhanced Status Information System (ESIS) display where they must be retrieved and hand entered. Although the TBFM documentation does not currently specify this, AIR presumes that line controllers will be able to select the reroute and then send it directly to Data Comm–equipped aircraft.

TBFM will provide the following potential benefits to NAS stakeholders:

- Reduced workload for line controllers
- Reduced congestion on radio frequencies
- More efficient use of arrival airspace
- Better decision-making by controllers regarding the control actions required to maneuver aircraft to meet the required times of arrival
- Greater access to arrival times, which will allow air carriers to better manage both ground resources and aircraft schedules

The most recent NextGen Implementation Plan suggests that the development, prototyping, and deployment of TBFM's time-based metering and scheduling capabilities will be complete by

[8] Because the purpose of this report is to describe the impact of NextGen Drivers on the ARTCC line controller, many of the functionalities that are planned for TBFM are not described here.

2018. Based on the progress in TBFM development and according to the most recent infrastructure road map, TBFM will be implemented in all ARTCCs by 2018.

Section V. Characteristics of NextGen ARTCC Work and Workers

Introduction

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

This description is organized by the 10 ARTCC NextGen Drivers described in Section IV: 4-Dimensional Weather Data Cube (4-D Wx Data Cube); Automatic Dependent Surveillance-Broadcast Out (ADS-B Out); Conflict Resolution Advisories (CRA); Data Communications (Data Comm); Flexible Airspace Management (FAM); High Altitude Airspace; Initial Tailored Arrivals (ITAs); Integrated Arrival/Departure Air Traffic Control Service (Big Airspace); Performance-Based Navigation (PBN); and Time-Based Flow Management Program (TBFM). 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 on only a few controllers) and others having a more broad 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 the 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 ARTCC 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 ARTCC 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 ARTCC 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 ARTCC NextGen Drivers will affect the clearances, instructions, and other messages that are issued by controllers. However, recall that Activity 2 (*A2-Manage Communications*) captures Tasks associated with the basic communication process, not the issuing of a specific communication. Consequently, the impacts of Drivers on specific communications are identified in the Activity where that communication occurs.

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

DRIVER 1: 4-DIMENSIONAL WEATHER DATA CUBE

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

Overview of Changes From Implementing 4-D Wx Data Cube

Table 9 provides a visual summary of the changes that will occur to the job as a result of implementing 4-D Wx Data Cube. Additional details regarding these changes can be found in the sections that follow.

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

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

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO 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 T7 T8 T11 T15 T16 T22 T43 T47 T75 T79 T82 T83 T89 T92 T93 T98 T105 T121 T122 T134 T135 T147 T152 T160 T165 T170 T173 T174 T178 T179 T182 T195 T197 T200 T205 T209 T214 T222 T235 T239 T251 T256 T257 T259 T260 T261 T262 T263 T264 T265 T266 T267 T268 T272 T280 T284 T288 T289 T291 T320 T321 T326 T327 T328 T332 T334 T338 T339 T341	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 K22.9	Sk1 Sk3 Sk8 Sk11 Sk20 Sk23 Sk25 Sk26 Sk46 Sk47 Sk48 Sk49 Sk52 Sk53 Sk54	Ab1 Ab4 Ab5 Ab8 Ab11 Ab19 Ab24 Ab26 Ab28	O14	

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC line controllers, AIR considered both whether the Driver will require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks) and whether the Driver will change *how* Tasks will 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 gives 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 ARTCC line controllers currently perform, AIR proposes that 4-D Wx Data Cube and the associated 4-D Wx SAS will affect *how* ARTCC line controllers perform many of those Tasks. The implementation will affect many Tasks because weather information is 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 information ensures 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 Tasks in nine of the 11 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 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 ARTCC automation platform 4-D Wx Data Cube will exist. However, based on the information synthesized to date, AIR believes that it is most likely that the data will be fed through the Host or En Route Automation Modernization (ERAM) 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 the ARTCC controller. Hence, controllers will scan a different piece of equipment or system to access weather information (*T11*). Scan time is likely to stay the same because it is presumed that the Weather and Radar Processor (WARP) will be decommissioned.

To the extent that 4-D Wx Data Cube displays are more customizable than WARP, which seems reasonable given that WARP is placed centrally but 4-D Wx Data Cube will be a workstation tool, its implementation adds another piece of equipment to be configured (*T7*) and to scan for configuration (*T8*), which will increase the overall time required for system configuration. Although controllers will have another piece of equipment to adjust when assuming position responsibility (*T7*), the implementation of 4-D Wx Data Cube should allow controllers to scan more efficiently.

Because 4-D Wx Data Cube will provide a synthesis of different and highly accurate sources of information via 4-D Wx Single Authoritative Source (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*).

Activity 3. Manage Flight Plan Data

Controllers use weather information today when evaluating flight plan requests (*T43*) and when determining the need for flight plan amendments (*T47*). 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 that controllers will be less likely to change a flight trajectory because of weather when such a change is not required.

Activity 4. Manage Air Traffic

When ARTCC controllers evaluate flight plan data today as part of managing air traffic, they take weather information into account (*T75*). 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, ARTCC controllers must identify potential conflicts (*T79, T89*), which requires mentally projecting an aircraft's current position into the future. Because projections are affected by the presence of weather, having a greater amount 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 (*T82, T92, T121*). 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 (*T83, T93, T122*). 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 ARTCC controllers when determining an appropriate plan of action in response to special operations (*T98*). Knowing with greater certainty the location (e.g., perimeters, altitudes, times) of severe weather will allow them to create flight plans or flight trajectories that safely avoid severe weather but do 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 (*T105*). 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 whether 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 about the weather (e.g., pilot's out-the-window view, close proximity of surveillance of weather via onboard sensors) and the information controllers have about the weather (e.g., remotely gathered and subsequently delayed distribution) will mean that controllers will be better able to coordinate with pilots to determine whether such requests are advisable (*T134*). If a request for deviation is approved but restrictions are required, controllers have to generate an alternative clearance. Again, the appropriate clearance is influenced by weather (*T135*). 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 mentally projecting 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 (*T147, T160, T170*). 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 (*T152, T165, T174*). In addition, more accurate weather information will allow controllers to more precisely determine whether an airspace violation occurred as a result of weather (*T173*). This is important because controllers must ascertain facts and details regarding the potential airspace violation.

Controllers will be able to use 4-D Wx Data Cube information to more accurately determine the need for advisories or alerts (*T178*) owing 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 (*T179*). Finally, controllers will be better able to determine whether and when the weather has returned to normal and will be more likely to cancel the advisory/alert at a more appropriate time (*T182*), 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 choke points are likely to occur. This information allows more real-time adjustments to sequences. First, it will allow them to determine the most appropriate sequences within the departure flows (*T195*) and arrival flows (*T200*) and also assist them when they reevaluate those departure (*T197*) and arrival flows (*T205*).

4-D Wx Data Cube will provide ARTCC line controllers with weather information that looks more similar to the weather information that the traffic management unit (TMU) already has available. Consequently, this will make the discussion of traffic management initiatives (TMIs) (*T209*) and the coordination with TMU (*T214*) much easier for controllers. Further, if the Federal Aviation Administration (FAA) elects to give TMUs access to 4-D Wx Data Cube, it will make decision making and coordination between controllers and TMU even easier because then they will be looking at the exact same weather information (*T209, T214*). The availability of shared information is likely to improve the quality and timeliness of decisions.

Activity 7. Transfer of Radar Identification
Coordination between controllers, including coordination required for initiating and accepting handoffs, will be more standardized and more productive because both controllers will have access to the same weather information (*T222, T235*). In addition, having more accurate weather information will allow controllers to make better decisions regarding the need for changes in flight trajectories and subsequently to determine the need or conditions for pointouts (*T239*). For example, controllers would not identify the need for a change in trajectory when one did not really exist; conversely, they would not fail to identify the need for a change in trajectory when one was required, thus reducing inefficiency in the NAS. Finally, having more accurate weather information will allow controllers to have more appropriate responses to pointout requests (i.e., controllers will know whether a restriction is necessary and consequently will not unnecessarily restrict aircraft; *T251*).

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 (*T256, T257*). 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 and notice of runway or airport condition changes would not need to be received directly 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 (*T259*, *T260*). The end result is reduced coordination requirements. Note that controllers will still have to forward runway condition use data 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 (*T261*).

Controllers will receive information regarding weather intensity and trend from a new display that provides information of higher quality and timeliness (*T262*). 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 (*T263*). Pilots will have to provide the information in four dimensions and controllers will have to request it in that format. This information will 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 subscribers will see the same weather depiction (*T264, T265*). In addition, receiving and requesting weather reports will no longer be active processes that require communication with

ATCT controllers. ARTCC controllers will simply scan the 4-D Wx Data Cube display to get the information (*T264, T265*).

The implementation of 4-D Wx Data Cube may decrease slightly the frequency of the weather interpretation Task because more weather data will have been mined and synthesized before being presented (*T266*). Controllers will still have to disseminate weather information but it is likely that they will be disseminating the information to fewer people (*T267*) and less often to other controllers. Because controllers will know with greater certainty the location of the perimeter and altitude of weather, they will make more accurate altitude or route changes to bypass weather (*T268*). Again, this information allows controllers to be more accurate, thus reducing inaccuracy and uncertainty in the NAS.

Activity 9. Manage Airspace

ARTCC controllers identify the need to use 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 (*T272*). For example, controllers will not identify the need for a change in trajectory when one does not exist. Conversely, they will not fail to identify a change in trajectory when one is 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 (*T280*). The coordination required for temporary release of airspace, once approved, will be eased and more productive because both controllers will have access to the same weather information (*T284*).

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 (*T288*, *T289*) will be standardized and more productive; less explanation will be required regarding the change and any associated restrictions. Further, 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 refine control actions so that they are more operationally appropriate and prevent them from generating "one size fits all options" (*T291*).

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 (*T320*, *T327*, *T332*, *T338*). 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 information will allow controllers to develop plans that both are viable and represent the best case scenario (*T321, T328, T334, T339*) without over- or undercontrolling.

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 (*T326, T341*). 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 U.S. Coast Guard or the U.S. military and can cover extremely 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 more closely match that available to others, shared situation awareness and ease of communications will increase.

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 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 the 4-D Wx Data Cube into the ARTCC environment does not require deleting or modifying the language of currently required KSAOs. 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 subcategory 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 facility Tools and Equipment Knowledge category, which is K19.

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 toward, perceive the usefulness of, and perceive the ease of use of technology, which is known as *Technology Acceptance*. 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 ARTCC 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 air traffic control (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 humans and machine; and concepts associated with decision support tools (DSTs), including the decision support tool–decision-making tool (DMT) continuum, evaluation strategies, and the concept of automation-based algorithms and the importance of understanding them.

4-D Wx Data Cube may change PIREP solicitation requirements (*K8.8-Pilot Report [PIREP] solicitation requirements*); for the information to be four-dimensional, controllers will have to know how to solicit the information from pilots in four dimensions.

ARTCC controllers will also have to learn new curriculum associated with the use of the tool (*K19-Knowledge of Facility Tools and Equipment*) including content for all the existing Knowledge subcategories (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators; K19.7-Minor troubleshooting; K19.8-Backup systems*). For example, if 4-D Wx Data Cube adds new sensors that do not exist today, controllers will need to be taught about the location, capabilities, and limitations 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, the curriculum will include information regarding how data from the new 4-D Wx Data Cube will be depicted on the radar/traffic display, how the system as a whole will interact with the existing Host or ERAM platform, and whether 4-D Wx Data Cube information will be displayed on other systems that currently display weather, such as the Enhanced Status Information System (ESIS).

4-D Wx Data Cube will also require that controllers learn new scanning strategies (*K22.3-Scanning strategies*) that incorporate 4-D Wx Data Cube information. Specifically, they will need to learn how to scan the tool to get the information 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 ARTCC environment. Although Knowledge of scanning strategies is important, it is unclear whether or how controllers are currently taught this Skill. Based on AIR's research, it appears to be taught by only 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 (*K22.9-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, although 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*).

Because more NAS users will have access to the same weather picture, the Knowledges associated with the recording and dissemination of weather information will be needed less often. For example, assuming that 4-D Wx Data Cube will have automated terminal information service (ATIS) information that is normally transmitted from the ATCT to the ARTCC via a landline or flight data input/output (FDIO), there will be a reduction in the amount of weather information recording that ARTCC line controllers will have to do 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, ARTCC 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—ARTCC 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*).

Because 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 a basis for making operational decisions.

In so far 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 operations (*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*).

Last, although the exact platform or platforms that will house 4-D Wx Data Cube are 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 ARTCC line controllers (e.g., TMU, TRACON controllers) also get a complete 4-D Wx Data Cube that includes weather observations and PIREPs, less information will have to be shared verbally. For that reason, ARTCC line controllers will spend less time using their Skill at verbally communicating information (*Sk1-Oral Communication*), Skill at attending to what others are saying and asking questions if needed (*Sk3-Active Listening*), and

working with others to accomplish air traffic Tasks (*Sk23-Coordination*). Note that it is currently unknown whether ARTCC line controllers will continue to coordinate with the ARTCC weather service unit. However, because 4-D Wx Data Cube will not have forecasting capability by 2018, AIR assumes that line controllers will still work with the ARTCC weather service unit, if available, to get weather forecasting and weather interpretation information.

Given that 4-D Wx Data Cube gives controllers the options 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 use the underlying raw data, their proficiency at information filtering becomes more important. Conversely, if controllers use 4-D Wx SAS, which synthesizes weather data, their proficiency at information filtering becomes less important.

4-D Wx Data Cube will also have different effects on Skills associated with interpreting weather data (*Sk46-Weather Data Interpretation*). The extent to which controllers use the system's underlying raw data will affect the Skills required for weather interpretation because they will be receiving more raw data to process. However, if controllers prefer to use 4-D Wx SAS, this 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 ARTCC line controllers (e.g., ATCT controllers, TMU personnel) also get 4-D Wx Data Cube, it will reduce the amount of time that ARTCC line controllers will spend using Abilities associated with communicating information and ideas verbally (*Ab1-Oral Expression*), understanding the principles governing the use of verbal concepts (*Ab4-Verbal Reasoning*), and understanding information that is presented verbally (*Ab5-Oral Comprehension*). Less information will be shared verbally and fewer discussions will take place regarding the impact of weather because that information will be on 4-D Wx SAS.

4-D Wx Data Cube will also increase the use of several Abilities. To the extent that controllers use raw data on the 4-D Wx Data Cube, they will be required to process large volumes of data. 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 will make these data reduction and summarization Abilities more important.

Because 4-D Wx Data Cube will provide new and more timely information to controllers, the Ability to combine pieces of information to form general conclusions and to find relationships among events (*Ab19-Inductive Reasoning*) will be more important and be required at a higher level. The weather information provided will be more dynamic and have more parameters.

ARTCC controllers will need to be able to adapt to having 4-D Wx Data Cube at their workstations (*Ab24-Flexibility*). If 4-D Wx Data Cube display increases the use of color for coding information, which seems likely given the substantive synthesis required for 4-D Wx SAS, the Ability to detect differences between colors (*Ab8-Visual Color Discrimination*) will be required more often. Finally, controllers will also need to be able to learn the Knowledge and Skills associated with 4-D Wx Data Cube and to apply lessons learned from experience using this new tool (*Ab28-Learning*). These Abilities are already required in the present job but will be increasingly required in NextGen for all Drivers.

Changes to Properties of Other Personal Characteristics

In addition to the new Other Personal Characteristic (*New O-Technology Acceptance*) that was described above, the addition of technologies increases the importance of believing that individuals have influence over the outcome of an event and taking responsibility for outcomes (*O14-Internal Locus of Control*). This characteristic is important because controllers need to understand 4-D Wx Data Cube thoroughly enough 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 19 risks associated with ARTCC 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, 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, safety and efficiency may decrease. 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, 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, including 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 ARTCCs, or if it is implemented on a significantly different schedule, the resulting differences in availability of weather/flight condition information or format of said information pose several risks, including the inability to disseminate information to other controllers and the difficulty in communicating about weather with other controllers.
- *Poor Computer-Human Interface design*: If the Computer-Human Interface (CHI) that provides line controllers with synthesized information (in the 4-D Wx SAS) 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), the possibility for error could increase, 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 ARTCC weather service unit personnel, 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 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, not until technologies are fielded and are being used by controllers can they 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

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

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

4-D Wx Data Cube may also reduce communications with others by making the same information available to all subscribers. This standardization will reduce workload and conserve resources for controllers. The information that controllers will have will more closely match the sophistication of the information that pilots receive through onboard avionics. This increases shared situation awareness (SA) 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 have an impact on the training content for ARTCC line controllers because it is a new tool. 4-D Wx Data Cube will make the job easier for ARTCC line controllers because it synthesizes weather information that currently is housed in multiple places into one single authoritative source and shares that common picture with all NAS subscribers. However, although 4-D Wx Data Cube adds functionality and reduces burdens associated with gathering information from multiple places, automation generally increases the need for basic technical/computing Knowledges and Skills required of controllers (e.g., controllers need to understand what information the automation has access to and the algorithms it is using in order to use it safely). They need to know which components are critical and which are not in cases of degradation or outages. In sum, the addition of automation does not result in the need for lower skilled employees but rather the opposite.

Finally, until 4-D Wx Data Cube is fully implemented, training on both the old weather systems and 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: Automatic Dependent Surveillance-Broadcast Out

Automatic Dependent Surveillance Broadcast (ADS-B) is a surveillance technology on board aircraft that transmits the aircraft's Global Positioning System (GPS)-identified position to ground stations, which in turn broadcast this 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

Table 10 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 ARTCC 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:[10] •T65 •T66 •T67 •T68 •T69 •T70 •T72 •T73		Add: •Service Orientation (*New Sk*)		Add: •Technology Acceptance (*New O*)	

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

	Tasks (T)	Knowledges (K)		Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	•T110 •T194 •T219 •T220 •T254						
Driver otherwise affects existing Task or KSAO:	T10 T14 T15 T16 T43 T65 T70 T75 T76 T77 T78 T79 T80 T81 T82 T83 T84 T85 T86 T87 T88 T89 T90 T91 T92 T93 T94 T95 T320 T345 T346 T347	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 K18.6 K18.15 K18.17 K19.4 K19.8 K21.2 K21.3 K22.6 K22.7 K27.4	Sk17	Ab24 Ab28	O12 O14	

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC 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) and 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 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 three of the 11 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 (*T65-T70, T72, T73*) will be modified by deleting the word *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 use different ARTCC equipment. Additionally, under processing requests for VFR flight following, controllers will still identify aircraft, but use ADS-B Out instead of radar (*T110*).

Activity 6. Manage Air Traffic Flows and Sequences
Similarly, radar identification of aircraft (*T194*) 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.

Activity 7. Transfer of Radar Control
Finally, the title of Activity 7 (*A7-Transfer of Radar Control*) and some of the Tasks within it will need to be modified to replace the word *radar* with *aircraft*. More specifically, controllers will receive requests for transfer of aircraft identification, instead of requests for transfer of radar identification (*T219*). Similarly, controllers will determine the need for transfer of aircraft identification as opposed to radar identification (*T220*). Last, controllers will still declare aircraft contact (*T254*). 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 have the most direct impact on 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 for four of the 11 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 on board 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*). Assuming that equipage information is encoded in some way into the data block, controllers will also spend more time scanning to gather information regarding whether aircraft are ADS-B Out equipped (*T10*).

Further, 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 the 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 because 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 consider when evaluating the flight plan (*T43*).

Activity 4. Manage Air Traffic
Knowing with greater certainty where aircraft are located in time and space affects several controller job responsibilities associated with performing radar separation of aircraft. More specifically, in areas that have currently have no, little, or unreliable radar coverage, the implementation of ADS-B Out will mean that controllers will observe aircraft entering airspace (*T65*) more often and will perform radar-based position correlation procedures more often (*T70*). Controllers will perform Tasks associated with radar separation (*T75-T85*) more often. Conversely, because ADS-B Out will proved give 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 (*T86–T95*) less often.

Activity 11. Respond to Emergencies and Unusual Situations
ADS-B Out will enhance emergency alerting for ARTCC 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 (*T320*) and shown on the radar/traffic display. To the extent that aircraft are ADS-B Out equipped, controllers will initiate backup systems (*T345*), implement backup procedures (*T346*), and initiate nonradar separation procedures (*T347*) 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 ARTCC Controllers
When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 gives 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 on board 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 on board aircraft will add a new Skill at providing preferential services to properly equipped aircraft (*New Sk-Service Orientation*). It will also add a new Other Personal Characteristic to capture the necessity for ARTCC controllers to adopt positive attitudes toward technology (*New O-Technology Acceptance*).

Changes to Curriculum Required to Teach Knowledges
The accuracy of ADS-B Out data will have a positive effect on the design and usage of the airspace. The introduction of ADS-B Out will change air route structure and airspace systems architecture to reflect new positional accuracy (e.g., terrain obstruction clearance, special airspace avoidance). For example, the 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. Further, controllers need to be trained in the relative importance of NAVAIDs, use of NAVAIDs by aircraft with different equipage (*K7.2-Types of NAVAIDs*), and a new type of satellite-based navigation that is possible as result of ADS-B Out technology (*K7.3-Types of navigation*).

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

If ADS-B Out is not currently being taught, it will need to be taught as an additional component of the surveillance systems architecture (*K9-Knowledge of Surveillance Systems Architecture*) including all the associated Knowledge subcategories (*K9.1-Types of surveillance systems; K9.2-Fundamentals; K9.3-Components; K9.4-Utility; K9.5-Limitations)*. Further, 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 avionics capabilities that enable ADS-B Out (*K11.5-Avionics*), including the process whereby an aircraft's 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 ARTCC 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 and understanding this information must be taught as part of Knowledge interpretation (*K19.4-Interpretation of information provided*).

To the extent that facilities gain new aircraft positional awareness as a result of ADS-B Out, the number of positively controlled aircraft being managed will increase, thus influencing flows. Controllers will need to be taught the new flow patterns and procedures (*K18.15-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 (*K18.17-Facility specific directives and procedures*).

Increases in accuracy regarding the identification and position of aircraft that is possible as a result of ADS-B Out could support the reduction of separation minima (*K21.2-Separation Minima*), requiring controllers to learn the new 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 IFR cancellation notices. Consequently, controllers can begin using that unused airspace without having to wait for IFR cancellation notices from pilots or control facilities. Controllers will no longer be required to wait to release subsequent IFR departures when previously they would have waited until the first aircraft was in an area of radar coverage. Instead, controllers will have accurate positional information from ADS-B Out, which they can substitute for radar coverage that will allow them to release the next aircraft. Finally, controllers will need to be taught new information to consider when assuming responsibility for conducting 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 use latitude and longitude for geo-referencing. In addition, four-dimensional (i.e., latitude, longitude, altitude, time) way points will be used more often instead of identifying locations on the basis of ground-based NAVAIDs or radar-identified positions. Consequently, controllers will apply Knowledge of geo-referencing more often (*K7.6-Geo-referencing*). Compulsory position reporting will be needed less often (*K7.7-Compulsory position reporting*), especially for Oceanic aircraft, because controllers will know where the aircraft are even in areas with no radar coverage (e.g., Gulf of Mexico). ADS-B Out will decrease the frequency with which controllers will apply Knowledge of altimeter setting (*K12.4-Altimeter setting criteria*), especially at ARTCC altitudes, because these data are available to controllers via the satellite-based navigation system.

ADS-B Out reduces aircrafts' navigational reliance on ground-based NAVAIDs because positional data are available to them through a satellite-based navigation system. Consequently, Knowledge of NAVAIDs will be used less often (*K18.6-Local navigation aids*). This is a substantive benefit because NAVAIDs are prone to outages from malfunction, loss of power, and atmospheric conditions such as weather. In addition, their reception is limited by terrain.

Satellite-based technology such as 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 for 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.

Because ADS-B Out represents a shift from a "first come first served" strategy of air traffic management to a "best equipped best served" (BEBS) strategy, controllers will need to be taught the Skill of 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. ARTCC 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 currently an important Other Personal Characteristic for ARTCC controllers. However, risk tolerance will increase in importance because of the potential reduction in aircraft-to-terrain and aircraft-to-aircraft separation standards. Also, controllers' belief that they have control over the outcome of events (*O14-Internal Locus of Control*) will increase in importance because it is vital for controllers to believe that maintaining separation is under their control instead of shifting responsibility to the pilot or 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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Ten potential risks with regard to the implementation of ADS-B Out are:

- *Best equipped, best served strategy*: 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, it could result in inconsistencies and lack of standardization in the ADS-B Out system.
- *Deficiencies in technology*: Although ADS-B Out technology remedies some of the vulnerabilities in existing technologies, to the extent that ADS-B Out relies on space based 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, 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 because of 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 ground stations or global positioning satellites that enable transmission of ADS-B Out data to controllers' displays. When the aircraft is flying in an area not covered by radar, the aircraft could drop off the radar/traffic display.
- *Lack of/inadequate training*: Lack of training or inadequate training in the capabilities of ADS-B Out, including any 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 CHI that provides line controllers 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), the possibility for error could increase thus reducing efficiency and safety.
- *Reduced separation minima*: The implementation of ADS-B Out theoretically supports a reduction in separation minima as a result of increases in certainty regarding aircraft position. As a result, controllers will need to remediate conflicts more quickly, which may require more precise and timely judgments. If conflicts are not remediated in time, loss of life or property may result.
- *Skill decay*: Implementation of ADS-B Out as aircraft equipage has the potential for the decay of the Skills required for managing traffic using nonradar procedures. The result may be a lack of preparedness by line controllers and a reduction in safety during unusual situations where the automation either is 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 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, not until technologies are fielded and are being used by controllers can they be fully evaluated from a functional perspective. If controllers are not fully utilizing the tools, they will be unable to provide the feedback that is vital to system evolution.

Driver Impact Summary

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

The impact of ADS-B Out will be felt primarily by controllers who currently manage airspace with no, little, or unreliable radar coverage. It is one of the most important Drivers in terms of increasing capacity and positively affects virtually every stakeholder. This Driver also embodies the notion of BEBS. Aircraft that are ADS-B Out equipped will have many opportunities and advantages, such as availability of more direct routes, which result in fuel savings. Finally, controllers can be flexible in routing these aircraft through airspace with no, little, or unreliable radar coverage and be less dependent on existing ground-based radar stations or NAVAIDs.

Driver 3: Conflict Resolution Advisories

Conflict Resolution Advisories are DSTs that will support ARTCC line controllers in the mitigation of aircraft-to-aircraft conflicts. In the mid-term, CRA will consist of three main menus that will exist on the radar and radar associate consoles. The CRA Altitude Menu, the CRA Heading Menu, and the CRA Search All Menu will provide controllers with CRA that have been probed by the automation for feasibility. Controllers will be able to select an automation-generated resolution and model that potential resolution on a graphic display of the aircraft trajectory. Once controllers select a resolution from the menu options, the automation will be provided with intent data (i.e., the automation will have access to the control actions that have been given to the aircraft). CRA will use this information to send a reminder to the appropriate controller for future maneuvers to get the aircraft back on the original trajectory after the conflict has been resolved. CRA will also use the more accurate and up-to-date information in conflict probes to improve conflict detection capabilities.

CRA are enabled by many other NextGen technologies, automation, and procedures, including Data Comm. However, changes that result from these other Drivers are discussed in their respective sections of this report.

Overview of Changes From Implementing CRA

Table 11 provides a visual summary of the changes that will occur as a result of implementing CRA. Additional details regarding these changes can be found in the sections that follow.

Table 11. Overview of the Impact of CRA

	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: •Conflict Resolution Advisories (*New TE*)
Driver otherwise affects existing Task or KSAO:	T78 T79 T82 T83 T84 T134 T135 T147 T148 T152 T155 T159 T321 T327 T334 T338	K19.1 K19.2 K19.3 K19.4 K19.5 K19.6 K19.7 K19.8 K21.3 K22.3 K27.5	Sk5 Sk19 Sk27 Sk42 Sk43 Sk52 Sk53 Sk54 Sk56 Sk57	Ab8 Ab16 Ab24 Ab25 Ab28 Ab30 Ab34	O14	

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC 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) and 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 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 CRA will not require adding to, deleting from, or modifying the language in the Tasks that ARTCC line controllers perform in 2018, CRA will directly affect *how* ARTCC line controllers perform their jobs. More specifically, CRA will have a large impact on how ARTCC line controllers identify and resolve potential and actual aircraft-to-aircraft conflicts. This work is captured in these three current Activities:

- Activity 4: Manage Air Traffic
- Activity 5: Resolve Conflicts
- Activity 11: Respond to Emergencies and Unusual Situations

Activity 4: Manage Air Traffic
If controllers opt to use CRA while performing radar separation of aircraft, they will have another tool and source of information to attend to during these Tasks (*New TE*). CRA will provide controllers with a graphical projection of an aircraft's trajectory on the radar/traffic display in addition to their mental projection (*T78*). CRA will also use automated projections to identify potential aircraft-to-aircraft conflicts in addition to controllers' mental identification of potential conflicts (*T79*).

Once a potential conflict is identified, the method that controllers use to determine control actions to resolve it will be substantively different with CRA. In addition to creating their own self-generated potential control actions, controllers will have to look at CRA-generated control actions (*T82*). Similarly, to prioritize these control actions, controllers will have to evaluate all the control actions that were generated, including those they generated and those the automation generated (*T83*). Because the automation (i.e., CRA) generated the options, the potential control actions are known to the automation. Consequently, it will be theoretically possible for controllers to choose one of the computer-generated options and send it automatically via Data Comm to properly equipped aircraft. Controllers may just have to click the option and not have to type the instruction in Data Comm. However, the instruction will be issued this way only if it is not time critical. Otherwise, the control instruction will likely continue to be issued verbally over the radio (*T84*).

Controllers could use CRA to evaluate requests for flight plan deviations and probe for potential aircraft-to-aircraft conflicts for the requested deviation (*T134*). If there are potential conflicts, CRA will help controllers determine multiple alternative clearances (*T135*).

Activity 5: Resolve Conflicts
To the extent that CRA brings improved trajectory capabilities to identify potential conflicts above and beyond what currently exists with the User Requested Evaluation Tool (URET), the method that controllers use to perform aircraft conflict resolutions may be different. CRA will use its algorithms to identify potential aircraft-to-aircraft conflicts (*T147*). What controllers receive as a notice for aircraft conflict and how it looks could be different (*T148*). As discussed in Activity 1, how controllers determine the control action(s) required to resolve the conflicts will be substantively different. In addition to creating their own self-generated potential actions, they will also have to evaluate CRA-generated control actions (*T152*).

Finally, to the extent that the CRA allows intent information to be known to the automation, alerts and alarms will be more accurate because they will be based on more up-to-date information. False alarms will be less common, and so the suppression of alerts is likely to occur less often (*T155*), as will the restoration of the conflict alert function to normal (*T159*).

Activity 11: Respond to Emergencies and Unusual Situations
Controllers may use CRA to quickly probe for and identify an aircraft-to-aircraft conflict-free path/altitude when determining a plan of action to respond to emergencies (*T321*) or unusual situations (*T334*). They could also use CRA to reevaluate the emergency (*T327*) or unusual situation (*T338*) for aircraft conflict and revise the plan of action if necessary.

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and whether the Driver would change other features of the KSAOs (e.g., changes to the course curriculum required to teach a Knowledge or Skill; increase or decrease in how often a KSAO may be required on the job). Considering both impacts on individual KSAOs allows 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 CRA into the ARTCC work environment does not require deleting or modifying any currently required KSAOs. However, it does require adding two new Knowledges. The need for Knowledge regarding ATC automation will be added under the general *K5* category of human factors in aviation *(New K-ATC automation).* In addition, a new Knowledge will be required to capture information regarding how facility Tools and Equipment will work in conjunction (*New K-Interoperability*). This Knowledge will be added under the general *K19* category of facility Tools and Equipment.

The implementation of CRA will require adding one new Other Personal Characteristic that captures the requirement for controllers to have positive attitudes toward, perceived usefulness of, and perceived ease of use of technology (*New O-Technology Acceptance*). That is, for controllers to use CRA to perform their job efficiently, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges
The introduction of CRA will require that ARTCC line controllers learn new training material associated with the use of the new Knowledge regarding ATC automation (*New K-ATC automation*). Training content that is relevant for the new Knowledge 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 allocation of Tasks to humans and machine; and concepts associated with DSTs, including the decision support tool–decision-making tool continuum, evaluation strategies, and the concept of automation-based algorithms and importance of understanding them.

Controllers will also need to be taught about the new tool, including content associated with all the existing Knowledge subcategories (*K19.1-Types of tools and equipment; K19.2-Functionality of tools and equipment; K19.3-Operation of tools and equipment; K19.4-Interpretation of information provided; K19.5-Limitations; K19.6-Degradation indicators; K19.7-Minor troubleshooting; K19.8-Backup systems*). For example, controllers will have to learn new content with regard to the DSTs, including the algorithms they employ and the source of information

(*K19.4-Interpretation of information provided*). Controllers will also have to learn about the interaction between CRA and other facility Tools and Equipment (*New K-Interoperability*). For example, CRA DSTs allow Host or ERAM to have access to intent information, which will result in substantive changes to the alarms and alerts that controllers experience on these computer systems. Controllers will need to be taught about this difference in the alarms and alerts, what to expect, and what it means operationally.

In addition to new content about the DSTs, controllers will need to learn how to integrate CRA into their work. Controllers will need to be taught about how to identify new CRA-developed aircraft conflict resolution strategies, how to evaluate them, and how to select from among them (*K21.3-Conflict resolution strategies*). Controllers will need to be taught new scanning strategies (*K22.3-Scanning strategies*) for scanning CRA for the DSTs and associated information. Last, controllers will need to be taught how to use CRA DSTs to quickly identify an aircraft conflict-free heading/altitude for use in dealing with emergencies or unusual situations (*K27.5-Emergency assistance techniques*).

Changes to Properties of Knowledges

Although CRA will bring with it the need to teach new curriculum for using the new DSTs for conflict resolution, it will also reduce the need for some of the content currently taught in this area. Because CRA generates strategies for controllers to use in the mitigation of aircraft-to-aircraft conflict, the need for controllers to know how to generate their own conflict resolution strategies will be reduced (*K21.3-Conflict resolution strategies*).

Changes to Curriculum Required to Teach Skills

ARTCC line controllers will need to learn and practice new Skills for resolving aircraft-to-aircraft conflicts using CRA. Skill at developing viable conflict resolution strategies (*Sk42-Conflict Resolution Strategy Development*) will have to include training and practice at identifying the conflict resolution strategies generated by the DSTs in addition to maintaining Skill at developing strategies independently (apart from the automation). Skill at selecting a conflict resolution strategy (*Sk43-Conflict Resolution Strategy Selection*) will have to include training and practice on how to evaluate the computer-generated solutions in addition to maintaining Skill at evaluating controllers' self-generated strategies. There are many potential strategies for how to evaluate computer- and self-generated options, but the appropriate technique will be depend on how well the automation's options take into consideration all the information that controllers can consider. This will determine whether controllers should develop their own strategy and then go to the automation to find their choice or whether they should simply compare the computer-generated options.

Controllers will also need to learn and practice the new CRA functionalities as part of tool and equipment operation. More specifically, they will need training and practice in Skill at using CRA and DSTs effectively (*Sk52-Tool and Equipment Operation*), Skill at recognizing degradation or failure in the automation (*Sk53-Tool and Equipment Status Recognition*), and Skill at responding to degradation or failure of CRA, including performing minor troubleshooting and executing backup procedures, which likely involves returning to the self-generation of aircraft conflict resolution strategies (*Sk54-Tool and Equipment Degradation/Failure Response*).

Further, controllers will need to learn and practice new Skills for emergencies. They will need to be taught and practice using CRA DSTs as a tool for developing viable response options to emergencies or other unusual situations (*Sk56-Emergency Response Development*). Teaching the Skill at selecting a response option for an emergency or unusual situation (*Sk57-Emergency Response Selection*) will now have to include training and practice on how to evaluate the computer-generated solutions in addition to maintaining Skill at evaluating self-generated strategies.

Changes to Properties of Skills

CRA will increase the use of two Skills required for ARTCC line controllers. To the extent that the review/evaluation of DST-provided options requires controllers to shift their focus to the computer-generated options—albeit for just a few seconds—Skills at shifting rapidly between visual sources of information (*Sk5-Attention Switching*) will be used more often. The evaluation of CRA DSTs requires controllers to shift their attention to the DST-provided options and spend extra time evaluating those options. It represents an additional time requirement to controllers during an already busy and time-sensitive situation (i.e., conflict), which could increase stress and consequently increase the need for Skills at performing safely and effectively even in busy or stressful situations (*Sk19-Composure Maintenance*). Note that although the extra time required to manage computer-generated DSTs will not lessen substantively over time, the evaluation process may become easier for controllers as they become more familiar with and gain confidence in the automation's algorithms and proposed solutions.

CRA will also decrease the use of two Skills required for ARTCC line controllers. Controllers will need Skills at mentally projecting an aircraft's future position to identify conflicts less often because the CRA projection tool will allow controllers to see a visual image of the projected path (*Sk27-Object Projection*). If CRA DSTs provide reasonable, useful, and valid options, Skill at developing viable conflict resolution strategies (*Sk42-Conflict Resolution Strategy Development*) may also be needed less often because the automation will be developing and providing options to controllers.

Changes to Properties of Abilities

The implementation of CRA will increase the need for several Abilities for controllers to use the tool effectively. CRA will require the Ability to detect differences between colors to be used more often because it uses color coding to indicate problem status (*Ab8-Visual Color Discrimination*). The evaluation of CRA DSTs requires additional time for controllers to shift their attention to the DST-provided options and spend extra time evaluating those options during an already busy and time-sensitive situation (i.e., conflict). As a result, the implementation of CRA could increase stress and thereby increases the need for controllers to have the Ability to think clearly in stressful situations (*Ab25-Composure*). Note that even though the extra time required to manage computer-generated DSTs will not lessen substantively over time, the increasing need for this Ability may still lessen over time because the evaluation process may become easier for controllers as they become more familiar with and gain confidence in the automation's algorithms and proposed solutions. To the extent that the review/evaluation of DST-provided options requires controllers to shift their focus to the computer-generated options—albeit for just a few seconds—the need will increase for controllers to be able to shift back and forth between two or more sources of information, including the radar/traffic display showing the situation, controller-generated options, and CRA-generated options (*Ab34-Time Sharing*).

CRA is a new tool for controllers, and its implementation represents a substantive change to aircraft conflict resolution. Consequently, the Ability to adjust and adapt to these changing work conditions will become increasingly important (*Ab24-Flexibility*). Because this tool is designed to assist during potential/actual conflicts, it will be critical for controllers to work to understand the new tool and its capabilities. The Ability to apply what they have learned to resolve conflicts quickly and efficiently will also become increasingly important (*Ab28-Learning*).

If controllers opt to use CRA for aircraft conflict resolutions, CRA will decrease the need for controllers to have two Abilities. The Ability to quickly develop a number of strategies for aircraft conflict resolution will be needed less often because CRA DSTs will generate the options for controllers (*Ab16-Fluency of Ideas*). Controllers will not have to generate the options on their own—at least not the initial set of options. The Ability to imagine how an aircraft will look after it is moved will also be needed less often because CRA will provide a graphic representation of proposed trajectories for controllers (*Ab30-Visualization*). Again, controllers will not have to generate this picture mentally.

Changes to Properties of Other Personal Characteristics

The implementation of CRA will increase the importance of controllers' belief that they have influence over the outcomes of events (*O14-Internal Locus of Control*). That is, controllers will need to see themselves as being in control of CRA and its DSTs and hence being responsible for the outcomes of potential/actual conflicts instead of simply responding to the technology.

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Ten potential risks with regard to the implementation of CRA are:

- *Change in culture*: Developmental- and Certified Professional Controller (CPC)-level line controllers will need to demonstrate willingness to learn to use CRA 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 increase the possibility of making an error.
- *Deficiencies in technology*: If the CRA DSTs do not provide reliable or valid options, controllers' selection of one of those options could result in threats to safety or efficiency. In addition, if the algorithms do not take into account the same or more information than controllers would when generating strategies, controllers will be reluctant to use them. Any resulting controller-developed workarounds mean that the tools are not being used to their full potential, which decreases efficiency and results in unrealized benefits from investments in the automation.
- *Degradation or failure of equipment or systems*: If the CRA DSTs fail or degrade, controllers will have to revert to self-generation of conflict resolution strategies. If controllers are unable to quickly revert to this process, the risk for potential conflicts

not to be resolved in a timely manner increases, which poses a risk to safety and efficiency.

- *Improper reliance on automation or procedures*: If controllers are complacent and over rely on CRA DST-generated options, they may simply accept DST-generated options without fully considering whether they represent viable options for conflict resolution in any given circumstance. This could negatively affect safety. In contrast, if controllers do not fully utilize the DST-generated options, which are theoretically optimized to resolve the conflict, and instead rely on their own strategies, this potentially reduces efficiency.
- *Lack of/inadequate training*: Lack of training or inadequate training in the capabilities of CRA and the DST algorithms, including any limitations, may result in poor controller performance in aircraft conflict resolution, which could increase the possibility for error and reduce safety and efficiency.
- *Mixed ATC tools, equipment, or procedures*: If CRA is not implemented in all ARTCCs, or if it is implemented on a significantly different schedule, an added training requirement on the facility will be created if controllers arrive without any training on this tool. This could increase the time required to certify new controllers, thus reducing efficiency.
- *Poor Computer-Human Interface design*: If the CHI that provides line controllers with potential conflict resolution strategies 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), the possibility for error could increase, thus reducing efficiency and safety.
- *Skill decay*: The implementation of CRA has the potential for the decay of Skills required for resolving potential/actual aircraft conflicts without automation. Any resulting lack of preparedness by line controllers to self-generate control options could negatively influence their ability to evaluate the DST-provided options or to self-generate options. This reduces efficiency and increases the possibility of errors.
- *Technology development and maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is unlikely that CRA 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, not until technologies are fielded and are being used by controllers can they 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.
- *Unknown impact of experience*: Controllers with varying levels of experience may perform cognitive information processing involved in evaluating controller-generated versus CRA-generated options differently. Until such differences, if any, are identified, it will be impossible to optimize training or utilization of the conflict resolution strategies.

Note that the introduction of CRA DSTs represents a relatively substantive change to the work environment for ARTCC controllers. Tasks that were the responsibility of controllers are now being performed by automation. However, these are *decision support* tools, not *decision-making* tools. Controllers will still be required to evaluate the DST-provided options as well as to perhaps generate their own options. In sum, the DSTs do not "do" the job for controllers, but rather support controllers in their job. Consequently, AIR did not include the risk regarding Improper Allocation of Tasks to Automation, which addresses challenges associated with monitoring and vigilance.

Driver Impact Summary

CRA is designed to help prevent conflicts from occurring. To the extent that this occurs, the negative impacts of implementing CRA on the ATCS job that occur during an actual conflict situation (i.e., time-critical events that may already be stressful) would not happen as often. However, there is risk that it takes time for controllers to evaluate the CRA-generated options. They have to have time to read and evaluate them all before making a selection, in addition to evaluating any self-generated options. The DSTs are designed to help controllers be more efficient by reducing potential problems that may reduce workload. However, workload will also increase a bit owing to the increase in time for evaluating computer-generated options.

A primary benefit and outcome of CRA is the addition of intent information (i.e., control actions taken by controllers to resolve potential/actual aircraft conflicts) into Host or ERAM that is not incorporated today. Once this information is in the system, it can be shared with others and can also then be used in the projection algorithms.

An additional benefit is the reduction of unnecessary alerts and alarms resulting from the improved and more up-to-date information used in alert/alarm algorithms. Such a reduction could improve the work environment for controllers in many ways. Instead of a "one size fits all" alert/alarm, the alerts and alarms will occur more often when an actual problem exists, which could decrease distractions to controllers, increase trust in automation, and reduce the likelihood that alerts are suppressed inappropriately.

A final benefit is the possibility of using CRA as a training tool. It will give controllers better four-dimensional awareness of the position of aircraft and show them strategies for aircraft-to-aircraft conflict resolutions.

Driver 4: Data Communication

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

Overview of Changes From Implementing Data Communications

Table 12 provides a visual summary of the changes that will occur as a result of implementing the Data Comm system. Additional details regarding these changes can be found in the sections that follow.

Table 12. Overview of the Impact of Data Comm

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver requires changes to the current Task or KSAO list:	Add: • Evaluate the situation to determine if and when to use data communication (*New T)* • Establish data communications with pilots (*New T)* • Verify accuracy of data communication messages (*New T)* • Evaluate the status of data messages in the queue (*New T)* • Prioritize data messages (*New T)* • Verify the communication loop is complete (*New T)* • Manage the interaction between radio and Data Comm systems (*New T)* • Override a message if necessary (*New T)*	Add: • ATC automation (*New K*) Add: • Interoperability (*New K*)	Add: • Service Orientation (*New Sk*) Modify Definition: • Sk10		Add: • Technology Acceptance (*New O*)	Add: • Data Comm (*New TE*)
Driver otherwise affects existing Task or KSAO:	T3 T176 T7 T180 T8 T196 T10 T198 T17 T218 T18 T228 T22 T230	K5.1 K5.2 K10.1 K10.2 K10.3 K10.4 K10.5	Sk1 Sk3 Sk4 Sk6 Sk10 Sk17 Sk18	Ab1 Ab2 Ab3 Ab4 Ab5 Ab11 Ab14	O4 O14	

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	T30	T245	K11.5	Sk20	Ab23		
	T31	T263	K16.2	Sk24	Ab24		
	T32	T267	K16.4	Sk26	Ab28		
	T33	T269	K18.17	Sk52	Ab33		
	T34	T275	K19.1	Sk53	Ab34		
	T35	T283	K19.2	Sk54	Ab35		
	T36	T292	K19.3				
	T37	T322	K19.4				
	T38	T323	K19.5				
	T39	T326	K19.6				
	T40	T328	K19.7				
	T41	T335	K19.8				
	T43	T337	K20.1				
	T84	T340	K20.2				
	T94	T341	K20.3				
	T102		K20.4				
	T136		K20.5				
	T156		K22.3				
	T168		K22.4				
	T202		K22.7				
	T203		K22.9				
	T204		K22.10				
	T206		K22.11				
	T215		K27.5				

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC 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) and 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 a more complete understanding of how the job overall will change.

Changes to Current Task List

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

- Activity 2. Manage Communications

Activity 2. Manage Communications

Because not every pilot-controller communication will be achieved via Data Comm in 2018, establishing and terminating radio communications and all the associated Tasks will still have to be performed for every aircraft. However, additional Tasks associated with the Data Comm process and issuing the Data Comm messages will also have to be performed. These new tasks will need to be added to Activity 2 (*A2-Manage Communications*). More specifically, these include new Tasks associated with evaluating the situation to determine whether and when to use data communications (*New T*) and establishing data communications with pilots (*New T*).

Controllers will need to perform Tasks for verifying the accuracy of Data Comm messages before transmission (*New T*), evaluating the status of Data Comm messages in the queue (New *T*) that will be created by the latency in delivery and receipt of these messages, prioritizing these messages (*New T*), and then verifying that the communications loop is complete before closing out the Task (*New T*). Finally, controllers will need Tasks to manage the interaction between radio and Data Comm systems (*New T*) and to override and intercept Data Comm messages with radio messages and vice versa if necessary (*New T*).

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

- 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 the Impact of Weather
- Activity 9: Manage Airspace
- Activity 11: Respond to Emergencies and Unusual Situations

Activity 1: Establish Situation Awareness
The implementation of Data Comm results in a new tool for controllers to scan (*New TE*). Assuming that the Data Comm system allows ARTCC line controllers to input personal preferences, such as the use of color or the order of messages in a queue, Data Comm will increase the time required for controllers to adjust their workstations (*T7*) and check the workstations' configurations (*T8*). In addition, assuming that equipage information is encoded in some way into the data block, controllers will require more scanning time to gather information regarding whether aircraft are Data Comm equipped (*T10*).

Controllers will have to monitor the Data Comm system for system status (*T17*), and they may also receive equipment and automation status information (*T18*) about Data Comm. This availability of extra information will result in additional time required to receive (*T3*) or give a position relief briefing (*T22*).

Activity 2: Manage Communications
There is the potential for the total number of clearances, instructions, or other messages to be composed and sent to be reduced because controllers can now compose a message one time and send it to multiple aircraft simultaneously. Consequently, Tasks associated with issuing clearances, instructions, or other messages would be performed less often (*T30-T41*). The clearance, instructions, or other messages that are required could be sent either via radio

communications as they are today, by data communications, or by a combination of both. Data Comm may reduce how often controllers have to perform hearback/readback Tasks (*T35, T36, T38, T39*) and the number of corrections (i.e., restating clearance, instruction, or message if required) that have to be made (*T37*) because of hearback/readback errors.

Activity 3: Manage Flight Plan Data
Because not all aircraft will be equipped with Data Comm, controllers will have to consider this when evaluating flight plans (*T43*). For example, to the extent that airspace is restricted to only aircraft that are equipped with Data Comm, controllers will need to know this to determine whether a particular route or usage of airspace is possible.

Activity 4: Manage Air Traffic
Depending on time constraints, the nature of the control instructions, and aircraft equipage, controllers will be able to issue control instructions for radar separation of aircraft (*T84*) or nonradar separation of aircraft (*T94*) and respond to pilot requests for flight path deviations (*T136*) via data communications, radio communications, or both. Controllers may also be able to use Data Comm when coordinating special operations (*T102*). For example, they will be able to issue a single message to multiple aircraft or communicate with a single aircraft more discreetly.

Activity 5: Resolve Conflicts
Controllers will be able to issue messages simultaneously to multiple aircraft if they are Data Comm equipped. This capability may help when resolving conflicts between aircraft because controllers will be able to issue advisories or alerts simultaneously to all other aircraft that are not involved in conflicts (*T156*), thereby focusing on only aircraft that need immediate assistance. Additionally, controllers will be able to issue advisories while performing unsafe altitude (*T168*), airspace violation (*T176*), and unsafe condition (*T180*) resolutions via data communication messages sent simultaneously to multiple aircraft. Data Comm messages will not likely be used during communication with aircraft involved in a potential or actual conflict owing to the latency associated with the delivery and receipt of Data Comm messages.

Activity 6: Manage Traffic Flows and Sequences
If aircraft are appropriately equipped and the messages are not time critical, instead of issuing clearances and revisions via voice communications, controllers may be able to issue these messages via Data Comm. Consequently, when issuing control instructions to sequence departures into existing traffic to optimize flow (*T196*), controllers may send Data Comm messages instead of using radio communications. Additionally, controllers may issue revised control instructions to manage departure flows and sequences (*T198*), verify that the pilot has current approach information (*T202*), issue current approach information (*T203*), and issue appropriate control instructions to implement approach sequences (*T204, T206*) via Data Comm, provided that the messages are not time critical. Finally, to the extent that the cancellation of a TMI requires communication with aircraft, it will also affect how controllers issue instructions to comply with TMIs (*T215*) and coordinate cancellations of TMIs with others (*T218*).

Activity 7: Transfer of Radar Identification
Although the actual transfer of radar identification occurs between two controllers, controllers may have to issue control instructions to aircraft as a result of the timing or terms of transfer. Data Comm could be used to issue these control instructions to pilots. If aircraft are

appropriately equipped and the required messages are not time critical, controllers can issue messages associated with a manual handoff (*T230*), a redirect from airspace (*T228*), and as the result of a rejected pointout (*T245*) via Data Comm.

Activity 8: Assess the Impact of Weather
If aircraft are appropriately equipped and the required messages are not time critical, controllers can solicit PIREPs (*T263*) and disseminate severe weather information (*T267*) via Data Comm. Severe weather avoidance information can also be issued (*T269*) via Data Comm rather than via radio.

Activity 9: Manage Airspace
Last, when managing airspace, if aircraft are appropriately equipped and messages are not time critical, controllers can issue messages regarding temporary release of airspace (*T275, T283*). In addition, instructions concerning changes in airspace status (*T292*) can be issued via data communications rather than voice communications because it allows greater efficiency.

Activity 11: Respond to Emergencies and Unusual Situations
Controllers will be able to use Data Comm to communicate during emergencies and unusual situations. Although controllers will not communicate with an aircraft experiencing a time-critical emergency or during a time-critical unusual situation, they will be able to send a message to multiple aircraft simultaneously regarding the situation, communicate discreetly with a single aircraft, or communicate with a "no radio" (NORDO) aircraft via Data Comm (*T322, T326, T328, T337, T340, T341*). Although an actual emergency would likely not be declared via Data Comm, this method could be used to provide supplemental information that is repetitive (*T323*), thus saving time and allowing controllers to focus on the emergency aircraft. Similarly, it is unlikely that security notifications would be sent out solely via Data Comm, but controllers may issue them via Data Comm to supplement the voice transmission (*T335*).

Changes to Characteristics Required of ARTCC Controllers
When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing lists of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 a more complete understanding of how the job overall will change.

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

Second, the implementation of Data Comm will require changing the definition of the reading comprehension Skill (*Sk10-Reading Comprehension*). The definition will have to change from its current focus on static documents, such as regulations and operating procedures, to include dynamic text-based air traffic information because Data Comm messages will likely include control instructions, weather, and other dynamic information. It will require adding a new Skill at providing preferential service to properly equipped aircraft (*New Sk-Service Orientation*).

Finally, implementation of the Data Comm system will require the addition of a new Other Personal Characteristic to capture the requirement for ARTCC controllers to have positive attitudes toward and be willing to use Data Comm technology (*New O-Technology Acceptance*) to take advantage of its positive benefits. For controllers to use Data Comm to perform their job efficiently, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges

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

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

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

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

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

Controllers will also need to be taught new Knowledges associated with providing ATC services, including composing clearances and control instructions (*22.4- Procedures for composing clearances and control instructions*), as well as new strategies for severe weather avoidance (*K22.9-Strategies for severe weather avoidance*), such as using data communications to send weather-related messages to all aircraft in the area. However, Data Comm messages will not likely be sent to an aircraft being diverted because these would likely be time-critical messages. Controllers may also need to learn new requirements for transferring control of aircraft (*K22.10-Transfer of control requirements*) and for transferring communication of aircraft (*K22.11-Transfer of communication requirements*) because they will no longer be restricted to voice communications for issuing the change of frequencies.

Moreover, controllers may need to be trained on how to most effectively use Data Comm during emergency situations (*K27.5-Emergency assistance techniques*). For instance, controllers could use Data Comm to communicate information quickly to other aircraft not in distress by sending the same message to multiple aircraft simultaneously. Controllers could also use Data Comm to communicate with aircraft who are NORDO or to selectively communicate with only one aircraft without requiring the pilot to make numerous radio frequency changes.

Changes to Properties of Knowledges

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

The implementation of Data Comm will increase the importance of understanding onboard avionics and their capabilities (*K11.5-Avionics*) and the importance of knowing which specific aircraft are Data Comm equipped, which is contained in the flight plan (*K16.4-Evaluation strategies*) and also likely in the data block (*K19.4-Interpretation of information provided*).

One Knowledge will be used less often. The compulsory position reporting requirements that are typically part of the ARTCC nonradar environment will be used less often (*K22.7-Nonradar procedures*) because controllers will be able to contact pilots directly using Data Comm system.

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

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

Additionally, because Data Comm is a new tool, controllers will need to be taught Skills associated with effectively using the Data Comm (*Sk52-Tool and Equipment Operation*) including input devices, Skill at recognizing when the tool is malfunctioning (*Sk53-Tool and Equipment Status Recognition*), and Skill at responding to malfunctions by conducting minor troubleshooting or initiating backup procedures (*Sk54-Tool and Equipment Degradation/Failure Response*).

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

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

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

Changes to Properties of Abilities

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

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

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

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

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

Changes to Properties of Other Personal Characteristics

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

Potential Driver-Induced Risks to Safety and Efficiency

The implementation of NextGen technologies, automation, and procedures introduces the possibility of risks into the NAS. A comprehensive list of the 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Twelve potential risks with regard to the implementation of Data Comm are:

- *Best equipped, best served strategy*: The BEBS strategy is proposed to require controllers to give preference to appropriately equipped aircraft in certain situations. However, the requirement for controllers to consider BEBS in addition to the more critical considerations of safety and efficiency when engaging ATC Tasks may lead to increased cognitive workload and thus could increase the possibility for error.
- *Change in culture*: Developmental- and CPC-level line controllers will need to demonstrate willingness to learn to use Data Comm for communicating with aircraft under certain circumstances. A lack of interest in learning and using Data Comm may lead to underutilization and also the creation of very different classes of controllers within a facility (i.e., early adopters versus late or non-adopters), which may reduce efficiency and could increase the possibility of making an error.
- *Coordination of multiple stakeholders*: NextGen is affecting—and will continue to affect—numerous diverse stakeholders. Significant intra- and inter-team coordination will be required to build and implement the Data Comm system and accompanying policies and procedures that will govern its use. If this coordination is not handled effectively, lack of standardization in the design, implementation, or use of Data Comm could result. This decreases predictability, which poses a threat to safety and could reduce efficiency as controllers work to adapt to the inconsistencies.
- *Deficiencies in technology*: Latency or delay in Data Comm message transmission and response will shift controllers away from a synchronous type of communication (e.g., instant messaging) and toward an asynchronous type of communication (e.g., email). The asynchronous type of communication will fragment controllers' flow of work Tasks and will introduce work interruptions, which may reduce efficiency and increase the possibility for error. In addition, it may increase the possibility of miscommunication or communication interruptions resulting from delayed messages and could reduce safe and effective operations.

- *Degradation or failure of equipment or systems*: If the Data Comm system fails or degrades, controllers will have to revert to radio communications. This shift to pass information previously sent over Data Comm that is now required to be sent over radio will be more time consuming and create a new interruption to the work flow, which will reduce efficiency and increase the possibility for error.
- *Lack of/inadequate training*: Lack of training or inadequate training in the capabilities of the Data Comm, including any limitations, may result in poor controller performance in communication management and thus reduce efficiency and increase the possibility of error.
- *Loss of party line information*: A loss of party line information—information that is available to multiple pilots via the radio when a single controller is interacting with a pilot—is expected as a result of the use of Data Comm. This loss of shared SA could result in controllers having to communicate separately with many pilots. This could also have a negative impact on safety because some information may be omitted altogether.
- *Mixed aircraft equipage*: Data Comm will not be installed on all aircraft. If controllers do not have easy access to near real-time and current information on their displays regarding aircraft equipage, this could increase cognitive workload and decrease efficiency. Additionally, controllers will have to differentiate which is the most appropriate method of issuing instructions based on aircraft equipage. This could potentially further increase cognitive workload and further decrease efficiency.
- *Mixed ATC tools, equipment, or procedures*: If Data Comm is not implemented in all ARTCCs, or if it is implemented on a significantly different schedule, the resulting differences in communication capability poses several risks, including the inability to communicate across data systems and difficulty in transferring aircraft across airspace boundaries. This could reduce efficiency and increase the possibility for error.
- *Poor Computer-Human Interface design*: If the CHI that provides line controllers with Data Comm messages is not designed to present the information in a meaningful way or is not well integrated into existing systems (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), the possibility for error could increase, thus reducing efficiency and safety.
- *Skill decay*: Data Comm will decrease the use of skills associated with creating and issuing clearances and instructions via radio, including skill at picking up subtle verbal cues from others. The removal of subtle but rich verbal cues may result in controllers being less adept at situation assessment and could lead to communication errors (e.g., when gathering information from pilots), both of which have a negative impact on safety and efficiency.
- *Technology development and maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is unlikely that Data Comm will be released into the NAS with known deficiencies, the full impact of using it in an operational context may be not realized until the system goes live. For example, the system may not have reliable interoperability with other systems. In addition, not until technologies are fielded and are being used by controllers can they

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

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

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

Data Comm adds new Tasks but does not delete any. Thus, its introduction results in an additional training requirement as well as an increase in the mental workload of controllers who will be responsible for working with two forms of communication instead of one. However, the implementation of Data Comm will result in reduced congestion on radio frequencies, which will free up communication channels for more important messages. Although the Data Comm system will reduce certain errors such as hearback/readback, it will simultaneously increase controller workload—and hence the possibility of error—through Task fragmentation and Task switching. It is not yet known how the responsibility for Data Comm will be divided between Radar or “R-side” and Data or “D-side” controllers. Depending on how responsibilities are divided by the position at the sector, the Data Comm system could have considerably different impacts on the subsequent workload of each position.

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

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

Driver 5: 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 predefined inter- and intra-facility airspace configurations and bidirectional 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 while moving the boundaries and ownership of the airspace around air routes instead.

Overview of Changes From Implementing FAM

Table 13 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 13. 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: • T286 • T290 • T293 • T296 • T300 • T304 Modify: • Identify that another controller's airspace is needed (*Modified T272*) • Evaluate options for temporarily releasing airspace (*Modified T280*)				Add: • Technology Acceptance (*New O*)	

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
Driver otherwise affects existing Task or KSAO:	T43 T46 T47 T98 T102 T134 T195 T197 T200 T205 T270 T273 T274 T276 T282 T284 T285 T288 T297 T298 T299 T301 T302 T303 T305 T306 T307 T310 T316 T321 T322 T326 T327 T334 T338 T341	K2.7 K7.1 K16.4 K17.4 K18.7 K18.8 K18.9 K18.15 K18.17 K18.18 K22.3 K22.4 K22.9 K22.10 K22.11 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 ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC 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) and 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 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 ARTCC line controllers perform in one out of the 11 ARTCC job Activities:

- 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 will make decisions about the new airspace configuration and will input these decisions directly into automation, AIR assumes that some Tasks associated with managing airspace will no longer be necessary. Supervisors or traffic managers will change the automation to reflect the change in airspace status instead of ARTCC line controllers (*T286*, *T290*). Updating status information areas will no longer be required because new airspace configurations will automatically show up on the radar/traffic display (*T293*). 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 (*T296*). Note that controllers will not discontinue using all memory aids but rather just the ones that reflect airspace and route configuration. Automation will configure communication and reflect airspace changes (*T300, T304*) for controllers, freeing up controllers to perform other Tasks.

In addition to deleting some Tasks associated with managing airspace, FAM will require the modification of Task statements. The Task *Determine that another controller's airspace is needed* (*T272*) will be changed to *Identify that another controller's airspace is needed* (*Modified T272*) 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 *Evaluate feasibility of temporarily releasing airspace* (*T280*) will be changed to *Evaluate options for temporarily releasing airspace* (*Modified T280*). Controllers will not be evaluating just 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 ARTCC job Tasks, the implementation of FAM will have an impact on *how* controllers will perform the Tasks in seven of the 11 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 ARTCC line controllers need to consider when evaluating flight plans (*T43*). If controllers know in advance that a route or airspace configuration is going to change, flight plans affected by that change will need to be evaluated. Changing routes or configurations will need to be considered when making decisions about clearances. ARTCC airspace has larger geographical areas, and typically flights operating in those areas have longer trajectories with fewer time constraints than what occurs in TRACON airspace, so the clearances issued for flight plans and the amendments made to flight plans are likely to be affected to a lesser degree by changes to airspace and air route reconfigurations. However, clearances issued will still need to include instructions about changing airspace configuration or route (e.g., route, altitude, frequency) when appropriate (*T46*). 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 (*T47*).

Activity 4: Manage Air Traffic
FAM can 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 part of the plan of action (*T98*). This plan will require less coordination on the landline because ARTCC line controllers will be assigned a preplanned airspace or route configuration that works around the special operation (*T102*). 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 being used as a response to special operations, FAM will provide controllers with more information to consider when evaluating requests from pilots to deviate (*T134*). They will need to be aware if a requested route is about to be changed or if the airspace around the route is about to be 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 (*T134*).

Activity 6: Manage Traffic Flows and Sequences
ARTCC line controllers' decision-making process for determining and reevaluating departure sequences (*T195, T197*) and arrival sequences (*T200, T205*) 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 will be more changes in airspace and air route structures.

Activity 8: Assess Impact of Weather
FAM will provide ARTCC 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 the change. They will relay information and coordinate with TMU or the supervisor (*T270*), who will make the final decision.

Activity 9: Manage Airspace
If FAM is selected as an option for providing temporary release of airspace, the method for releasing the airspace will change. Controllers will request use of the airspace (*T273*) from the TMU or the supervisor instead of another controller. Likewise, controllers will receive approval including any conditions (*T274*) from the TMU or the supervisor instead of another controller. The TMU or the supervisor will decide whether to approve or deny FAM change requests (*T282*). Controllers will not return the airspace to the other controller but instead will inform the TMU or the supervisor when it is no longer needed (*T276*). Then the TMU or the supervisor will notify the appropriate controller that the airspace has been returned (*T285*). Overall, the coordination of changes in airspace status will require less coordination between controllers (*T284, T288*). 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 the facility.

Although FAM will remove some of the Tasks required of ARTCC line controllers and shift some responsibility to the 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 the Tasks associated with transferring and receiving position/sector for reconfiguration, except those Tasks that have been removed by automation to automation communication (*T300, T304*), will be done more often (*T297–T299, T301–T303, T305–T307*).

Activity 10: Manage Resources
FAM will become an additional strategy for reducing the workload of ARTCC line controllers. Controllers will be able to identify airspace or air route reconfigurations as a possible workload reduction strategy (*T310*) and request the change from the TMU or the 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 that might be affecting controllers differentially (*T316*).

Activity 11: Respond to Emergencies and Unusual Situations
Finally, FAM will provide ARTCC line controllers with more options for responding to emergencies or unusual situations. Controllers will be able to select changing airspace or air routes as a plan of action for dealing with emergencies (*T321*) or unusual situations (*T334*). Being able to modify airspace to more closely fit an operation will help controllers isolate small sections of airspace. Controllers will be better able to focus on the problems at hand (*T322*) 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, the coordination of information between controllers will also be reduced (*T326, T341*). 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 will have to reevaluate the emergency or unusual situation, and considering airspace and route changes will become part of this reevaluation (*T327, T338*).

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 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 and does not require deleting or modifying the language of these worker requirements. It does, however, require adding a new Other Personal Characteristic related to the need for controllers to have positive attitudes toward, 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 ARTCC environment in terms of automation. For FAM to be used most effectively to help ARTCC 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, ARTCC 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 the TMU, is to balance out traffic and thus the 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 (*K18.9-Sector configurations*) resulting from airspace reconfigurations. They will also need to be taught any new facility traffic flows (*K18.15-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 (*K18.17-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 (*K18.18-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 severe weather avoidance (*K22.9-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. Further, as airspace boundaries change, transfer of control points (*K22.10-Transfer of control requirements*) and transfer of communication points (*K22.11-Transfer of communication requirements*) may change, requiring controllers to learn how different configurations will affect the 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 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 (*K25.2-Departure Routes*) 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, which will not be static the 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 (*K18.7-Airspace dimensions*), adjacent airspace (*K18.8-Adjacent airspace*), and sector configurations (*K18.9-Sector configurations*) will also become more important. Controllers will have to understand these at a deeper level to quickly manipulate the information about changes to airspace or air route configurations. However, the differences in ARTCC and TRACON airspace in terms of density and temporal urgency suggest that this change will not be as substantive for ARTCC line controllers as it will be for TRACON line controllers.

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 previously required coordination and communications because the plan for dealing with the special operation will now be understood by controllers and the TMU, thus decreasing 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 back and forth between different airspace and air route configurations. Although the difference in ARTCC and TRACON airspace in terms of density and temporal urgency suggest that this change will not be as substantive for ARTCC line controllers as it will be for TRACON line controllers, it will still require new Skills to be taught to and practiced by ARTCC line controllers. ARTCC line controllers have to be taught and practice the Skill of 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 the Skill of returning quickly to managing traffic after the air route or space configuration has changed (*Sk6-Interruption Recovery*). Skill in consistently applying the procedures even though they will be changing more often than today (*Sk12-Rule Application*)—although this will happen less often than in TRACON facilities—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 the strategies that 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 in 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 noninvolved 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 the 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 monitor 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 occur 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 the 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 have to deal with and consider not only the current configuration but also a large number of potentially different configurations that could be pending.

Further, 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 or 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 the 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 believe that they are in control of the changes in route and airspace configurations that the automation is making on their radar/traffic displays.

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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Five potential risks with regard to the implementation of FAM are:

- *Improper reliance on automation or procedures*: If controllers do not feel comfortable requesting changes to airspace or route structure, they may not use this option when such changes are appropriate. This will reduce the very efficiencies that FAM was designed to provide.
- *Lack of/inadequate training*: Lack of training or inadequate training in new procedures, the intensive coordination required to achieve resectorization resulting from the implementation of FAM, and any limitations of the associated technology 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 ARTCCs, or if it is implemented on a significantly different schedule, 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 nonstandard 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 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, not until technologies are fielded and are being used by controllers can they 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

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 better use the 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 the workload, it could still create more work for controllers because of the additional coordination required with the 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 ARTCC 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.

Driver 6: High Altitude Airspace

High Altitude Airspace in NextGen mid-term is designated as airspace between FL 340 and FL 590 that will be restricted to high-performance aircraft (i.e., aircraft equipped with Data Comm and RNAV/RNP capability). This airspace can be broken down into two types: generic and nongeneric. Generic high altitude airspace (GHAA) will exist where traffic is mainly in level flight, the level of complexity is low with regard to crossing patterns, and traffic density is low to moderate. Nongeneric high altitude airspace (NGHAA) will exist where there are climb and descent profiles, the level of complexity is greater with regard to crossing patterns, and there are unique local features (e.g., special activity airspace). Note that although Data Comm and PBN support High Altitude Airspace, the impacts of these NextGen Drivers on controllers will be described in their respective sections.

For this report, AIR assumed that GHAA and NGHAA are separate airspaces that will not switch from one type to the other. It is also assumed that GHAA will not be combined or decombined with any airspace other than other GHAA. These assumptions are being made on the basis that generic sectors are being created specifically to allow greater staffing flexibility to better respond to fluctuations in traffic demand. Controllers managing generic airspace will be interchangeable intra-facility, and to a limited extent, the control of generic airspace will be able to be moved to other facilities. Further, generic airspace will be adaptable to allow reconfigurations of sector size and/or shape and will be able to be combined. As a result of these assumptions, AIR proposes that the job of controllers who will manage NGHAA will look like the job of the NextGen 2018 ARTCC line controllers as described in this report. They will use the same tools and concepts. However, controllers who will manage GHAA will be a new type of controller. They will perform fewer Tasks and need less training. Consequently, the description below is of the impact of the implementation of High Altitude Airspace on controllers managing the GHAA portion of this airspace. With only a few exceptions (e.g., Knowledges that will need to be taught to all ARTCC controllers regarding this new airspace), this description is *only* about the impact on the job of controllers working GHAA. Such exceptions are noted in the text.

Overview of Changes From Implementing High Altitude Airspace

Table 14 provides a visual summary of the changes that will occur to the job of the GHAA controller as a result of implementing High Altitude Airspace. Additional details regarding these changes can be found in the sections that follow.

Table 14. Overview of the Impact of High Altitude 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:	Delete:		Delete:	Modify:		Add:	
	•T42	•T190	•K7.8	•Sk10		•Technology Acceptance (*New O*)	
	•T43	•T191	•K8.11				
	•T44	•T192	•K13.1				
	•T45	•T193	•K13.2				
	•T46	•T194	•K13.3				
	•T104	•T195	•K13.4				
	•T105	•T196	•K13.5				
	•T106	•T199	•K16.5				
	•T107	•T200	•K18.6				
	•T108	•T201	•K18.10				
	•T109	•T202	•K18.11				
	•T110	•T203	•K18.12				
	•T111	•T204	•K18.13				
	•T112	•T207	•K22.12				
	•T113	•T272	•K23.2				
	•T114	•T273	•K23.3				
	•T115	•T274	•K23.5				
	•T116	•T275	•K24.2				

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	•T117 •T118 •T119 •T120 •T121 •T122 •T123 •T124 •T125 •T126 •T127 •T128 •T129 •T130 •T131 •T132 •T183 •T184 •T185 •T186 •T187 •T188 •T189	•T276 •T277 •T278 •T279 •T280 •T281 •T282 •T283 •T284 •T285 •T286 •T287 •T288 •T289 •T290 •T291 •T292 •T293 •T294 •T295 •T296 •T297 •T298 •T299 •T300 •T301 •T302 •T303 •T304 •T305 •T306 •T307	•K24.3 •K24.4 •K24.5 •K24.6 •K24.7 •K24.8 •K24.10 •K24.11 •K25.1 •K25.2 •K25.3 •K25.4 •K25.5 •K25.6 •K25.7 •K27.1 •K27.4 •K27.6 •K27.7				
Driver otherwise affects existing Task or KSAO:	T14 T24 T25 T26 T27 T28 T29 T86 T87 T88 T89 T90 T91 T92 T93 T94 T95 T96	T180 T181 T182 T239 T240 T241 T242 T243 T244 T245 T246 T247 T248 T249 T250 T251 T252 T253	K2.4 K2.5 K7.1 K7.4 K7.7 K8.1 K8.4 K11.5 K15.1 K18.7 K18.9 K18.15 K18.16 K18.17 K21.3 K22.7 K22.9 K26.1	Sk1 Sk2 Sk3 Sk6 Sk10 Sk23 Sk28 Sk32 Sk33 Sk34 Sk35 Sk36 Sk37 Sk38 Sk39 Sk40 Sk41 Sk42	Ab1 Ab2 Ab3 Ab4 Ab5 Ab11 Ab14 Ab22 Ab24	O2 O4 O11 O12	

	Tasks (T)		Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	T97	T254	K26.2	Sk43			
	T98	T255	K26.3	Sk44			
	T99	T262	K26.4	Sk45			
	T100	T263	K27.2	Sk46			
	T101	T264	K27.3	Sk47			
	T102	T265	K27.5	Sk48			
	T103	T266	K27.8	Sk49			
	T133	T267	K27.9	Sk50			
	T134	T268		Sk51			
	T135	T269		Sk55			
	T136	T270		Sk56			
	T137	T271		Sk57			
	T147	T309		Sk58			
	T148	T310					
	T149	T311					
	T150	T312					
	T151	T313					
	T152	T314					
	T153	T316					
	T154	T320					
	T155	T321					
	T156	T327					
	T157	T332					
	T158	T334					
	T159	T338					
	T160						
	T161						
	T162						
	T163						
	T164						
	T165						
	T166						
	T167						
	T168						
	T169						
	T178						
	T179						

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of GHAA controllers, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks) and 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 a more complete understanding of how the job overall will change.

Changes to Current Task List
The implementation of High Altitude Airspace will require substantive changes to the list of ARTCC Tasks. Many Tasks currently performed by line controllers will not be performed, but this impact is on line controllers working GHAA only. Other controllers working other sectors will not be affected in this way. The changes are part of four of the 11 ARTCC job Activities:

- Activity 3. Manage Flight Plan Data
- Activity 4. Manage Air Traffic
- Activity 6. Manage Traffic Flows and Sequences
- Activity 9. Manage Airspace

Activity 3. Manage Flight Plan Data
The first Tasks to be deleted are associated with Activity 3. For aircraft to fly in High Altitude Airspace, they have to be properly equipped. This information will be part of the flight plan data. Therefore, it is unlikely that ARTCC line controllers in this airspace will perform Tasks associated with *Entering flight plan data* (*T42–T46*); all aircraft flying in generic High Altitude Airspace will have approved flight plans in the NAS already. However, Tasks associated with amending flight plan data will still be required.

Activity 4. Manage Air Traffic
Several Tasks that are part of Activity 4 will also not be required by ARTCC line controllers working GHAA. Because they will be managing a more homogenous mix of air traffic, they will not perform many of the Tasks associated with this Activity that concern providing assistance to specific types of aircraft. Tasks for *Processing requests for VFR flight following* (*T104–T114*) will not be performed because there should not be any VFR aircraft operating in this airspace. Consequently, Tasks for *Providing radar assistance to VFR aircraft* (*T115–T126*) will not performed either. Finally, controllers will not have to perform Tasks for *Monitoring uncontrolled objects/aircraft* (*T127–T132*) because there will not be any uncontrolled objects/aircraft in this airspace.

Activity 6: Manage Traffic Flows and Sequences
Because ARTCC line controllers working GHAA will be primarily maintaining in-trail separation, the majority of Tasks associated with *Managing departure flows and sequences* (*T183–T196*) and with *Managing arrival flows and approach sequences* (*T199–T204, T207*) will not occur. There should be little or no climbing and descending in this airspace.

Activity 9. Manage Airspace
Assuming that GHAA does not switch between being generic and nongeneric and does not get combined or decombined with other airspace, ARTCC line controllers working this airspace will not have to perform any of the Tasks associated with managing airspace (*A9-Manage Airspace*), Including Tasks for *Requesting temporary release of airspace* (*T272–T277*), *Responding to requests for temporary release of airspace* (*T278–T286*), *Responding to changes in airspace status* (*T287–T296*), *Transferring position/sector for reconfiguration* (*T297–T301*), and *Receiving position/sector for reconfiguration* (*T302–T307*).

Changes to How Tasks Are Performed

In addition to requiring changes to the Task list, High Altitude Airspace will also affect *how* ARTCC line controllers perform many of their job Tasks, but the impacts are on controllers working GHAA only. Other controllers working other sectors will not be affected in the ways described below. AIR proposes that the High Altitude Airspace will most directly affect how Tasks that are a part of seven of the 11 Activities will be performed:

- Activity 1: Establish Situation Awareness
- Activity 2. Manage Communications
- Activity 4. Manage Air Traffic
- Activity 5. Resolve Conflicts
- Activity 7. Transfer of Radar Identification
- Activity 8. Assess Impact of Weather
- Activity 10. Manage Resources
- Activity 11. Respond to Emergencies and Unusual Situations

Activity 1: Establish Situation Awareness

Aircraft flying GHAA will be equipped with ADS-B Out and so will be represented on the radar/traffic display even if the radar system is not functioning. Consequently, nonradar separation procedures will only rarely be performed in this airspace. This will result in controllers requesting aircraft position reports much less often (*T14*).

Activity 2. Manage Communications

Access to High Altitude Airspace will be restricted to aircraft equipped with Data Comm. Consequently, controllers working this airspace will likely perform Tasks for *establishing and terminating radio communications* (*T24–T29*) less often (e.g., receiving initial radio communication from pilot, determining most appropriate transmitter-receiver site) and Tasks for establishing data communications more often.[11]

Activity 4. Manage Air Traffic

Tasks associated with *Performing nonradar separation of aircraft* (*T86–T95*) will be performed much less often because all aircraft flying in High Altitude Airspace will be ADS-B Out equipped and will be displayed on the radar/traffic display. ARTCC line controllers assigned to GHAA will work more homogenous airspace with less complex traffic patterns than lower altitude airspace. To the extent that the goal of high altitude is to clear the way for fewer interruptions, Tasks associated with *Responding to special operations* (*T96–T103*), such as evaluating the impact of operations and coordinating with others, will be performed much less often because special operations are less likely to take place in GHAA. Tasks associated with *Responding to pilot requests for flight plan deviation* (*T133–T137*), such as receiving and evaluating requests to deviate, will be performed less often because aircraft in this airspace will likely be on an assigned trajectory or a trajectory of their choosing and will less likely need to be vectored. The impact of severe weather is somewhat less at these higher altitudes, and therefore the demands of operations in GHAA will be more homogenous.

[11] Note that Tasks associated with Data Comm are not on the current ARTCC line controller Task list. However, they will be added to the Task list for NextGen mid-term controllers. Please see Data Comm in this section to learn more about the impacts of that Driver on the job.

Activity 5. Resolve Conflicts

GHAA will have no transitions, less climbing and descending, and more homogenous operational requirements (including homogenous aircraft equipage requirements), so ARTCC line controllers working this airspace should have fewer areas for potential conflict. Consequently, controllers will carry out Tasks associated with *Performing aircraft conflict resolutions* (*T147–T159*) less often. Controllers will rarely have to carry out Tasks for *Performing unsafe altitude resolutions* (*T160–T169*). Last, because unsafe conditions are less likely to occur in this airspace (e.g., the impact of weather is less, there is less traffic, there is less climbing and descending), controllers will be less likely to perform Tasks associated with *Issuing unsafe condition advisories* (*T178–T182*).

Activity 7. Transfer of Radar Identification

Because GHAA will be set aside for properly equipped aircraft and will require less complex traffic operations, line controllers managing this airspace will be required to perform Tasks for *Issuing pointouts* (*T239–T246*) and *Responding to pointouts* (*T247–T255*) much less often. There should be a less need for aircraft in this airspace to deviate into other airspace.

Activity 8: Assess the Impact of Weather

ARTCC line controllers working GHAA will likely have to perform Tasks for responding to severe weather information (*T262–T271*) less often because the impact of weather in these extreme high altitudes is generally less than in lower altitudes.

Activity 10. Manage Resources

Many of the Tasks associated with *Managing personal and position workload* (*T309–T314*) are likely to be performed less often because the chances of being overloaded in GHAA will not be great. The airspace is not complex (e.g., more homogeneous aircraft in terms of equipage, more homogeneous airspace, little/no climbing and descending). Also, it will be less important for GHAA controllers to *Maintain internal en route facility awareness* (*T316*) because they will likely interact with adjacent sectors less often.

Activity 11. Respond to Emergencies and Unusual Situations

When emergencies and unusual situations do occur in GHAA, they could be easier for GHAA line controllers to handle because there will be fewer differences in equipage and other factors to consider. Controllers will still have to evaluate the situation, determine the appropriate plan of action, and reevaluate the situation for emergencies (*T320, T321, T327*) and for unusual situations (*T332, T334, T338*), but the process for these Tasks is likely to be less complex for GHAA because of its lack of restrictions.

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of High Altitude Airspace on the characteristics required of GHAA controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 a more complete understanding of how the job overall will change.

Changes to Current Knowledges, Skills, Abilities, or Other Personal Characteristics List
The introduction High Altitude Airspace into the ARTCC environment will not require adding, deleting, or modifying the language of currently required Abilities. However, it does require deleting many Knowledges for GHAA controllers, thus making this new ARTCC role substantively different from any existing ATCS role. In addition, one Skill will need to be modified and one Other Personal Characteristic will need to be added.

With regard to the deletion of Knowledges, ARTCC controllers managing GHAA will not need to know about terrain features because they will manage only aircraft at very high altitudes (*K7.8-Terrain features*). Similarly, Knowledge of many facility-specific characteristics will not be required, including local navigation aids (*K18.6-Local navigation aids [NAVAIDs]*), runway configurations (*K18.10-Runway configurations*), local geography (*K18.11-Local geography*), the influence of local topography (*K18.12-Impact of local topography on flight*), and local obstructions or other obstacles (*K18.13-Local obstructions/obstacles*).

GHAA controllers will not need to know about the conditions under which aircraft can fly under VFR rules (*K8.11-Weather minimums*) because they will not be conducting operations near the ground and all of the aircraft flying in their airspace will fly under positive control, or IFR. Because these controllers will not be responsible for controlling aircraft to the ground (airport) level, they will need to know general airport characteristics, such as what the airport identifier represents (*K13.1-Decoding airport identifiers)*, the types services and equipment offered at airports (*K13.2-Services and equipment)*, the various types of airport lighting (*K13.3-Types of airport lighting*), the basic notion of noise abatement (*K13.4-Noise abatement concepts*), and types of obstructions/obstacles (*K13.5-Types of obstructions/obstacles*), all to a lesser degree. GHAA controllers will not need to know about entering flight plan data because this will be completed before aircraft reach this airspace (*K16.5-Flight plan processing*). However, they will still be responsible for amending flight plans as necessary.

Some services will not be provided by GHAA controllers and consequently the Knowledges associated with them will not be required. GHAA controllers will not provide radio navigation services because aircraft in this airspace will navigate by satellite-based systems; consequently, controllers will not need to know these procedures (*K23.2-Direction finding (DF) services*). Because VFR operations will not take place in this airspace, GHAA controllers will not need to apply Knowledge of VFR flight following (*K23.3-Visual flight rule [VFR] flight following*). Aircraft will not be allowed to fly in this airspace unless they are being separated by air traffic control; therefore, GHAA controllers will not need to know procedures for working with these aircraft (*K23.5-Uncontrolled aircraft*). Finally, approach control service will not be provided by these controllers, so they will not need to know these procedures (*K22.12-Approach control service*).

GHAA controllers are likely handing off aircraft in their sector to another ARTCC controller who is managing the airspace below them. Consequently, these controllers will not need to know many of the Knowledges associated with approach/arrival operations, including instrument approaches (*K24.2-Instrument approaches*), arrival routes (*K24.3-Arrival routes*), standard terminal arrival routes (*K24.4-Conventional standard terminal arrival routes [STARS]*), area navigation arrival routes (*K24.5-Area navigation [RNAV-enabled] arrival routes*), and arrival sequences (*K24.11-Arrival sequence*). Certain special approaches will not be managed from this airspace, including visual approaches (*K24.6-Visual approaches*), missed approaches (*K24.7-Missed approaches*), VFR arrivals (*K24.8-Visual flight rule [VFR] arrival*), or practice approaches (*K24.10-Practice approaches*), so these controllers will not need to know these procedures. Similarly, GHAA controllers will not need to know many of the Knowledges associated with departure operations, including sequencing departures (*K25.1-Departure sequences*), departure routes (*K25.2-Departure routes*), information required for departing aircraft (*K25.3-Departure information*), standard instrument departures (*K25.4-Conventional standard instrument departures [SIDs]*), RNAV-enabled departure routes (*K25.5-Are navigation [RNAV-enabled] departure routes*), VFR departures (*K25.6-Visual flight rule [VFR] departures*), or procedures associated with a missed approach (*K25.7-Missed approach procedures*).

Certain emergencies and unusual situations will be largely out of scope for the GHAA controller. For example, these controllers will not need to know about ground emergencies or operations (*K27.1-Types of ground emergency or unusual operations*). In addition, because any aircraft in High Altitude Space experiencing an emergency will be descending rapidly out of that airspace and will likely be handed off to the controller responsible for the airspace below, specific emergencies/unusual situations will likely not be handled by the high altitude controller, including search and rescue (*K27.4-Search and rescue*). Knowledge of the procedures associated with these situations will also not be required, including requirements for coordinating with other emergency operations organizations (*K27.6-Coordination requirements*) and requirements associated with notifying others in case of an emergency (*K27.7-Notification requirements*). Consequently, GHAA controllers will not need to know these Knowledge topics.

In addition to the deletion of these 41 Knowledges, the implementation of High Altitude Airspace requires the modification of the definition of one Skill. The definition of reading comprehension (*Sk10-Reading Comprehension*) will have to be modified from its current focus on static documents such as regulations and operating procedures to include dynamic text-based air traffic information because GHAA aircraft will be Data Comm equipped. In addition, it will require the addition of a new Other Personal Characteristic—the need for controllers to have positive attitudes toward, perceive the usefulness of, and perceive the ease of use of technology (*New O-Technology Acceptance*). For controllers to work successfully in GHAA, they must be comfortable using automation and working with aircraft that are equipped with many new technologies.

Changes to Curriculum Required to Teach Knowledges

In addition to GHAA controllers requiring substantively fewer Knowledges than their line controller counterparts, the implementation of High Altitude Airspace changes the curriculum required to teach the Knowledges. In some cases, the new content will need to be taught to all ARTCC controllers; in other cases, it is specialized Knowledge that will be required only for the GHAA controller. First, all ARTCC controllers will need to be taught this new High Altitude Airspace role (*K2.4-Types of ATC positions in each facility type*) and its responsibilities (*K2.5-ATCS responsibilities for each position in each facility type*). The implementation of High Altitude Airspace will likely require the development of new GHAA routes, which will need to be taught to GHAA controllers (*K7.1-Air route structure*). Aeronautical route charts (*K7.4-Aeronautical charts*) will be changed to reflect the new airspace and routes and will also have to be taught to GHAA controllers. Because of the extreme altitude in this airspace, high altitude controllers will have to be taught the impact of weather on high altitude flight operations (*K8.1-Atmospheric properties*). GHAA will likely be a new airspace classification. Consequently, all line controllers will have to be taught the new classification (*K15.1-Airspace classification*). GHAA controllers will also need to be taught the specific characteristics of the new sectors, including the airspace dimensions (*K18.7-Airspace dimensions*), and sector configurations (*K18.9-Sector configurations*). All controllers will need to learn the new facility traffic flows (*K18.15-Facility traffic flows*) and facility-specific directives and procedures (*K18.17-Facility specific directives and procedures*) concerning High Altitude Airspace.

Changes to Properties of Knowledges

GHAA controllers will rarely need to apply their Knowledge of nonradar procedures (*K22.7-Nonradar procedures*) because all aircraft will be ADS-B Out equipped (and hence will be visible to controllers on the radar/traffic display even in the event of a radar failure). For this reason, controllers will also use their Knowledge about the requirements or procedures related to position reporting (*K7.7-Compulsory position reporting*) much less often.

Variable weather conditions, such as winds aloft, will become more important to controllers working GHAA (*K8.4-Weather features*). Line controllers will need an increased understanding of avionic capabilities required for GHAA operations (*K11.5-Avionics*). GHAA operations are more homogenous and less complex with few if any aircraft climbs/descents and changes in direction or speeds. Consequently, Knowledge of hot spots (*K18.16-Areas with high potential for confliction [hot spots]*) and Knowledge of strategies for separation of aircraft, including those required for resolving conflicts (*K21.3-Conflict resolution strategies*), will be used less often by GHAA controllers. Because weather has less of an impact on operations at high altitudes, GHAA controllers will not use Knowledge of strategies for avoiding severe weather as often (*K22.9-Strategies for severe weather avoidance*).

There will be a slight increase in the need for Knowledges associated with Special Operations for GHAA controllers because special operations will take place in that airspace, including unmanned aircraft operations and military, government, or commercial space operations. GHAA controllers will apply their Knowledge of the types of special operations (*K26.1-Types of special operations*), the clearances and instructions required for these special operations (*K26.2-Required clearances and control instructions*), and the coordination (*K26.3-Coordination requirements*) and notification requirements (*K26.4-Notification requirements*) more often.

As stated above, some of the Knowledges associated with emergency and unusual situations will not be needed by GHAA controllers. However, in case of an emergency, GHAA controllers will still be required to respond to aircraft in distress. Consequently, some Knowledges in this category, including Knowledge of types of in-flight emergencies and unusual situations (*K27.2-Types of in-flight emergency or unusual operations*), techniques for providing assistance during emergencies (*K27.5-Emergency assistance techniques*), the clearances and control instructions required to deal with these situations (*K27.3-Required clearances and control instructions*), the reporting requirements (*K27.8-Reporting requirements*), and national security contingency plans (*K27.9-National security contingency plans*), will be still be used but much less often.

Changes to Curriculum Required to Teach Skills
The curriculum required to teach skills to GHAA controllers is not proposed to change as a result of the implementation of High Altitude Airspace.

Changes to Properties of Skills
Aircraft operating in GHAA will be primarily on non-changing and non-conflicting trajectories; little communication will be required with these aircraft. Consequently, GHAA controllers will use Skill at communicating verbally (*Sk1-Oral Communication*), Skill at attending to what others are saying and actively engaging them to ensure complete understanding (*Sk3-Active Listening*), and Skill at coordination (*Sk23-Coordination*) less often. Writing Skills (*Sk2-Written Communication*) and Skill at understanding written material (*Sk10-Reading Comprehension*) will increase in use because GHAA aircraft will be equipped with Data Comm and at least some of the communication will be managed using this system. Skill at recovering from interruptions (*Sk6-Interruption Recovery*) will be needed less often because the airspace and the aircraft in it are so homogenous; there will be fewer changes and interruptions. Skill at monitoring activity in adjacent sectors within a facility will be less of a priority because GHAA controllers will be interacting less with other controllers (*Sk28-Facility Monitoring*).

Because GHAA operations are relatively homogenous and uncongested, Skill at developing separation strategies (*Sk32-Separation Strategy Development*), selecting a separation strategy (*Sk33-Separation Strategy Selection*), and implementing that strategy (*Sk34-Separation Strategy Implementation*) will be used less often. Similarly, Skills at developing sequencing and spacing strategies (*Sk35-Sequencing Strategy Development*, *Sk38-Spacing Strategy Development*), Skills at selecting a strategy (*Sk36-Sequencing Strategy Selection*, *Sk39-Spacing Strategy Selection*), and Skills at implementing strategies (*Sk37-Sequencing Strategy Implementation, Sk40-Spacing Strategy Implementation*) will be used less often.

The likelihood of having potential or actual conflicts in GHAA is less, which means that Skill at resolving conflicts, including Skills at identifying conflicts (*Sk41-Conflict Identification*), developing viable strategies to resolve conflicts (*Sk42: Conflict Resolution Strategy Selection*), selecting an appropriate strategy (*Sk43-Conflict Resolution Strategy Selection*), implementing the strategy (*Sk44-Conflict Resolution Strategy Implementation*), and using advisories and alerts as tools to reduce threats to safety (*Sk45-Advisories/Alerts Utilization*) will not be used as often.

Weather is less of a factor at the higher altitudes, so GHAA controllers will engage in weather mitigation Skills less often. These Skills include interpreting weather data (*Sk46-Weather Data Interpretation*), assessing the impact of weather on operations (*Sk47-Current Weather Assessment*), projecting weather information to determine potential future impact on operations (*Sk48-Weather Projection*), developing viable weather mitigation strategies (*Sk49-Weather Strategy Development*), selecting an appropriate weather mitigation strategy (*Sk50-Weather Strategy Selection*), and applying weather mitigation strategies (*Sk51-Weather Strategy Implementation*).

As stated above, it is proposed that GHAA controllers will have less responsibility for emergencies and unusual situations because any distressed aircraft will be rapidly descending. Consequently, Skills associated with emergencies will be used less often. These Skills include recognizing emergency situations (*Sk55-Emergency Recognition*), formulating viable response options (*Sk56-Emergency Response Development*), selecting the best option quickly (*Sk57-Emergency Response Selection*), and implementing the options to resolve the emergency (*Sk58-Emergency Response Implementation*).

Changes to Properties of Abilities

Because GHAA is homogeneous and aircraft will be traversing the space relatively unconflicted, less coordination will be required with these aircraft. Consequently, GHAA controllers will need verbal communication Abilities less often, including the Ability to communicate information 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 presented verbally (*Ab5-Oral Comprehension*). Although verbal communication will be used less often, writing Abilities will be needed more often because aircraft in GHAA will be Data Comm equipped and controllers will likely communicate at least some messages via this new method. Consequently, the Ability to communicate information in writing (*Ab2-Written Expression*) and the Ability to read and understand information and ideas presented in writing (*Ab3-Written Comprehension*) will be needed more often.

The operational demands that require perceptual speed and accuracy will be reduced for GHAA controllers because the airspace will be less dense and controllers will manage fewer operations and less complex operations (*Ab11-Perceptual Speed and Accuracy*). Similarly, demands on working memory will be less (*Ab14-Working Memory*). Demands on controllers' concentration will be reduced because there will be fewer changes, distractions, and disruptions (*Ab22-Concentration*). The need for flexibility will be reduced because the operational context will be very stable, and new controllers who are not trained or qualified to work other types of airspace will not likely do so (*Ab24-Flexibility*).

Changes to Properties of Other Personal Characteristics

Being conscientious and maintaining vigilance in monitoring even when the operational context is routine will become more important (*O4-Conscientiousness*). Similarly, because this airspace is less complex and because GHAA controllers are primarily maintaining separation, having the motivation to learn through challenges on the job and to progress to a higher level of Skill (*O2-Motivation*), having an interest in or preference for high intensity work situations (*O11-Interest in High Intensity Work Situations*), and being risk tolerant (*O12-Risk Tolerance*) will be less important. In fact, these characteristics may be detrimental for hiring or maintaining controllers in this new role because the GHAA work context does not provide these sorts of opportunities.

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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Six potential risks with regard to the implementation of GHAA are:

- *Lack of challenge*: Controllers managing GHAA airspace will do more monitoring in this airspace and less active controlling, which is likely to lead to less vigilance and proactive behavior and as a result to increased reaction times and risk to safety.
- *Lack of/inadequate training*: Lack of training or inadequate training for maintaining vigilance and alertness in an active monitoring role for High Altitude, as well as any

limitations of the required onboard avionics, will result in poor GHAA controller performance, which could lead to decreases in safety.

- *Mixed ATC tools, equipment, or procedures*: If High Altitude Airspace is not implemented in all ARTCCs, or if it is implemented on a significantly different schedule, the resulting differences in airspace could create difficulty in transferring aircraft across airspace boundaries, which could reduce efficiency and increase the possibility for error.
- *New ATCS role*: GHAA creates a new controller model that is significantly different from the existing model in that it relies more on the monitoring capabilities of controllers rather than proactive managing of air traffic. Because controllers who are trained only to manage GHAA airspace will lack many core contemporary ATCS skills, they will not be readily transferrable to other facilities, which could decrease system wide efficiency in controller training.
- *Skill decay*: Because the airspace is significantly less complex, requiring GHAA controllers to perform a number of Tasks less often, the implementation of High Altitude Airspace has the potential for the decay of Skills. However, the decay will apply only to controllers who were previously certified to manage non-GHAA airspace and who are then assigned to GHAA positions and will primarily be problematic when they return to non-GHAA positions. The resulting lack of preparedness by line controllers could threaten safety.
- *Technology development and maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is unlikely that the High Altitude Airspace concept will be implemented 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 concept may not have reliable interoperability with other concepts and systems. In addition, not until concepts are fielded and are being used by controllers can they 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

The impact of the implementation of High Altitude Airspace on controllers managing the generic portion of it is substantive. A new ATCS role will be created and the new job is substantively different. Many Tasks are not applicable and will not be performed by GHAA controllers. Other large groups of Tasks will be performed significantly less often. Many Knowledges and Skills will no longer be required and many others will diminish in frequency of use and hence importance. The elimination of so many requirements suggests how different the job will be from the current roles assigned to ATCSs. These differences present unique challenges with regard to training and staffing. NextGen has been thought, by some, to convert the job of the ATCS into a monitor instead of a manager. The research conducted for this report does not generally support this notion. However, this Driver does in fact create a new ATCS, and the role of this new ATCS is as an air traffic monitor instead of an air traffic controller.

The homogenous nature of GHAA airspace and the aircraft in it suggests that this airspace would lend itself to being automated. However, this might require aircraft to self-separate, and currently the procedures required for this Activity have not been established and the equipment and tools have not been developed. The primary motivation for air carriers to equip aircraft to be able to fly in High Altitude Airspace is the substantive fuel savings.

Driver 7: Initial Tailored Arrival

Initial Tailored Arrivals are arrival paths that support continuous descent operations for Future Air Navigation System (FANS)–equipped aircraft. ITAs reduce lateral and vertical deviations from the most direct or preferred path. Based on what is known to date, including ITA trials, ITAs will be prenegotiated long before the flight takes place. They will be built on a published approach procedure (e.g., ILS28L) and an arrival route (either a "tailored" arrival route or an existing route). Pilots will request an ITA from an ARTCC Oceanic sector controller while the aircraft is still in cruise phase. Controllers will assess the operational context and if appropriate will create a clearance for the aircraft to fly the ITA that will typically include the waypoints for the cruise portion of the route, the descent profile, the arrival runway, and any restrictions regarding speed and altitude. The clearance will be sent directly to the onboard flight management system (FMS) through the Advanced Technology and Oceanic Procedures (ATOP) system for approval and acceptance by the pilot.

The current ARTCC Task list does not contain any Tasks unique or specific to Oceanic sector ARTCC controllers.[12] Consequently, some of the Tasks discussed below are identified as "new" but are new only to the ARTCC Task list, not new to the job of Oceanic controllers. Because ITA is an Oceanic concept, the impact will be on ARTCC line controllers working Oceanic sectors. Consequently, the changes to work and workers discussed apply to Oceanic controllers only.

Overview of Changes From Implementing ITA

Table 15 provides a visual summary of the changes that will occur as a result of implementing ITAs. Additional details regarding these changes can be found in the sections that follow.

Table 15. Overview of the Impact of Initial Tailored Arrivals

	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: •Continuous descent operations (*Modified K24.9*)	Add: •Service Orientation (*New Sk)*		Add: •Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T10 T76 T152 T200 T201 T204	K7.1 K16.2 K16.4 K18.15 K18.17 K19.4	Sk1 Sk3 Sk23 Sk25 Sk32 Sk35	Ab1 Ab4 Ab5 Ab21 Ab22 Ab24	O4 O14	

[12] The lack of Tasks specific to ARTCC line controllers working Oceanic sectors is due to the highly specialized and technical nature of these Tasks and difficulty in gaining access to the very few subject matter experts (SMEs) available to consult on this topic. This deficit could be remedied in future research.

	Tasks (T)	Knowledges (K)	Skills (Sk)	Abilities (A)	Other Personal Characteristics (O)	Tools and Equipment (TE)
	T222	K21.3 K22.4 K22.12 K24.3 K24.4 K24.5 K24.9 K24.11	Sk38 Sk42	Ab28		

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of the ARTCC line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks) and 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 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 ITA on the job of line controllers working in the ARTCC environment reveals that it will not likely require adding to, deleting from, or modifying any of the current job Tasks, to the extent that ITA affects controller-to-pilot and controller-to-controller communications, it will have a direct impact on *how* Tasks performed as part of the following job six of the 11 Activities will be conducted:

- Activity 1. Establish Situation Awareness
- Activity 2. Manage Communications
- Activity 4. Manage Air Traffic
- Activity 5. Resolve Conflicts
- Activity 6. Manage Traffic Flows and Sequences
- Activity 7. Transfer of Radar Identification

Activity 1. Establish Situation Awareness

For aircraft to fly ITA routes, they must be FANS equipped. Assuming that equipage information is encoded in some way into the data block, controllers will require more scanning time to gather information regarding whether aircraft are FANS equipped (*T10*).

Activity 2. Manage Communications
Because ITAs are prenegotiated and published[13] paths, the number of data communications via ATOP will be reduced between Oceanic controllers and pilots flying aircraft on ITA paths (*New Tasks*).[14] ITAs are a type of smooth continuous descent so if an ITA is approved an aircraft will be issued fewer control messages via ATOP for the descent profile, including speed and altitude restrictions, instead of the multiple voice messages used today.

Activity 4. Manage Air Traffic
For aircraft to fly an ITA, they must be FANS equipped, which means at a minimum they are capable of monitoring their own conformance to the ITA path and are Data Comm equipped. Consequently, Oceanic controllers will have to verify that aircraft flying ITAs are in conformance with flight plans (*T76*) less often because the aircraft will be doing this.

Activity 5. Resolve Conflicts
To the extent possible, Oceanic controllers will want to keep aircraft on their ITA paths to maximize the benefits of ITAs to users. Although ARTCC Oceanic airspace is typically less dense than TRACON airspace and there is a longer lead time available to make decisions in Oceanic airspace, controllers may still have to develop new strategies when determining the appropriate action to resolve aircraft conflict situations (*T152*). The new strategies will likely attempt to allow the ITA aircraft to continue on its path and to adjust other aircraft as necessary.

Activity 6. Manage Traffic Flows and Sequences
ITAs require aircraft to be FANS-equipped. To the extent that not all aircraft in Oceanic sectors are FANS equipped, controllers will have to balance the needs of aircraft with mixed aircraft equipage and intentions (e.g., ITA aircraft vs. non-ITA aircraft). Oceanic controllers will have to take into account mixed aircraft equipage of aircraft with different capabilities and intentions when determining arrival sequences (*T200*) and ensuring coordinated arrival routings (*T201*).

The control instruction required to implement an ITA approach will be longer even though it contains a prenegotiated path because the route starts farther from the airport—perhaps before top of descent (TOD)—and covers the aircraft's instructions down to the runway. An ITA, then, covers more airspace and will require more waypoints and restrictions that may be tailored for specific fixes (*T204*). However, although the control instruction will contain many components, it will be issued via a data communication, so controllers will issue it in fewer, instead of multiple, steps.

Activity 7. Transfer of Radar Identification
Although ITA reduces the number of communications between Oceanic controllers and pilots, it may increase the number of communications between controllers. Oceanic controllers will issue the complete ITA path down to the runway to aircraft via their data messaging system via ATOP, but that clearance will have to be relayed to the downstream controller at handoff (*T222*). At

[13] Because ITAs are available to only a small group of aircraft, they are not "published" in the strictest sense of the word but rather are known in advance to controllers and the relevant air carriers.
[14] Note: Tasks associated with issuing data communications are not new to Oceanic controllers and are performed today. However, Tasks that are specific to the Oceanic environment are not captured in the current list of Tasks for ARTCC line controllers.

least in the immediate term, this longer control instruction will have to be verbally communicated and will likely take more time than a handoff for other aircraft not on ITA paths.

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 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 ITAs does not require deleting any KSAOs. It does, however, require the modification of one Knowledge to make it more generic and to more appropriately capture the fact that there are several types of continuous descent operations, including Optimized Profile Descents (OPDs) and ITAs (*Modified K24.9-Continuous descent operations*). It also requires the addition of one new Skill related to Oceanic controllers providing preferential service to properly equipped aircraft flying ITAs (*New Sk-Service Orientation*). Finally, the introduction of ITAs requires the addition of one new Other Personal Characteristic related to the technologies required to support ITA routes. The implementation of ITAs requires controllers to have positive attitudes toward, perceive the usefulness of, and perceive the ease of use of technology (*New O-Technology Acceptance).* In order for controllers to implement ITAs successfully, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges

ITAs are a new type of continuous descent operation. Consequently, Oceanic controllers will need to be taught a new type of route, ITA, as part of the air route structure (*K7.1-Air route structure*). In addition to learning a new type of route, controllers will need to be taught about aircraft equipage as a requirement of flight plans (*K16.2-Required components*). Controllers will also need to be taught strategies for taking aircraft equipage into consideration when evaluating flight plans (*K16.4-Evaluation strategies*). The data block itself will be taught as part of Knowledge about the information provided by the tool/equipment (*K19.4-Interpretation of information provided*).

Oceanic controllers will also have to learn the impact of adding ITA routes to facility traffic flows (*18.15-Facility traffic flows*) as well as new LOAs/standard operating procedures (SOPs)/procedures (*K18.17-Facility specific directives and procedures*) that will likely be required between the TRACON and ARTCC facilities.

Because it is preferred that ITA aircraft continue along their ITA route once they begin (due to the many benefits of ITAs, such as reduced fuel burn), Oceanic controllers will need to learn new separation/conflict resolution strategies (*K21.3-Conflict resolution strategies*) that will maintain the course and speed of the ITA aircraft to the extent possible and that will adjust other aircraft accordingly. ITAs require special clearances; as a result, Oceanic controllers will need to be taught new procedures for composing clearances and any required restrictions (*K22.4-Procedures for composing clearances and control instructions*).

Additionally, Oceanic controllers will need to be taught about new procedures for providing approach control service to ITA aircraft (*K22.12-Approach control service*). They will need to be taught new ITA arrival routes (*K24.3-Arrival routes*), and how to merge ITA and non-ITA aircraft appropriately into the arrival flow (*K24.11-Arrival sequence*).

Changes to Properties of Knowledge
Knowledge of continual descent operations including ITAs (*Modified K24.9-Continual descent operations*) will become important to more controllers at more facilities as more ITAs are added in the mid-term. Further, Knowledge of conventional standard terminal arrival routes (STARs) (*K24.4-Conventional standard terminal arrival routes [STARs]*) and RNAV-enabled arrival routes (*K24.5-Area navigation [RNAV-enabled] arrival routes*) will gain importance because these routes may enable ITAs.

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 ITAs 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 available ITAs to FANS-equipped aircraft.

Because ITA aircraft should be routed differently than other aircraft, one variable in the air traffic management process is the fixed path that ITA-enabled aircraft will fly. 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*), a new spacing strategy development Skill (*Sk38-Spacing Strategy Development*), and a new conflict strategy development Skill (*Sk42-Conflict Resolution Strategy Development*).

Changes to Properties of Skills
Because ITAs are predefined and published paths, once the aircraft begins the ITA, fewer verbal control instructions will be required for this procedure. Consequently, the implementation of ITAs will reduce the time Oceanic controllers spend 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*) but only for communications associated with ITA aircraft. However, this reduction could be offset by an increase in communications to set up the ITA and to hand off the ITA aircraft to the receiving TRACON controller. These two processes will require an increase in the time Oceanic controllers have to verbally communicate information (*Sk1-Oral Communication*), attend to what others are saying (*Sk3-Active Listening*), and work with others to accomplish air traffic Tasks (*Sk23-Coordination*) with other controllers and with aircraft around ITAs.

ITAs are pilot-directed routes, so Oceanic controllers will monitor more and actively manage aircraft flying ITAs less. As a result, Skill at applying scanning strategies to quickly and accurately search for relevant ATC information will become more important (*Sk25-Strategic Scanning*).

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 be less important for controllers managing ITA aircraft after they have begun the ITA. Conversely, 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 be more important for controllers managing the airspace around ITA aircraft because of the increased coordination required to keep them separated from ITA aircraft and the increased communication required for transfer of ITA aircraft.

Because Oceanic controllers will primarily monitor instead of actively manage aircraft on ITAs, Abilities associated with monitoring, including the Ability to stay focused on the job for long periods of time (*Ab21-Sustained Attention*) and the Ability to focus on job Activities amid distractions for short periods of time (*Ab22-Concentration*), will become more important because monitoring will be much more difficult.

Finally, because ITAs are new routes that change how things are done today, controllers' Ability to learn new Skills and Knowledges associated with ITAs (*Ab28-Learning*) and to adapt to new situations using new ITA routes (*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 aircraft flying an ITA route will not be managed actively but rather monitored. Controllers will have to maintain their vigilance even when they are not actively involved in managing aircraft.

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 ITA. In this case, controllers will need to believe that they are still responsible even if the aircraft's FANS equipment is monitoring conformance to the ITA 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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Ten potential risks with regard to the implementation of ITA are:

- *Best equipped, best served*: Only a few ITAs will be available in the mid-term, and their use will be restricted to certain aircraft types and certain air carriers. This creates a BEBS environment for controllers, the impact of which is complex. Although controllers will need to spend more time formulating and issuing potentially lengthy and complex clearances to support the ITAs, actually managing aircraft on an

ITA saves time because controllers will primarily monitor their conformance to the route. The net effect on efficiency is currently unknown.

- *Coordination of multiple stakeholders*: ITAs require the coordination of numerous diverse stakeholders, including the FAA, air carriers, and aircraft manufacturers. Significant intra- and inter-team coordination will be required to build and implement ITAs. If this coordination is not handled effectively, the result could be inefficiencies, including delays in the implementation of ITAs and the benefits they provide, and challenges in the coordination between pilots and controllers required to initiate ITAs.
- *Degradation or failure of equipment or systems*: The implementation of ITAs is dependent on FANS and ATOP. If there is a degradation or failure in either of these systems, ITAs will not be a viable route option. Consequently, the efficiencies associated with ITAs will not be realized.
- *Improper allocation of tasks to automation*: The implementation of ITAs requires the allocation of certain Tasks that were previously the line controllers' responsibility to aircraft and facility automation. The result is that once controllers formulate and issue the ITA clearance, they are monitoring the aircraft instead of actually 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 could pose a threat to safety.
- *Improper reliance on automation or procedures*: If controllers do not feel comfortable using ITAs, they may not approve their use in situations where they are appropriate, or they may issue ITAs with unnecessary restrictions. This will reduce efficiencies that ITAs were designed to support.
- *Lack of/inadequate training*: Lack of training or inadequate training in the implementation of ITA procedures, how to follow them in an operational context, and any limitations of the technologies required to support it may result in delays in controllers' formulation and communication of ITA clearances, as well as increases in the possibility for errors in those clearances.
- *Mixed aircraft equipage*: ITAs are implemented by controllers in a mixed aircraft equipage environment (i.e., not all aircraft are FANS equipped). If controllers do not have easy access to near real-time and current information on their displays regarding aircraft equipage, this could increase cognitive workload and decrease efficiency. In addition, to the extent that controllers have to determine which type of route is appropriate (i.e., ITA or non-ITA) based on aircraft equipage, this could potentially further increase cognitive workload and decrease efficiency.
- *More dynamic work environment*: Because only a few ITAs currently exist and are approved on a case-by-case basis for only a small percentage of aircraft, the result is an increase in the dynamic nature of the job of controllers as they work to support both participating and nonparticipating aircraft. This could increase the 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 ITA on workload is unknown because some ITA procedures could increase workload (e.g., formulation of lengthy clearance) and some could decrease workload (e.g., elimination of requirement for active management after the aircraft begins ITA).

- *Skill decay*: Because aircraft flying ITAs self-monitor conformance to their route, implementation of ITAs 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. Although there are very few ITAs today, it is anticipated that additional ITAs 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 unlikely that ITAs 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, ITAs may not have reliable interoperability with other air traffic concepts. In addition, not until ITAs are fielded and are being used by controllers can they 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

Although ITAs and OPDs are both continuous descent operations and are very similar, there are key differences. First, Oceanic aircraft have to be FANS equipped to fly in that airspace, so the implementation of ITA does not require new aircraft equipage unlike OPDs, which will be implemented in airspace that does not currently require aircraft to be FANS equipped. Second, ITAs begin farther from the airport before TOD, which is where OPDs start, so they do not have as much of a time-critical component. Also, the impacts of a continuous descent operation are different on ARTCC controllers than TRACON controllers. The nature of ARTCC airspace is less dense with fewer time constraints, and ARTCC controllers only start the process, whereas TRACON controllers are responsible for aircraft during most of the descent. Consequently, the impact of ITAs on the job and KSAOs of Oceanic ARTCC controllers is different from the impact of OPDs on TRACON controllers. Although the impacts look similar, ITAs will have less of an impact on Tasks and KSAOs for Oceanic controllers. The impact on the KSAOs required of Oceanic controllers is primarily related to the fact that once an aircraft has started on the ITA path, there is less active management of the aircraft and more monitoring.

The primary impetus for ITA is fuel savings and reduced carbon dioxide emissions. However, this Driver has benefits for most NAS users. The increased benefit for the community is reduced noise. Benefits to pilots are reduced communications and more standardization, which will be especially helpful for Oceanic pilots whose first language is not English. The net benefit to controllers is not clear. ITAs may reduce control instructions required between Oceanic controllers and ITA aircraft due to increased predictability of the ITA routes that results from standardization and the fact that these aircraft monitor their own adherence to it. Conversely, ITAs may increase communication for Oceanic controllers as they work to set up the potentially lengthy clearance required for the ITA route and hand off ITA aircraft to other controllers. Overall, workload for Oceanic controllers could increase in the mid-term until DSTs are built for ITAs.

Finally, ITA paths will increase efficiency in the NAS. The paths will be more standardized and predictable, assuming they do not get interrupted by weather and traffic, although it should be noted that this occurs routinely.

Driver 8: 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. 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 current minima for diverging courses in all arrival and departure airspace, as well as the use of visual separation standards above 18,000 feet.

For the purposes of this report, and to reduce repetition for the reader, the changes discussed in this section pertain only to the ARTCC line controllers who will continue to work from the ARTCC after responsibility for the Super Density airspace is moved to the TRACON, not those who will be collocated with a TRACON controller to work the Super Density airspace from the TRACON facility. The changes to the work of the ARTCC controllers who will be collocated with the TRACON controller are discussed in the TRACON report. Also, although FAM and PBN (RNAV/RNP) both support the concept of Big Airspace, they are captured in this report as separate NextGen Drivers. Consequently, changes to the ARTCC line controller job produced by procedures and automation associated with FAM and PBN will be discussed elsewhere in this section of report.

Overview of Changes From Implementing Big Airspace

Table 16 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 16. 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:	T80 T207 T311 T312	K2.2 K2.3 K2.4 K2.5 K18.7 K18.8 K18.9 K18.11 K18.12 K18.13 K18.15 K18.19 K22.4 K22.13 K24.11 K25.1	Sk1 Sk3 Sk19 Sk23 Sk32 Sk35	Ab1 Ab4 Ab5 Ab24 Ab25 Ab28	O11	

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC 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) and 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 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 the Big Airspace concept in Super Density areas will not require adding to, deleting from, or modifying language in the current ARTCC Task list, it is proposed to have an impact on *how* controllers will perform Tasks associated with three of the 11 Activities:

- Activity 4: Manage Air Traffic
- Activity 6: Manage Traffic Flows and Sequences
- Activity 10: Manage Resources

Activity 4: Manage Air Traffic

ARTCC line controllers still have to establish required separation (*T80*), but Big Airspace may change the geographic point at which the separation standard switches from 5 to 3 miles because airspace boundaries between ARTCC and TRACON will likely change. ARTCC sectors in transition airspace in Super Density areas will be moved to TRACON, which will move the airspace boundary between the two facilities farther out. Consequently, although it is unclear exactly where the point to switch from 5 to 3 miles of separation standard will be, it is likely to be deeper into the ARTCC airspace than the current location.

Activity 6: Manage Traffic Flows and Sequences

ARTCC line controllers will still have to perform all Tasks associated with managing departure and arrival flows and sequences. However, the implementation of Big Airspace, including the shifting of responsibility of transition airspace to the TRACON and the collocation of controllers who work that airspace into TRACON facilities in Super Density areas, will substantively reduce the amount of coordination between ARTCC controllers and controllers working adjacent sectors near Super Density airspace (*T207*). The control of transition airspace will be completely in the TRACON facility, so control of aircraft through this space will no longer require coordination between ARTCC and TRACON.

Activity 10: Manage Resources

The removal of more complicated transition airspace from ARTCCs in Super Density areas will reduce the overload that occurs in those ARTCCs. Thus, controllers working in those ARTCCs will have to inform supervisors of current or potential overloads (*T311*) and request assistance (*T312*) less often for that remaining airspace and for overloads that occur as a result of traffic in the transition airspace between ARTCC and TRACON.

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 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 adding new KSAOs, deleting KSAOs, or modifying KSAOs, it will require changes to the training curriculum. Because Big Airspace will be collocating sector teams of TRACON and ARTCC controllers in one (TRACON) facility, all ARTCC line controllers will need to learn about this new type of collocated TRACON 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 roles 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*).

As stated previously, the implementation of Big Airspace will require moving responsibility for the transition airspace in Super Density areas from ARTCC to TRACON. Consequently, there will be changes to airspace configurations at ARTCC facilities in these areas. ARTCC line controllers will have to be taught the new dimensions of this airspace (*K18.7-Airspace dimensions*), the new dimensions of adjacent airspace (*K18.8-Adjacent Airspace*), and the new sector configurations in this airspace (*K18.9-Sector configurations*). Because some of the airspace and accompanying geography will be removed from ARTCCs in these areas, controllers will also have to be taught the new local geography (*K18.11-Local geography*) in this airspace. To the extent that local geography and any unique characteristics associated with it are no longer part of ARTCC airspace and are no longer under the control of ARTCC line controllers, the impact of local topography on flight could change and would need to be taught to controllers (*K18.12-Impact of local topography on flight*). Similarly, to the extent that airspace that has been removed from the ARTCC's responsibility contained obstructions/obstacles, the local obstructions/obstacles in the remaining airspace will change and need to be taught to controllers (*K18.13-Local obstructions/obstacles*). Controllers will also need to learn new facility traffic flows in the remaining ARTCC airspace (*K18.15-Facility traffic flows*). Even though the volume of aircraft feeding into this airspace will be the same, the flows should be less complicated because airspace is less complex. Further, ARTCC line controllers will need to learn new local procedures and directives (*K18.19-Facility specific directives and procedures*) between ARTCC and TRACON with new airspace boundaries.

Big Airspace will make ARTCC airspace in Super Density areas less complex by removing the difficult transition airspace sectors to TRACON. Consequently, ARTCC line controllers will need to be taught new curriculum for approach control service (*K22.13-Approach control* *service*). They will be doing less sequencing and spacing because the transition airspace has been removed.

Changes to Properties of Knowledges

Big Airspace will decrease the use and level of complexity for several Knowledges for ARTCC line controllers because responsibility for the most complex/dense transition airspace in Super Density areas will be moved to the TRACON facility. The remaining ARTCC airspace in these areas will be more homogenous and less complex. The aircraft will fly at higher altitudes farther from the airport, farther apart from other aircraft, and with fewer time constraints. Because controllers working near Super Density areas will no longer be responsible for the transition airspace that requires the most control instructions to manage, ARTCC line controllers will need to use Knowledge of procedures for composing clearances and control instructions less often (*K22.4-Procedures for composing clearances and control instructions*). Managing the approach and departure sequences in these areas should be easier because ARTCC controllers will likely be responsible for merging fewer streams of traffic into a single flow. Thus, controllers may need to learn about arrival sequences (*K24.11-Arrival sequence*) and departure sequences (*K25.1-Departure sequence*) in less depth.

Changes to Curriculum Required to Teach Skills

Based on the information available to date, AIR does not anticipate that the implementation of Big Airspace will change the curriculum required to teach ARTCC controller Skills.

Changes to Properties of Skills

The implementation of the Big Airspace concept, which moves the most congested transition airspace from ARTCCs to TRACONs in Super Density areas, will reduce the frequency of use of several Skills. 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*) will be used less often because there less coordination will be needed between ARTCC and TRACON controllers for managing the transition airspace.

Additionally, to the extent that the transition airspace was considered particularly challenging by ARTCC controllers and is no longer their responsibility, they will need Skill at performing safely and effectively in stressful situations (*Sk19-Composure Maintenance*) less often. Controllers will need Skills for separation strategies that are critical for and often used in high-density airspace (*Sk32-Separation Strategy Development*), such as speed control, less often because this airspace will be removed. Finally, the proficiency level for Skill at developing viable sequences (*Sk35-Sequencing Strategy Development*) may be reduce because controllers will have more time to think about sequences. Their airspace will be farther from airport and they will have fewer time constraints. Sequencing could also be less challenging in terms of controllers having fewer streams of traffic to sequence into the flow.

Changes to Properties of Abilities

ARTCC line controllers working in Super Density areas will need several Abilities less often because they will not be responsible for the complex transition airspace. 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 be used less often because of the decrease in coordination between controllers..

To the extent that managing the transition airspace was considered by ARTCC controllers to be particularly challenging, those controllers who were previously managing that airspace will no longer be doing so and consequently will likely need the Ability to think clearly in stressful situations less often (*Ab25-Composure*).

The Ability for controllers to adapt to changing situations (*Ab24-Flexibility*) will become more important because ARTCC line controllers in Super Density areas will be responsible for different airspace. Controllers will also need to learn to take advantage of the new procedures associated with Big Airspace (*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 remove the most complex/difficult transition airspace from ARTCCs in Super Density areas, so the need for controllers to have significant interest in, or preference for, working in high-intensity situations (*O11-Interest in High Intensity Work Situations*) is going to be less important for these facilities. These ARTCC facilities may have difficulty attracting challenge-seeking controllers because their remaining airspace will be less complex.

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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Three potential risks with regard to the implementation of Big Airspace are:

- *Lack of challenge*: CPC and developmental line controllers will need to demonstrate willingness to work in ARTCCs that are associated with a TRACON that is responsible for Big Airspace. The resulting job will involve managing less complex/difficult airspace because the transition airspace has been reassigned to the TRACON. It may difficult to attract/retain challenge-seeking controllers to work in these specific areas.
- *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, and any limitations of the technologies required to support it will result in reductions in efficiency and increases in 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 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, not until concepts and systems are fielded and are being used by controllers can they be fully evaluated from a functional perspective. If controllers are not fully

utilizing Big Airspace, they will be unable to provide feedback that is vital to system evolution.

Driver Impact Summary

Big Airspace is not a new tool or piece of equipment, but rather a procedural change in how airspace surrounding large metroplex areas is configured. At first glance, one might assume that procedural changes would affect the work of line controllers less than the implementation of new Tools and Equipment. In reality, this change will have a large impact on the job of ARTCC line controllers who will remain in the ARTCCs. The job should be less challenging because the responsibility for complicated transition airspace will be moved to TRACON. Coordination between TRACON and ARTCC controllers will be reduced, especially when managing arrivals.

Personnel requirements for ARTCC controllers in these facilities could change. The implementation of Big Airspace will have an impact on the ease with which controllers can be moved among facilities and whether they are suitable candidates for transition. Moving controllers who have been working in these ARTCCs that do not have the complex transition airspace to a facility that requires a higher level of expertise may be difficult because these controllers will be less proficient. Attaining certification at a busier facility will likely take longer, whereas before, it was an easier transition and required less check out time.

The implementation of the Big Airspace concept will have a larger impact on the TRACON than on the ARTCC. Because ARTCC controllers working transition sectors will be moved to TRACON, the most substantive changes are described in the TRACON report.

The impact of this Big Airspace on the KSAOs of ARTCC line controllers in Super Density areas is relatively minor because this Driver is removing worker requirements but not adding any, as most of the other Drivers do. However, despite the relatively innocuous nature of the impact of this Driver on the ARTCC, some challenges will be created, most specifically with skill decay and changes in the level of challenge of the job.

Once the more complex transition airspace has been removed from the responsibility of ARTCCs in Super Density areas, the remaining airspace could be restructured to be used more efficiently, especially as it relates to the feeding of aircraft into that transition airspace (the feeder function/capability). The implementation of Big Airspace creates the potential for additional system improvements in the remaining ARTCC airspace.

Driver 9: Performance-Based Navigation

Performance-Based Navigation 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 direct routes. Navigation specifications refer to a set of aircraft and aircrew performance requirements that support navigation in a particular defined airspace. For example, the specifications describe the ability of the aircraft and aircrew to conduct optimized routes as opposed to conventional zigzag paths based on ground-based NAVAIDs.

Overview of Changes From Implementing PBN

Table 17 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 17. 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 T43 T62 T63 T64 T76 T84 T135 T142 T152 T195 T196 T200 T201 T204 T268 T310 T325 T334	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 ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of the ARTCC line controller, AIR considered both whether the Driver would require changes to the existing list of Tasks (i.e., addition, deletion, or modification of Tasks) and 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 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 line controllers working in the ARTCC environment will not likely require adding to, deleting from, or modifying any current job Tasks, PBN will have an important impact on *how* the job is performed. PBN has a direct impact on the job in eight of the 11 ARTCC 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
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, controllers will have another piece of information to attend to when evaluating the flight plans (i.e., that individual aircraft's equipage). 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 (*T43*). If departure and en route time information is entered via automation, the ARTCC controllers will not be actively involved and the Tasks will not change. However, if the automation does perform this function, controllers will enter an increased number of departure or en route time messages (*T62–T64*).

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 that result from nonconformance (*T76*).

RNAV/RNP routes are very specific, detailed routes. Although controllers will still instruct pilots to fly the route, they will be required to provide little (if any) additional control instructions (*T84*). 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 to return aircraft to the original or a modified route. However, controllers will have different potential resolutions (*T142*) 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 a 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 (*T135*).

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 (*T152*) 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 predefined, 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 (*T196*) and arrival (*T204*) sequences will be accomplished in two ways. First, the control instructions will have fewer components. Second, there will be fewer messages/instructions to be relayed to the aircraft, which will ease controller workload and reduce radio frequency congestion. Last, 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 (*T195*), determining arrival flow (*T200*), and ensuring coordinated arrival routing (*T201*).

Activity 8. Assess Impact of Weather
PBN-enabled aircraft are more flexible in their routing and holding options; these aircraft can use more direct routes, and controllers may use this capability as a potential strategy when determining ways to avoid severe weather (*T268*). 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
PBN-enabled aircraft will provide flexibility in flying more direct routes and curved paths. This capability may become a new work overload reduction strategy that controllers can use in the future (*T310*).

Activity 11. Respond to Emergencies and Unusual Situations
PBN-enabled aircraft can be more flexible in their routing and holding options. This flexibility can also be used by controllers to expedite these aircraft in case of emergencies or during unusual situations. Controllers and pilots can use these capabilities to great advantage with minimum impact to other operations in existing airspace (*T325*).

The flexibility that PBN-enabled aircraft provide can be used by controllers when determining a plan of action to deal with unusual situations (*T334*). Last, 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 ARTCC Controllers
When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing KSAO) and 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 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 ARTCC environment will not require deleting or modifying the language of currently required KSAOs. However, it will require adding a new Skill at providing preferential service to aircraft equipped for PBN-related services (*New Sk-Service Orientation*). PBN will also require adding a new Other Personal Characteristic. Controllers will need to have positive attitudes toward, perceive the usefulness of, and perceive the ease of use of technology, which is known as *Technology Acceptance*. That is, for controllers to fully utilize the capabilities associated with PBN, they must be comfortable using automation.

Changes to Curriculum Required to Teach Knowledges
Controllers will need to learn new route structure (*K7.1-Air route structure*) and 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. Additionally, PBN enables many RNAV and RNP air routes, so aeronautical charts will look different (*K7.4-Aeronautical charts*). 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, so aircraft do not have to depend on ground-based NAVAIDs.

Controllers will need to be taught about aircraft equipage as a required component of flight plans (*K16.2-Required components*) and new flight plan evaluation strategies to determine whether specific aircraft can fly the proposed RNAV/RNP routes (*K16.4-Evaluation strategies*). 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*). The data block itself, which will likely also contain information regarding equipage, will be taught as part of Knowledge about the information provided by the tool/equipment (*K19.4-Interpretation of information provided*).

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 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, 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 thus 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 reinitiate 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 and 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 will 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 an emergency situation, controllers can move PBN-enabled aircraft on any of the PBN routes (satellite based) as well as on 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 because pilots of RNP aircraft will take on some responsibility for conformance to routes (*K21.1-Types of separation standards*). Conversely two Knowledges will increase in importance: 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

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 PBN 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 available PBN routes to RNAV/RNP-equipped aircraft.

Because NextGen represents a shift from a "first come first served" strategy of air traffic management to a BEBS strategy, 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 than they are today (e.g., curved flight paths, climb then descend to get over airspace). Therefore, controllers will need to be trained on and practice 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 use 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; hence, controllers will have many 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 best use the new routing options.

Changes to Properties of Skills

Because RNAV/RNP arrival and departure routes are predefined and 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*), the number of times active listening Skills are required (*Sk3-Active Listening*), and the amount of 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 made to the course 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 that pilots have to enter data by hand into the FMS, 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. 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 predefined and known in advance to pilots, 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 use oral expression (*Ab1-Oral Expression*), verbal reasoning (*Ab4-Verbal Reasoning*), and oral comprehension (*Ab5-Oral Comprehension*) Abilities.

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. Further, 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 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 four dimensions owing 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 it accordingly.

Changes to Properties of Other Personal Characteristics
Three Other Personal Characteristics 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 manage these aircraft actively, but instead monitor them. 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*). Third, 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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Ten potential risks with regard to the implementation of 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 BEBS environment for controllers, the impact of which is complex. Although controllers will spend less time actually managing aircraft on a PBN route, they may spend more time managing non-PBN-equipped aircraft. The net effect on efficiency is currently unknown.
- *Deficiencies in technology*: Although 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, 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 because of wide outage areas and the substantive amount of time involved for system restoration. Both risks could threaten safety and efficiency.
- *Degradation or failure of equipment or systems*: The implementation of PBN-based operations is dependent on 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 the adherence of PBN capable aircraft to their routes and using ground-based aids for navigation. These backup procedures rely on older and inferior technologies and systems that are less

efficient. In addition, controllers may be inefficient in their use, which has the potential to cause delays or increase errors.

- *Improper allocation of tasks to automation*: The implementation of PBN-based operations requires the allocation of certain Tasks that were previously the line controllers' responsibility to aircraft and facility automation. The result is that controllers will monitor 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 using PBN-enabled routes, they may not use them when they are 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 of the new avionics capabilities as well as any limitations 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, parallel runway approaches that have two aircraft turning toward each other will be a critical time for controllers to know whether the aircraft are in conformance. Some approach paths are 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 will increase workload and decrease efficiency for controllers. In addition, if controllers are not provided with immediate access to current information regarding 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 will be 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 that results from the predictable nature of aircraft flying PBN routes and reductions in communications required to manage them.
- *Skill decay*: Because RNP-equipped aircraft self-monitor conformance to their route, 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 unlikely that the components of the PBN operations 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 PBN-based operations may not have reliable interoperability with other systems. In addition, not until technologies are

fielded and are being used by controllers can they 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

PBN is primarily a benefit to air carriers in that it will save time and money by using direct routes. Although PBN is not automation for ARTCC controllers, its implementation does have an impact on line controllers. From a Task perspective, PBN operations reduce reliance on ATC for navigation assistance and 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 a significant impact on controllers' KSAOs. To the extent that procedures are running smoothly, an outcome of PBN is that controllers' workload will be reduced because they have to less actively manage PBN-enabled aircraft. More specifically, PBN operations reduce workload because less communication and coordination are 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 will allow system capacity improvements that are unmatched anywhere else in ARTCC 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 be able to self-navigate and self-monitor their performance while flying Oceanic and domestic routes. Additionally, this Driver has benefits for environmental issues because routes will use less fuel and emit less carbon.

Driver 10: Time-Based Flow Management Program

The Time-Based Flow Management Program is a plan to upgrade and enhance the Traffic Management Advisor (TMA), which is currently being used by Traffic Management Coordinators (TMCs) in ARTCC facilities. TMA identifies the trajectories and times that aircraft must reach or cross specific points in space on the arrival and departure paths. Consequently, the arrival and departure information is sent to the ARTCC line controllers who ensure that aircraft arrive at fixes at specific times. This concept is called Time-Based Metering (TBM). TMA will be upgraded to TBFM because TMA does not currently support key functionalities such as extended metering, 3-D-Path Arrival Manager (3D-PAM), and airborne rerouting. Although TBFM is a TMU tool and will have an impact on the TMC's job, these three key functionalities will directly affect Tasks performed by the line ARTCC controllers.

Overview of Changes From Implementing TBFM

Table 18 provides a visual summary of the changes that will occur as a result of implementing TBFM. Additional details regarding these changes can be found in the sections that follow.

Table 18. Overview of the Impact of TBFM

	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: • Verify aircraft is in conformance with flight plan (*New T*) • Verify aircraft is in conformance with any other specific control actions requested for spacing (*New T*) • Develop control actions to fix deviations from time meter fixes (*New T*) • Issue control actions to fix deviations from time meter fixes (*New T*)	Add: • ATC automation (*New K*)			Add: • Technology Acceptance (*New O*)	
Driver otherwise affects existing Task or KSAO:	T3 T10 T15 T22 T49 T201	K16.2 K16.4 K19.4 K22.8 K22.12	Sk4 Sk14 Sk18 Sk38 Sk39 Sk53 Sk54	Ab10 Ab11 Ab14 Ab16 Ab24 Ab28 Ab29	O14	

Changes to ARTCC Job Tasks

When determining the impact of a NextGen Driver on the job of ARTCC 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) and 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 a more complete understanding of how the job overall will change.

Changes to Current Task List

The implementation of TBFM requires changes to Tasks in one of the 11 Activities:

- Activity 6. Manage Traffic Flows and Sequences

Activity 6. Manage Traffic Flows and Sequences

Several new Tasks will need to be added to the existing list as part of the Activity of managing traffic flows and sequences. More specifically, Tasks associated with creating and maintaining proper spacing will be required. Specific Tasks likely include verifying aircraft conformance with the flight plan (*New T*) and verifying aircraft conformance with specific control actions request for spacing (*New T*). Further, Tasks associated with developing (*New T*) and issuing control instructions to correct deviations from time-based meter fixes will need to be added (*New T*). Spacing is required today, but it will be more important in mid-term 2018 with the implementation of TBFM because metering fixes will not be confined to any single center's airspace but will be extended throughout the NAS.

Changes to How Tasks Are Performed

In addition to requiring an expansion of the list of Tasks, the implementation of TBFM is projected to also affect *how* controllers perform three of the 11 job Activities:

- Activity 1: Establish Situation Awareness
- Activity 3. Manage Flight Plan Data
- Activity 6. Manage Traffic Flows and Sequences

Activity 1: Establish Situation Awareness

Because metering lists from TBFM will have more time-based meter points, controllers will require more scanning time to gather information about aircraft (*T10*). New and more information obtained from metering points will also increase the time required to interpret data to identify patterns and irregularities (*T15*). Because controllers will need to receive more and new information regarding the new metering points, receiving briefings from controllers being relieved (*T3*) and relaying information to relieving controllers (*T22*) will likely take longer.

Activity 3. Manage Flight Plan Data

To the extent that ARTCC controllers do not have to manually enter flight plan changes locally or into the NAS, TBFM's new functionality called airborne rerouting will allow DST-generated reroutes to be sent to ARTCC controllers' workstations. Consequently, controllers will be able to select the reroutes and send them to Data Comm–equipped aircraft (*T49*).

Activity 6. Manage Traffic Flows and Sequences

The Tasks identified above as new Tasks are performed today but are not adequately captured in the current ARTCC Task list. These aforementioned Tasks will be done more frequently because more metering fixes will be provided by TBFM and will become more important because they support the basic notion of Trajectory-Based Operations, which is what TBFM is designed to achieve. To the extent that coordinated arrival routing includes spacing, it will also be done more often and become more important (*T201*) because it ensures consistent and standardized flow. Last, Tasks associated with control actions to correct deviations from time-based metered fixes will be supplemented by the use of information from 3-D PAM DST.

Changes to Characteristics Required of ARTCC Controllers

When determining the impact of a NextGen Driver on the characteristics required of ARTCC line controllers to perform the job, AIR considered both whether the Driver would require changes to the existing list of KSAOs (i.e., addition, deletion, or modification of an existing

KSAO) and 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 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 TBFM into the ARTCC environment does not require deleting or modifying the language of currently required KSAOs. However, it does require adding a new Knowledge that captures concepts important for understanding and using automation (*New K-ATC automation*). This new Knowledge will be a subcategory under the existing Knowledge category K5, which captures general aviation human factors information (i.e., not system specific) that controllers must know.

The implementation of TBFM and its associated DSTs also requires the addition of a new Other Personal Characteristic: the need for controllers to have positive attitudes toward, perceive the usefulness of, and perceive the ease of use of technology (*New O-Technology Acceptance*). For controllers to use the DSTs to perform their job efficiently, they must be comfortable using these DSTs.[15]

Changes to Curriculum Required to Teach Knowledges
As stated above, the implementation of TBFM will require a new ATC automation Knowledge topic (*New K-ATC Automation*). Training content relevant for this new Knowledge topic area should include 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 humans and machine; and concepts associated with DSTs including the decision support tool–decision-making tool continuum, evaluation strategies, and the concept of automation-based algorithms and the importance of understanding them.

Controllers will need to learn new curriculum regarding new flight plan components (*K16.2-Required components*). More specifically, controllers will need to be taught about time-based metering fixes that exist today but that will increase in number as a result of TBFM's capabilities. Additionally, controllers will be taught how to read, find, and evaluate metering points in the adjacent sector that they cannot see today. Further, controllers need to be taught how to evaluate these new flight plan components (*K16.4-Evaluation strategies*). Controllers will also be taught new content associated with 3-D PAM DSTs, including the number, type, and functionalities of 3-D PAM as well as the algorithms, the source of information, and limitations of DSTs in general. Last, controllers will learn how to work with the DSTs, including evaluating options provided and whether or how to override them and learning how to respond to DST failure/degradation. This new information regarding the DSTs will likely be taught as part of interpreting information from DSTs (*K19.4-Interpretation of information provided*).

[15] Although Technology Acceptance is likely required in some way today, this Other Personal Characteristic is not on the current list and the addition of TBFM represents a substantive increase in the need for this requirement.

Changes to Properties of Knowledges
Because there will be more time-based metering fixes in the flight plan, controllers will increasingly ensure adherence to flight plans (*K22.8-Conformance assurance*). Further, the spacing component of providing approach control service will become much more important (*K22.12-Approach control service*) because metering points will not be confined to a single center's airspace but will extend throughout the NAS.

Changes to Curriculum Required to Teach Skills
None.

Changes to Properties of Skills
Several controller Skills will either increase in importance or be performed more frequently. Because controllers will need to strictly conform to additional time-based metering fixes along flight trajectories, Skill at shifting rapidly between managing aircraft that are flying a high constrained time-based route and those that are not will become more important (*Sk4-Task Switching*). Skill at performing work Tasks in the right order (*Sk18-Task Timing*) will also be more important. Moreover, controllers will need Skill at recognizing DST degradation or failure (*Sk53-Tool & Equipment Status Recognition*) more often because traffic management coordinators will send controllers DST-generated metering information and controllers will need to recognize the accuracy or lack thereof. Similarly, controllers will need Skill at responding to DST degradation or failure (*Sk54-Tool & Equipment Degradation/Failure Response*) more often because they will regularly use the information from DST-generated metering points.

Several Skills will either be used less often or be less important. First, Skill at applying the basic principles in metering will be used less often because DSTs will generate the options for fixing deviations from time-based metering fixes, whereas controllers today have to do these calculations mentally (*Sk14-Principle Application*). Skill at developing viable spacing strategies (*Sk38-Spacing Strategy Development*) will be less important because 3-D PAM will generate options for controllers. Skill at selecting a spacing strategy (*Sk39-Spacing Strategy Selection*) that optimizes the use of airspace will be different because there will be more options from which to choose. Some of the options will likely still be self-generated. Others will be provided by 3-D PAM.

Changes to Properties of Abilities
Several controller Abilities will be required less often. More specifically, the Ability to detect physical movement of objects and judge their direction (*Ab10-Movement Detection*) will be needed less often because it relates to judgment in speed or closure to the metering point and controllers' attention will be directed to DSTs that will provide this sort of information. To the extent that TBFM requires more time-critical management of aircraft, the Ability to perceive information quickly and accurately will become more important (*Ab11-Perceptual Speed and Accuracy*).

The demands on controllers' working memory (*Ab14-Working Memory*) are mixed. Demands will be reduced because mental processes required to determine control actions to get aircraft to certain fixes on time will be performed by the DSTs. However, demands will be increased to the extent that controllers manage a more dynamic environment where time is a more critical feature of aircraft management. Moreover, controllers' Ability to quickly generate multiple strategies (*Ab16-Fluency of Ideas*) will be used less often because DSTs will generate at least the initial set of options for controllers.

ARTCC controllers' Ability to adapt (*Ab24-Flexibility*) to a display with new and more information about metering points and to profit from their own and others' experience (*Ab28-Learning*) will be important. Finally, understanding closure rates of aircraft to a fix will be required less often because DSTs will provide this information. As a result, the Ability to perceive and understand principles governing relationships among objects (*Ab29-Visuospatial Reasoning*) will be needed less often.

Changes to Properties of Other Personal Characteristics

The DSTs associated with 3-D-PAM will increase the importance of internal locus of control because controllers need to see themselves as being in control of the DST and hence responsible for the outcomes instead of simply responding to the technology (*O14-Internal Locus of Control*).

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 19 risks associated with ARTCC NextGen Drivers is presented in Appendix B. Eleven potential risks with regard to the implementation of TBFM are:

- *Change in culture*: Developmental- and CPC-level line controllers will need to demonstrate willingness to learn to use metering point information from DSTs when managing air traffic. A lack of interest in learning and using the new DSTs may lead to underuse of these tools, which may lead to inefficiency and an increase in the possibility of making an error in the selection of the best option.
- *Deficiencies in technology*: If the 3-D-PAM DSTs do not provide reliable or valid options, controllers' selection of one of those options could reduce efficiency and increase the possibility for error. In addition, if the algorithms do not take into account the same or more information than controllers would when generating strategies or if the system does not provide options in a timely manner, controllers will be reluctant to use them. Any resulting controller-developed workarounds will mean that the tools are not being used to their full potential, which could decrease efficiency and result in unrealized benefits from investments in the automation.
- *Degradation or failure of equipment or systems*: If 3-D-PAM's DSTs fail or degrade, controllers will have to revert to self-generation of strategies to ensure aircraft arrival at the required time of arrivals (RTAs). If controllers are unable to quickly revert to this process, this increases the risk that aircraft will not meet the metering fix time, which poses a risk to efficiency.
- *Improper reliance on automation or procedures*: If controllers are complacent and over rely on 3-D-PAM's DST-generated options, they may simply accept DST-generated options without fully considering whether they represent viable options for metering in any given circumstance. This could negatively affect efficiency. In contrast, if controllers do not fully use the DST-generated options, which are

theoretically optimized to ensure adherence to the RTAs, and instead rely on their own strategies, this also potentially reduces efficiency.

- *Lack of/inadequate training*: Lack of training or inadequate training in the capabilities of TBFM as well as any limitations may result in poor controller decision making, especially as it relates to the time-based metering of aircraft. For example, controllers may fail to implement the time-based fixes or fail to develop control instructions that are adequate for ensuring aircraft arrival at the fix. This decreases efficiency, not only in an individual controller's sector but perhaps across ARTCC boundaries, thus affecting larger portions of the NAS than would be affected today.
- *Mixed ATC tools, equipment, or procedures*: If TBFM is not implemented in all ARTCCs, or if it is implemented on significantly different schedules throughout the NAS, the resulting differences in capability for managing aircraft on time-based routes could increase the difficult of transferring aircraft across airspace boundaries, reduce efficiency system wide, and increase the possibility for error in adjusting routes on an individual basis.
- *More dynamic work environment*: The requirement for controllers to ensure aircraft adherence to more time-based metering fixes will create a more dynamic work environment. The introduction of time-based constraints could increase controllers' mental workload and thus increase the possibility for error.
- *Poor Computer-Human Interface design*: If the CHI that provides line controllers with the additional time-based metering fixes and DST-provided options is not designed to present the information in a meaningful way or is not well integrated into existing systems (e.g., distracts users from more critical information, cannot be retrieved quickly, is not easily distinguishable from other related information), this could increase the possibility for errors, thus reducing safety.
- *Skill decay*: The implementation of 3-D-PAM's DSTs has the potential for the decay of Skills required for developing control strategies that result in adherence to a time-based fix without automation. Any resulting lack of preparedness by line controllers to self-generate control options could negatively influence their ability to evaluate the DST-provided options or to self-generate options more generally. This reduces efficiency and increases the possibility of errors.
- *Technology development and maturation*: Although safety risk management analyses are required on every new piece of equipment before implementation, new tools are often developed and tested as stand-alone systems. Although it is unlikely that TBFM 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, not until technologies are fielded and are being used by controllers can they 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.
- *Unknown impact of experience*: Controllers with varying levels of experience may perform cognitive information processing Tasks associated with evaluating controller-generated versus CRA-generated options differently. Until such differences, if any, are identified, it will be impossible to optimize training or utilization of the provided options.

Note that the introduction of TBFM-based DSTs represents a relatively substantive change to the work environment for ARTCC controllers. Tasks that were the responsibility of controllers are now being performed by automation. However, these are *decision support* tools, not *decision-making* tools. Controllers will still be required to evaluate the DST-provided options as well as to perhaps generate their own options. The DSTs do not "do" the job for controllers; rather, they support controllers in their job. Consequently, AIR did not include a risk regarding increases in Improper Allocation of Tasks to Automation, which addresses increases in monitoring and vigilance requirements.

Driver Impact Summary

TBFM is a TMU-based tool whose primary impact will be on the TMC's job. However, because arriving at certain metering fixes must happen at a very specific time, pilots will also have a large role in the implementation of TBFM. Similarly, controllers will be substantively affected by its implementation. Overall, the biggest impact of TBFM for line controllers will be the addition of DSTs. The implementation of TBFM and its associated DSTs will require controllers to work to guarantee that aircraft are at specific metering points at specific times much more often than they do today. This will be very work intensive for controllers. The actual control actions required to ensure adherence to these time-based fixes will be less extreme because they will be spread out and mitigated across time, space, and controllers in other adjacent facilities. Controllers will be responding in real-time to constraints all along routes instead of pushing deviations to the ARTCC airspace closest to the destination airport.

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 in large part because NAS stakeholders' functions are to a great degree interdependent and changes that affect one consequently affect the others. However, NextGen brings with it some potential risks. The effort put forth by NextGen system engineers, hardware and software developers, human factors researchers, and other aviation professionals in the months and years to follow will determine whether these risks materialize and whether and how they can be mitigated.

The Job of the NextGen ARTCC Controller

This report describes the job of the Air Traffic Control Specialist (ATCS) working in the Federal Aviation Administration's (FAA's) Air Route Traffic Control Center (ARTCC) environment in the NextGen mid-term time frame. To summarize, NextGen—and the technology, automation, and procedures that it will bring—will have an impact on the job of the ATCSs. Although 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 frequency of the use of some Abilities and Other Personal Characteristics.

Limitations of the Current Research

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

Fortunately, NextGen is evolving. Technologies that are not well understood are being researched. New automation is being tested. Problems are being identified and addressed. However, the ever-changing nature of the concept means that AIR's description of the ARTCC 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 input from subject matter experts (SMEs) regarding this report and to work toward updating and further refining the ideas it contains. AIR will then work with the FAA to ensure that the data are relayed to the individuals within the FAA who can effect the changes necessary to prepare the workforce for work in 2018.

Expand the Current ATCS Job Analysis

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

Develop NextGen Job Description for Additional Jobs

Because the management of air traffic is becoming increasingly trajectory based, additional work should endeavor to develop NextGen Job Descriptions for other air traffic control (ATC) positions that interact directly with line controllers. An important job to consider first is the job of the traffic management unit (TMU) coordinator, with whom line controllers interact. Additionally, NextGen technologies and automation will likely have an impact on—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 ARTCC controller in this report is based on NextGen documentation as of January 2011[16] and is already in some ways 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 comprises a series of tests that measures specific ATCS Knowledge, Skills, Abilities, and Other Personal Characteristics (KSAOs) 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 the frequency of use of various aptitudes. More specifically, the FAA may want to consider whether increases in the need for

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

Knowledge 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, AIR recommends 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 19 potential risks associated with the implementation of NextGen Drivers (see Appendix B for the full list) in the ARTCC 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 1 or 2 Drivers, and others being associated with all 10. A high-level summary of the risks and AIR's recommendations are provided below.[17] 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 ARTCC 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.

[17] 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. Because some deficiencies in technology have already been identified (e.g., latency in delivery and receipt of Data Comm messages), existing research should be continued and perhaps additional research could be conducted to determine how to address these deficiencies. The research could address the problem from both an engineering standpoint (i.e., how might the latency be eliminated) and a human performance standpoint (i.e., how can controllers manage the task fragmentation that will result).

In addition to deficiencies in technology creating challenges, differences in the installation of technologies will also create challenges. NextGen will exacerbate what is already a mixed equipage environment. AIR recommends training for controllers in the specific capabilities offered by various NextGen avionics, and how their presence will affect aircraft performance. In addition, controllers will need access to real-time accurate and easily accessible information about the equipage of specific aircraft.

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

Risks Associated With the New Policies and Procedures

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

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

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

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

Risks Associated With the New Work Environment

Five risks were identified with regard to the new NextGen work environment. They are:

- Change in Culture
- Lack of Challenge
- Loss of Party Line Information
- More Dynamic Work Environment
- New ATCS Role

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

Training will need to include specific information regarding the benefits of the new NextGen technologies, automaton, and procedures. More important, this information could be accompanied by information regarding the limitations of the new tools (i.e., what is going on in the “black box”). Although generic high altitude airspace (GHAA) is reserved for the best equipped aircraft, management of this airspace will be less challenging. Two potential recommendations with regard to this airspace are to reserve it for new Certified Professional Controller (CPC)–level controllers who are in the process of becoming fully certified in the ARTCC and/or to have controllers rotate this assignment to avoid negative impacts. To the extent that loss of party line information that will result from the implementation of Data Comm reduces situation awareness, research could be conducted to inform whether and how information entered into the Data Comm system by one controller should be made available to both pilots and controllers not directly involved in the exchange.

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

Risks Associated With Individual Controller Performance

Although all NextGen risks potentially affect controller performance in some way, the implementation of ARTCC NextGen Drivers creates five direct potential risks with regard to individual controller job performance. They are:

- Degradation or Failure of Equipment or Systems
- Improper Reliance on Automation or Procedures
- Lack of/Inadequate Training

- Skill Decay
- Unknown Impact of Experience

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

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

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

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Appendix A: Current ATCS Job Analysis Data

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
A1	**Establish Situation Awareness**	
S1	*Assuming position responsibility*	
	T1	Review system status information areas to gain situation awareness
	T2	Consider current and projected traffic/weather/workload
	T3	Receive briefing from controller being relieved
	T4	Review briefing checklist to assure comprehensiveness of coverage
	T5	Determine if ready to accept position responsibility
	T6	Log into designated display/workstation in controller role
	T7	Adjust workstation parameters and display to personal preference
	T8	Check workstation for proper configuration, usability, and satisfactory status
	T9	Update system status information if required
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 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 system 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	Determine most appropriate transmitter-receiver site
	T26	Establish two way radio communications
	T27	Issue most current automatic terminal information service (ATIS) information
	T28	Determine frequency in use by receiving sector
	T29	Issue change of frequency to pilot
S6	*Issuing clearances, instructions, or other messages*	
	T30	Identify need for communication

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T31	Receive request requiring response
	T32	Determine appropriate recipient(s)
	T33	Construct clearance, instruction, or message with proper phraseology
	T34	Issue clearance, instruction, or message
	T35	Listen for read back
	T36	Verify correct read back
	T37	Restate clearance, instruction, or message if required
	T38	Listen for read back
	T39	Verify correct read back
	T40	Evaluate situation to determine need for additional communications
	T41	Issue additional clearance, instruction, or message if required
A3	**Manage Flight Plan Data**	
S7	*Entering flight plan data*	
	T42	Receive request for flight plan
	T43	Evaluate flight plan request
	T44	Enter flight plan data locally or into NAS as required
	T45	Evaluate flight plan for accuracy
	T46	Issue clearance as appropriate
S8	*Amending flight plan data*	
	T47	Determine the need for an amendment
	T48	Receive request for flight plan amendment
	T49	Enter flight plan changes locally or into NAS
	T50	Review amended flight plan for accuracy
	T51	Update information locally or in the NAS if required
	T52	Coordinate any unsuccessful transmission messages (UTMs)
S9	*Managing flight progress strips*	
	T53	Receive flight plan data
	T54	Evaluate flight plan data for accuracy
	T55	Preplan required changes
	T56	Utilize appropriate strip marking
	T57	Resequence flight progress strips as necessary
	T58	Update traffic count/status manually
	T59	File flight progress strips when responsibility for that aircraft ends as necessary
	T60	File records (e.g., facility log)
	T61	Drop flight plan and track from the NAS
S10	*Processing departure or en route time information*	
	T62	Enter departure or en route time message
	T63	Receive departure or en route time notices
	T64	Monitor departure or en route time notices
A4	**Manage Air Traffic**	
S11	*Establishing and maintaining positive aircraft identification and position*	
	T65	Observe aircraft entering radar coverage area

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T66	Receive request from pilot to verify radar identification
	T67	Observe loss of radar contact
	T68	Inform pilot that radar contact is lost if appropriate
	T69	Identify appropriate radar identification procedure(s)
	T70	Perform appropriate radar identification procedure(s)
	T71	Verify aircraft identification by observing procedure results
	T72	Inform pilot that radar contact has been re-established if appropriate
	T73	Transfer radar identification
	T74	Verify aircraft leaving sector
S12	*Performing radar separation of aircraft*	
	T75	Review flight plan data
	T76	Verify aircraft is in conformance with flight plan
	T77	Monitor aircraft progress through radar coverage area
	T78	Project mentally an aircraft's trajectory
	T79	Identify potential or actual conflicts
	T80	Establish required separation
	T81	Maintain required separation
	T82	Determine potential control actions
	T83	Prioritize control actions
	T84	Issue appropriate control instructions
	T85	Verify pilot conformance to instructions
S13	*Performing nonradar separation of aircraft*	
	T86	Request current pilot position report
	T87	Record flight information on flight progress strip
	T88	Track aircraft movement on flight progress strip
	T89	Identify potential or actual conflicts
	T90	Establish required separation
	T91	Maintain required separation
	T92	Determine potential control actions
	T93	Prioritize control actions
	T94	Issue appropriate control instructions
	T95	Verify pilot conformance to instructions
S14	*Responding to special operations*	
	T96	Receive notice of special operation
	T97	Evaluate impact of special operation
	T98	Determine appropriate plan of action
	T99	Implement plan of action as required
	T100	Re-evaluate plan of action
	T101	Revise plan of action if required
	T102	Coordinate special operation with others
	T103	Receive notice of termination of special operation
S15	*Processing requests for VFR flight following*	
	T104	Receive request for flight following

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T105	Evaluate conditions for providing flight following
	T106	Approve or deny flight following request
	T107	Issue beacon code to aircraft if applicable
	T108	Enter flight information into automation locally and the NAS if required
	T109	Ensure correct data entry for flight following requests
	T110	Radar identify the aircraft
	T111	Issue appropriate clearance or control instructions if required
	T112	Ensure compliance with clearance or control instructions as necessary
	T113	Receive request for cancelation of air traffic services
	T114	Acknowledge request
S16	*Providing radar assistance to VFR aircraft*	
	T115	Determine if pilot and aircraft are qualified and capable of IFR flight if appropriate
	T116	Request that the pilot file an IFR flight plan if appropriate
	T117	Receive clearance request from pilot
	T118	Acknowledge pilot request for flight plan
	T119	Query pilot regarding existence of IFR flight plan
	T120	Receive pilot response
	T121	Determine potential control actions
	T122	Prioritize control actions
	T123	Issue the appropriate clearance
	T124	Coordinate with adjacent/affected facilities if applicable
	T125	Receive request for cancelation of air traffic services
	T126	Acknowledge request
S17	*Monitoring uncontrolled objects/aircraft*	
	T127	Observe uncontrolled object/aircraft
	T128	Receive information about uncontrolled object/aircraft
	T129	Initiate track on uncontrolled object/aircraft if appropriate
	T130	Flight-follow uncontrolled object/aircraft if appropriate
	T131	Coordinate with others if appropriate
	T132	Delete track on uncontrolled object/aircraft when appropriate
S18	*Responding to pilot requests for flight path deviation*	
	T133	Receive pilot request to deviate
	T134	Evaluate pilot request for deviation
	T135	Determine alternative clearance if required
	T136	Issue appropriate control instructions if required
	T137	Coordinate deviation with the next controller if required
S19	*Responding to aircraft nonconformance*	
	T138	Observe aircraft nonconformance
	T139	Receive notice of aircraft nonconformance
	T140	Inform other controller of nonconformance in that controller's sector
	T141	Query pilot about intentions
	T142	Determine appropriate action to resolve nonconformance
	T143	Issue appropriate control instructions to correct nonconformance

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T144	Issue advisory or alert if required
	T145	Verify compliance with instructions
	T146	Inform supervisor of nonconformance and if necessary of violation
A5	**Resolve Conflicts**	
S20	*Performing aircraft conflict resolutions*	
	T147	Identify potential or actual loss of separation
	T148	Receive notice of potential or actual conflict
	T149	Inform other controller of potential or actual conflict in that controller's sector
	T150	Observe aircraft conflict alert indication
	T151	Evaluate validity of the potential or actual aircraft conflict
	T152	Determine appropriate action to resolve conflict situation
	T153	Issue appropriate control instructions to ensure separation
	T154	Verify pilot conformance with instructions
	T155	Suppress conflict alert if appropriate in accordance with procedures and directives
	T156	Issue advisory or safety alert as appropriate
	T157	Inform pilot when traffic no longer a factor
	T158	Report loss of separation as appropriate
	T159	Restore conflict alert function to normal
S21	*Performing unsafe altitude resolutions*	
	T160	Identify potential or actual unsafe altitude situation
	T161	Detect MSAW indication
	T162	Receive notice of potential or actual unsafe altitude situation
	T163	Inform other controller of unsafe altitude situation in that controller's sector
	T164	Determine validity of unsafe altitude/MSAW
	T165	Determine appropriate action to resolve unsafe altitude situation
	T166	Issue appropriate control instructions to resolve unsafe altitude situation
	T167	Suppress MSAW function if appropriate in accordance with procedures and directives
	T168	Issue advisory or safety alert as appropriate
	T169	Restore MSAW function to normal
S22	*Performing airspace violation resolutions*	
	T170	Identify potential or actual airspace violation
	T171	Receive notice of potential or actual airspace violation
	T172	Inform other controller of airspace violation in that controller's sector
	T173	Determine validity of airspace violation
	T174	Determine appropriate action to resolve airspace violation
	T175	Issue appropriate control instructions to ensure separation
	T176	Issue advisory or traffic alert if appropriate
	T177	Report airspace violation as appropriate
S23	*Issuing unsafe condition advisories*	
	T178	Determine need for advisory or alert
	T179	Generate advisory or alert appropriate for situation
	T180	Issue advisory or alert as appropriate
	T181	Monitor response to advisory or alert

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T182	Cancel advisory or alert when situation returns to normal
A6	**Manage Traffic Flows and Sequences**	
S24	*Managing departure flows and sequences*	
	T183	Receive request for release of departure aircraft
	T184	Verify departure route via automation and/or flight progress strip
	T185	Issue appropriate clearance with restrictions if required to establish departure flow
	T186	Approve departure release with restrictions if required
	T187	Enter departure or en route time message
	T188	Acknowledge departure or en route time notice
	T189	Receive notice of canceled departure
	T190	Coordinate the canceled or revised departure
	T191	Observe auto acquisition
	T192	Ensure that the correct flight plan information is in the NAS if auto acquisition is not observed
	T193	Associate the flight plan and data block with the aircraft if required
	T194	Radar identify the aircraft
	T195	Determine sequence within departure flow
	T196	Issue appropriate control instructions to sequence departures into existing traffic to expedite flow
	T197	Re-evaluate traffic sequence
	T198	Issue revised control instructions if required
S25	*Managing arrival flows and approach sequences*	
	T199	Observe radar target/data block/flight progress strip of arrival aircraft
	T200	Determine arrival sequence
	T201	Ensure coordinated arrival routing
	T202	Verify pilot has current approach information
	T203	Issue current approach information if required
	T204	Issue appropriate control instructions to implement approach sequence
	T205	Re-evaluate traffic sequence
	T206	Issue revised control instructions if required
	T207	Coordinate with adjacent sectors as required
S26	*Responding to traffic management initiatives*	
	T208	Receive information regarding traffic management initiative
	T209	Discuss impact of traffic management initiative with supervisor or traffic management unit
	T210	Evaluate traffic management initiative for effect on traffic flow
	T211	Develop options for bringing aircraft into conformance with traffic management initiative
	T212	Determine appropriate action to bring aircraft into conformance with traffic management initiative
	T213	Advise pilot of a traffic management initiative if necessary
	T214	Coordinate with local Traffic Management Unit (TMU) and/or appropriate air traffic facility as necessary
	T215	Issue appropriate control instructions to comply with traffic management initiative
	T216	Verify compliance with instructions by pilot and other facilities

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T217	Receive notice of cancellation of traffic management initiative
	T218	Coordinate cancellation of traffic management initiative with others
A7	**Transfer of Radar Identification**	
S27	*Initiating handoffs*	
	T219	Receive request for transfer of radar identification
	T220	Determine need for transfer of radar identification
	T221	Ensure all conflicts are resolved
	T222	Coordinate restrictions with receiving controller as necessary
	T223	Initiate automated handoff
	T224	Observe automated handoff failure
	T225	Retract handoff if required
	T226	Initiate a route force (RF) message if appropriate
	T227	Initiate manual handoff
	T228	Issue appropriate control instructions to redirect aircraft from airspace as required
	T229	Receive manual handoff acceptance
	T230	Issue appropriate control instructions as required
	T231	Observe the handoff acceptance
S28	*Accepting handoffs*	
	T232	Observe automated handoff request
	T233	Receive a request for manual handoff
	T234	Determine response to handoff request
	T235	Coordinate restrictions with initiating controller as necessary
	T236	Accept handoff
	T237	Deny handoff
	T238	Receive control of aircraft according to Letter(s) of Agreement (LOAs) and Standard Operating Procedures (SOPs)
S29	*Issuing pointouts*	
	T239	Identify need for pointout
	T240	Initiate automated pointout
	T241	Initiate manual pointout
	T242	Receive approval of pointout with restrictions if required
	T243	Adhere to restrictions if required
	T244	Receive rejection of pointout
	T245	Issue appropriate control instructions to remain clear of airspace if rejected
	T246	Initiate handoff if rejected
S30	*Responding to pointouts*	
	T247	Receive automated pointout request
	T248	Receive manual pointout request
	T249	Initiate automated track of aircraft as necessary
	T250	Ensure target data block correlation
	T251	Determine response to pointout
	T252	Approve pointout with restrictions if required
	T253	Deny pointout

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T254	Declare radar contact
	T255	Suppress automated track after pointout is no longer a factor
A8	**Assess the Impact of Weather**	
S31	*Processing weather information*	
	T256	Review graphical weather information
	T257	Review text-based weather information
	T258	Determine lowest usable flight level
	T259	Receive notice of runway or airport condition changes
	T260	Receive runway condition/use data
	T261	Forward runway condition/use data
S32	*Responding to severe weather information*	
	T262	Observe radar or satellite display of severe weather intensity and trend
	T263	Solicit PIREPs as required
	T264	Request severe weather information from others
	T265	Receive request for weather information
	T266	Determine the impact of severe weather on routes or flow
	T267	Disseminate severe weather information as appropriate
	T268	Determine altitude or route change to bypass severe weather
	T269	Issue appropriate control instructions to avoid severe weather
	T270	Inform supervisor or traffic management coordinator of weather impact on routes or flow
	T271	Receive new routing for weather avoidance from supervisor or traffic management coordinator
A9	**Manage Airspace**	
S33	*Requesting temporary release of airspace*	
	T272	Determine that the use of another controller's airspace is needed
	T273	Request the use of airspace
	T274	Receive approval including conditions if any for the use of airspace
	T275	Issue appropriate control instructions
	T276	Return airspace when no longer needed
	T277	Receive rejection
S34	*Responding to requests for temporary release of airspace*	
	T278	Receive request for temporary use of airspace
	T279	Observe affected traffic
	T280	Evaluate feasibility of temporarily releasing airspace
	T281	Request release of airspace from other controller as appropriate
	T282	Approve/deny temporary release of airspace
	T283	Issue appropriate control instructions
	T284	Coordinate temporary release of airspace if approved
	T285	Receive notification that released airspace is returned
	T286	Change automation associated with temporary use of airspace
S35	*Responding to changes in airspace status*	
	T287	Receive notice of the change in status of airspace
	T288	Coordinate change in status of airspace with others

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T289	Coordinate airspace restrictions with others
	T290	Change automation to reflect the change in airspace status
	T291	Determine appropriate actions to ensure separation from airspace
	T292	Issue appropriate control instructions
	T293	Ensure status information areas are updated
	T294	Receive notice that restriction is terminated
	T295	Inform others that restriction is terminated
	T296	Discontinue use of visual aids/memory joggers
S36	*Transferring position/sector for reconfiguration*	
	T297	Advise receiving controller to prepare for position/sector reconfiguration
	T298	Give briefing to the receiving controller taking the airspace
	T299	Verify that the receiving controller has necessary settings for communication system and automation system
	T300	Configure communication and automation system to reflect changes
	T301	Adjust display for the new configuration
S37	*Receiving position/sector for reconfiguration*	
	T302	Receive notice to prepare for sector or position reconfiguration
	T303	Adjust display for the new configuration
	T304	Configure communication and automation system to reflect changes
	T305	Receive briefing from the controller relinquishing the airspace
	T306	Determine if ready to accept position responsibility
	T307	Assume control of position/sector
A10	**Manage Resources**	
S38	*Managing personal and position workload*	
	T308	Ensure fitness for duty
	T309	Identify current or potential overload situations
	T310	Identify potential overload reduction strategies
	T311	Inform supervisor of current or potential overload
	T312	Request assistance if required
	T313	Implement overload reduction strategy as appropriate
	T314	Receive supervisor notice of implementation of overload reduction strategy
S39	*Supporting teamwork environment*	
	T315	Participate in training and other professional development activities
	T316	Maintain en route facility awareness
	T317	Inform supervisor of important situations
A11	**Respond to Emergencies and Unusual Situations**	
S40	*Responding to emergencies*	
	T318	Receive notice of emergency
	T319	Detect an emergency
	T320	Evaluate the situation
	T321	Determine appropriate plan of action
	T322	Respond to emergency as required
	T323	Declare emergency if necessary

ARTCC Activities, Sub-Activities, and Tasks **Activity (A-bold)** *Sub-activity (S-italics)* Task (T)		
	T324	Review emergency checklist
	T325	Amend traffic flow and sequence to expedite emergency aircraft
	T326	Coordinate emergency information with others
	T327	Re-evaluate emergency situation
	T328	Revise plan of action if required
	T329	Report emergency declared and action taken to supervisor
S41	*Responding to unusual situations*	
	T330	Detect unusual situation
	T331	Receive notice of unusual situation
	T332	Evaluate situation
	T333	Report situation to supervisor
	T334	Determine appropriate plan of action
	T335	Issue required security notifications immediately if necessary
	T336	Comply with security notifications and/or coordination as required
	T337	Implement plan of action
	T338	Re-evaluate situation
	T339	Revise plan if appropriate
	T340	Implement revised plan
	T341	Coordinate information with others as appropriate
S42	*Responding to system/equipment degradation or failure*	
	T342	Detect degradation or failure
	T343	Receive notice of degradation or failure
	T344	Coordinate degradation or failure information with others
	T345	Initiate backup system if appropriate
	T346	Implement backup procedures
	T347	Initiate nonradar separation procedures if required
	T348	Coordinate with others regarding repair if required
	T349	Receive notice of return to service
	T350	Verify accuracy of system data
	T351	Resume normal operations
	T352	Notify others of return to normal operations

ATCS Knowledges for ARTCC		
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
	K8.4	Weather features

ATCS Knowledges for ARTCC		
	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 covered in each ATC publication
	K14.6	Types of sensitive document
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
	K15.5	Flight information region (FIR)
K16	Knowledge of Flight Plan Data	

ATCS Knowledges for ARTCC		
	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	Facility radio frequencies
	K18.6	Local navigation aids (NAVAIDs)
	K18.7	Airspace dimensions
	K18.8	Adjacent airspace
	K18.9	Sector configurations
	K18.10	Runway configurations
	K18.11	Local geography
	K18.12	Impact of local topography on flight
	K18.13	Local obstructions/obstacles
	K18.14	Local weather patterns
	K18.15	Facility traffic flows
	K18.16	Areas with high potential for confliction (hot spots)
	K18.17	Facility specific directives and procedures
	K18.18	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
K22	Knowledge of Providing ATC Services	
	K22.1	Types of air traffic services

ATCS Knowledges for ARTCC		
	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	Strategies for severe weather avoidance
	K22.10	Transfer of control requirements
	K22.11	Transfer of communication requirements
	K22.12	Approach control service
	K22.13	Notice to Airmen (NOTAM)
K23	Knowledge of Additional ATC Services	
	K23.1	Aircraft Management Information System (AMIS)
	K23.2	Direction finding (DF) services
	K23.3	Visual flight rule (VFR) flight following
	K23.4	Flight information service (FIS)
	K23.5	Uncontrolled aircraft
	K23.6	Nonparticipating aircraft
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
	K27.3	Required clearances and control instructions
	K27.4	Search and rescue
	K27.5	Emergency assistance techniques
	K27.6	Coordination requirements

ATCS Knowledges for ARTCC		
	K27.7	Notification requirements
	K27.8	Reporting requirements
	K27.9	National security contingency plans

ATCS Skills

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

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

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

ARTCC Tools and Equipment

No	Category	Full Name	Acronym	Description
TE1	Automation	Host and Oceanic Computer System Replacement (HOCSR)	Host or HOCSR	▪ Host is a radar data processing and display system that consists of hardware and software. ▪ Host processes radar and Traffic Management Advisor (TMA) data and displays the information in real time to controllers who use the information to manage en route traffic. The back-up system for Host is the Enhanced Back-Up Surveillance (EBUS) system. ▪ Controllers interact with Host via Display System Replacement (DSR), which provides controllers an easily interpretable interface with customizable displays and other input devices such as an ABCD keyboard and a trackball or a mouse, and via the flight strip printer, which prints the flight strips generated by FDIO software. ▪ Host is currently being replaced by ERAM.
TE2	Automation	En Route Automation and Modernization	ERAM	▪ ERAM is a radar data processing and display system that consists of hardware and software. ▪ ERAM displays radar and Traffic Management Advisor (TMA) data in real time to controllers who use this information to manage en route traffic. ERAM also automates and modernizes the air traffic control system by allowing maximum airspace use, better conflict detection, and improved decision making for controllers via En Route Decision Support Tool (EDST). EDST tracks textual and graphical data via a high resolution color display with aircraft performance characteristics, and temperature and wind data to build four-dimensional flight trajectories that provide controllers with better decision-making. ▪ Controllers interact with ERAM via a high resolution flat panel color display, which provides controllers an easily interpretable interface with EDST and customizable views. Controllers may also input data via devices such as QWERTY keyboards and trackballs, and via the flight strip printer, which prints the flight strips generated by FDIO software. ▪ ERAM replaces the aging Host system and its backup system.

No	Category	Full Name	Acronym	Description
TE3	Automation	Micro-Processor En Route Automated Radar Tracking System	Micro-EARTS	▪ Micro-EARTS is a radar data processing and display system that consists of hardware and software. ▪ Micro-EARTS displays radar data in real time to controllers who use this information to manage en route traffic. It accepts and processes ADS-B surveillance data to provide air traffic control in non-radar areas like Alaska. ▪ Controllers interact with Micro-EARTS via Display System Replacement (DSR), which provides controllers an easily interpretable interface with customizable displays. Controllers may input data via input devices such as an ABCD keyboard and a trackball or a mouse, and via the flight strip printer, which prints the flight strips generated by FDIO software. ▪ Most ARTCC facilities use Host or ERAM as their primary automation system. Only a few facilities have Micro-EARTS.
TE4	Automation	User Requested Evaluation Tool	URET	▪ URET is a high resolution color display that receives flight plan data from Host in real time and tracks both textual and graphical data it receives from the Host computer. ▪ URET combines the real time data from Host with flight plan data, aircraft performance characteristics, temperature, and wind data (from National Weather Service) to build four-dimensional flight trajectories. URET enables more efficient routes and altitudes to be flown because of the accurate trajectory and conflict information it provides to the aircraft. Depending on the airspace and the facility infrastructure, URET may or may not be used primarily by the D-side controller. ▪ Controllers interact with URET via an easily interpretable interface that has a customizable views (or windows) and other input devices such as a standard keyboard and mouse or trackball. ▪ In facilities that have ERAM, URET becomes part of ERAM and is referred to as EDST.
TE5	Automation	Flight Data Input/Output System	FDIO	▪ FDIO is a hardware and software system that serves as a portal to the Host/local radar system and that also provides a tracking system for flight plan data and a printing system for paper flight strips. ▪ Controllers use the FDIO to enter and amend flight plan data, weather data, and general information concerning the NAS. Once entered into FDIO, these data are sent to Host/local radar system and then shared with other facilities. Controllers also monitor flight plan data and generate paper flight strips using FDIO. ▪ Controllers monitor the FDIO screen, input data using the FDIO QWERTY keyboard, and collect paper strips from the FDIO printer. ▪ FDIO is associated with the use of paper flight progress strips. It is being replaced with the EFSTS, which generates electronic flight strips.

No	Category	Full Name	Acronym	Description
TE6	Communications	Voice Switching and Control System / Voice Training and Backup Switch	VSCS /VTABS	▪ VSCS is the primary voice communication system for ARTCC. It consists of both hardware and software components, and support communication via both radio transmission and landline capability. ▪ VSCS allows air traffic controllers to establish air-to-ground and ground-to-ground calls. VTABS is a backup voice communications system if the main communications system (VSCS) becomes inoperable as a result of a power outage, a catastrophic system failure, or during system maintenance or upgrade activities. VTABS may also be used for training. ▪ Controllers typically interact with the system via corded single-sided and double-sided headsets and handsets as well with input devices such as foot pedals, and switches attached to headsets to engage the system and navigate between VHF, UHF, backup frequencies, and landlines.
TE7	Information Management	Weather and Radar Processor	WARP	▪ WARP is a system comprised of hardware and software that gathers weather information and presents it to controllers. Sources of information include next generation (NEXRAD) radars and satellite images. ▪ Controllers use the data provided by WARP to evaluate the current weather situation, evaluate trends, and to assess impact of weather on traffic and other things. These data provide more detailed weather information than ESIS and the primary radar display. ▪ Controllers monitor WARP's display to get weather information. The monitor is centrally located.
TE8	Information Management	En Route Information Display System	ERIDS	▪ ERIDS is interactive, real-time, electronic information stand-alone display system on an articulating arm. ▪ ERIDS is used as a dictionary of air traffic rules, standard operating procedures (SOPs), approach plates, notices to airmen, pilot reports, weather data, and serves as a local reference library. ▪ Controllers operate the system by using touch screen displays, a supplemental pointing device such as a mouse, or an electronic keyboard. ▪ ERIDS replaces the current ATC information display system, which consists mostly of paper sources of information.

No	Category	Full Name	Acronym	Description
TE9	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 a large centrally located monitor and/or on a smaller monitor(s) located elsewhere in the facility depending on the facility's unique configuration. Some facilities also have the option to put TSD information on ESIS.
TE10	Information Management	Enhanced Status Information System	ESIS	▪ ESIS is a large centrally located monitor/projector that displays air traffic control-related information. ▪ ESIS enables controllers to identify special airspace use restrictions, weather, and key traffic flow restrictions in TRACON airspace. ESIS displays data from multiple systems including weather data from Automated Surface Observing System (ASOS) and Integrated Terminal Weather System (ITWS). ▪ Controllers monitor the ESIS information on a large display that is centrally located where controllers can turn and look as needed.
TE11	Information Management	Overhead Charts	Charts	▪ Overhead charts are aeronautical paper charts that are positioned above controllers' workstations to show the boundaries of that facility's airspace and NAVAIDs and airways in that airspace. These charts are updated every 56 days. ▪ These charts provide basic information about the airspace and operations to controllers. ▪ Controllers periodically view the overhead charts for information.

Appendix B: Potential Risks

Potential Risk to ARTCC Driver Matrix

Potential Risk	ARTCC NextGen Driver: 4-D Wx Data Cube	ADS-B Out	CRA	Data Comm	FAM	High Altitude Airspace	ITA	Big Airspace	PBN	TBFM	**# of Drivers Affected**
Best Equipped, Best Served		●		●			●		●		**4**
Change in Culture			●	●						●	**3**
Coordination of Multiple Stakeholders		●		●			●				**3**
Deficiencies in Technology		●	●	●					●	●	**5**
Degradation or Failure of Equipment or Systems	●	●	●	●			●		●	●	**7**
Improper Allocation of Tasks to Automation							●		●		**2**
Improper Reliance on Automation or Procedures	●		●		●		●		●	●	**6**
Lack of Challenge						●		●			**2**
Lack of/Inadequate Training	●	●	●	●	●	●	●	●	●	●	**10**
Loss of Party Line Information				●							**1**
Mixed Aircraft Equipage		●		●			●		●		**4**
Mixed ATC Tools, Equipment, or Procedures	●		●	●	●	●				●	**6**
More Dynamic Work Environment					●		●		●	●	**4**
New ATCS Role						●					**1**
Poor Computer-Human Interface Design	●	●	●	●						●	**5**
Reduced Separation Minima		●									**1**
Skill Decay	●	●	●	●		●	●		●	●	**8**
Technology Development and Maturation	●	●	●	●	●	●	●	●	●	●	**10**
Unknown Impact of Experience			●							●	**2**
# of Risks Cited Per Driver	**7**	**10**	**10**	**12**	**5**	**6**	**10**	**3**	**10**	**11**	

Appendix C: Reviewed References

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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