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MITRE PRODUCT

A Qualitative, Initial Evaluation of Decision Support System (DSS) Use of ADS-B Pilot Intent Information

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Abstract

Pilot intent information in the form of flight plan (FP) information has been used since the beginning of air traffic control and today the FP still documents a pilot's intended route of flight. However, today's air traffic environment is very dynamic and factors such as heavy traffic and adverse weather conditions can alter the route originally intended. The advent of Free Flight will increase traffic complexity by enabling pilots to fly more user-preferred, non-standard routes. Additionally, projections of increased future traffic suggest an increasingly complex environment requiring the need for more and better information on where an aircraft is intending to fly.

In the near future, new technologies can help cope with future traffic increases. Automatic Dependent Surveillance Broadcast (ADS-B) can provide new cockpit-derived information to control personnel on the ground. This includes such dynamic information as the current (short-term) intent of the pilot and the current maneuvering status of the aircraft.

This document discusses the need and future use of intent information and maneuver occurrence information in ground-based Decision Support Systems (DSS). It presents DSS functional areas that could be enhanced by use of ADS-B pilot intent and aircraft maneuver information. It recognizes that a comprehensive view of aircraft intent and aircraft maneuver information should be taken to enable future operational benefits, and discusses the use of other sources of cockpit-derived intent information, such as Controller Pilot Data Link Communication (CPDLC) information, for use in conjunction with ADS-B. The document does not attempt to quantify parameters and requirements associated with the use of ADS-B information in ground based DSS, but it does identify areas for further investigation and research and provides recommendations on ADS-B use.

KEYWORDS: Automatic Dependent Surveillance Broadcast, ADS-B, intent, intent information, pilot intent, flight intent, aircraft intent, maneuver intent

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Section 1

Introduction

At the request of the Federal Aviation Administration (FAA), the Center for Advanced Aviation System Development (CAASD) was asked to evaluate potential Decision Support System (DSS) uses of Automatic Dependent Surveillance Broadcast (ADS-B) intent information.

1.1 Purpose

The purpose of this document is to present examples of potential DSS uses of ADS-B intent information (and other air-derived information) and to discuss operational benefits and issues associated with these uses. The objective is to show that use of air-derived information, such as ADS-B intent information, in ground-based system functions can enable the development of tools that will help controllers handle expected future increased traffic levels. The document recognizes that a comprehensive system-wide view of aircraft intent and aircraft maneuver information needs to be taken to enable future operational benefits.

The document represents an initial evaluation of the potential uses of air-derived intent and maneuver information in ground-based system functions. Although it discusses several ground-based functions that could use air-derived intent and maneuver information, the document is not intended to comprehensively cover all possible uses.

The audience is intended to be anyone in the aviation community interested in ground-based system use of air-derived information that is available from ADS-B, or other emerging technologies, for the purpose of increasing both the safety and capacity of the future Air Traffic Management (ATM) environment.

1.2 Approach

A literature search was conducted to acquire information on pilot intent use in air traffic management and airborne systems. The search found numerous documents including documents from the FAA, the National Aeronautics and Space Administration (NASA), EUROCONTROL, and MITRE that address the future use of pilot intent information. In general, the documents identify the future need for pilot intent information, however, none really concentrate in detail on the use of intent information in the ground-based DSS.

This document incorporates the literature search results, as well as additional ideas on the use of intent information in ground based DSS. It concentrates on intent information provided by ADS-B and discusses functional areas that could be enhanced through the use of ADS-B intent information. It expands the discussion to include the uses of maneuver occurrence information, which is also provided by ADS-B. It goes beyond ADS-B and gives a wider view of intent including intent provided by Controller Pilot Data Link Communications (CPDLC) and use of CPDLC for delivery of routes, such as Area Navigation (RNAV) routes, to aircraft systems.

The document recognizes that a comprehensive view of aircraft intent and aircraft maneuver information should be taken to enable future operational benefits. It does not attempt to quantify parameters and requirements associated with the use of ADS-B information in ground based DSS, but it does identify areas for further investigation and research.

1.3 Document Organization

Section 2 discusses the history associated with the use of intent information in the ATM environment and provides definitions of both intent and maneuver information that are used throughout the document. Section 3 discusses seven examples of the use of intent information. Each subsection provides one example and discusses the operational benefits of that example. Issues and potential research areas are also discussed.

Section 2

Background

The discussion that follows concentrates on the need for and future use of intent information and maneuver occurrence information in ground based DSS. Even though this document concentrates mainly on intent and maneuver occurrence information available from ADS-B, it does discuss other possible sources of this information.

2.1 Intent Information

Pilot intent information has been available almost since the beginning of Air Traffic Control (ATC). Prior to the availability of radar sensors, the flight plan (FP) was conceived to document when and where a pilot intended to fly. Ground personnel relied on this FP information while following the flight via radio progress reports issued by the pilot. Today flight progress over some oceanic areas is still followed in this same manner. However, over land, with the advent of ground based radar sensors after World War II, control personnel were given the ability to actively monitor flight progress without the need for radio progress reports. Use of radar and the FP continue today and the FP still documents a pilot's intended route of flight.

2.1.1 Definition of Intent

Even before a pilot files a flight plan, he or she has a certain flight intent in mind. Intent can be defined as the intended **future** path of an aircraft. Intent refers to the pilot's objectives and where that pilot intends to take the aircraft in the future. Sometimes, in the case of commercial flights, it applies to the future intent of the dispatcher before the dispatcher tells the pilot where to fly the aircraft to reach its destination safely and more efficiently. Also, the definition applies to both aircraft in the air during airborne phases of flight and aircraft on the ground during taxi-out or taxi-in phases.

The term "intent" includes the terms "pilot intent," "flight intent," "maneuver intent," and "aircraft intent." All of these terms are used throughout the document.

2.1.2 Future Need for Improved Intent Information

Future traffic levels are predicted to be greater than today's and so controllers and automated functions will need to have more information in a timely manner. The more controllers know about where aircraft are now, what they are doing now (maneuvering/not maneuvering), and where they intend to go (intent), the better, faster and safer they can do their job. Knowing these three things will help controllers envision the current traffic picture and the near-term traffic picture. The more automation functions know about these three things, the better they will perform, and the better they will aid controllers in doing their job.

This is especially true in an atmosphere of increased user flexibility (Free Flight) in choosing routes. ADS-B intent information and maneuver information can provide some of this information and is the first step in improving Air Traffic Management (ATM) and the ATM environment for users.

Filing a FP begins the process of communicating intent for a flight. This process is a continuing one that will result in redefining/reconfirming and changing a flight's intent throughout the flight's life until the flight is over. Many things can work against a flight achieving its intended flight. The intentions of other flights that are competing for the same airspace is one; the weather and its unpredictability is another. This is where the service provider comes in. The service provider serves as a negotiator, granting intended flight paths to some, negotiating and modifying the intentions of others. This service is for the overall good and safety of all flights.

2.1.3 Timeframe of Intent Information

"Intent" can apply to just the next intended change in an aircraft's trajectory, or to the entire intended route of the aircraft's planned flight from beginning to end, or to anything in between. Likewise, an ATM Decision Support System (DSS) function usually applies to a particular future timeframe.

In general, one can say that the shorter the timeframe of the intent information, the more reliable the information is. However, one can also say that the shorter the time frame of the intent information the more important it is for the information to be correct if it is used in DSS functions. Likewise, the longer the timeframe of intent information, the more likely that information will change due to unknowns. A function that uses intent information must compensate for the possibility that intent may not be followed.

Timeframes for intent information used in ground DSS system functions can be categorized into three categories:

1. Long-term intent

   Long-term intent information pertains to route information such as that contained in a flight plan. This information applies to the whole planned route of flight or a large portion of the planned route, and is subject to strategic amendment.

2. Medium-term intent

   Medium-term intent information pertains to route segments with lengths up to approximately 20 minutes into the future. These route segments can have definitions that are more detailed than those contained in a flight plan (e.g., RNAV routes). This information is subject to strategic or tactical amendment.

3. Short-term intent

   Short-term intent information pertains to route information for only the next 1-2 minutes into the future in an en route environment and only seconds into the future in the terminal environment. This information is subject to tactical amendment.

2.2 Maneuver Occurrence Information

2.2.1 Definition of Maneuver Occurrence

Maneuver occurrence information pertains to an action that is happening now as opposed to something intended to happen in the future. Maneuver occurrence is the indication from cockpit equipment that an aircraft is currently performing a horizontal and/or vertical maneuver. In other words, the aircraft is currently not following a straight and level trajectory.

2.2.2 Future Need for Maneuver Occurrence Information

Display of a maneuver occurrence information will serve as a positive indication of a maneuver and the controller will no longer need to watch several scans of radar returns for a horizontal trajectory change or several scans of mode C data for a vertical change. Also, use of maneuver occurrence information will enhance the performance of ground-based automated functions. Trackers will be told and will no longer need to "guess" that an aircraft is maneuvering. In the air, display of maneuver occurrence information on an airborne situation display will alert the pilot to the maneuvers of neighboring aircraft.

2.3 Sources of Intent and Maneuver Occurrence Information

The various sources of intent and maneuver occurrence information are either "current" sources or "future" sources. Current sources are available today and future sources are envisioned to be available with the implementation of new technologies.

2.3.1 Current Sources

Figure 2-1 is a high level-diagram of today's ATM environment showing the current sources of intent and maneuver occurrence information. The following paragraphs explain each source.

2.3.1.1 Flight Plan

To an ATM DSS, a flight plan is the initial source of intent information for a particular flight. The information contained in a FP can be considered intent information since it contains when and where the pilot is intending to fly. Filing of a flight plan formalizes this intent. In other words, an intended four-dimensional flight path is implied when a flight plan is filed.

2.3.1.2 Controller

Controllers can be a source of intent information and changes to a flight's intent. Controllers are in close voice contact with an aircraft throughout the life of the flight. When controllers know about a change in intent or about a current maneuver that was not originally intended, they can enter an amendment to the flight's flight plan.

2.3.1.3 Pilot via Voice Communications

The voice link from the pilot to the controller on the ground provides a communication vehicle for changes in a pilot's intent. However, once a change in intent is agreed upon by voice, the controller still must enter the change into the DSS ground system to keep the database current. Frequently, the controller is very busy and has no time to make the entry.

2.3.1.4 Surveillance/Tracking Function

The current surveillance and tracking function, provides basic information for the controller's aircraft situation display. The terminal automation system's tracking function also has a rudimentary horizontal maneuver sensor. It senses a maneuver when an aircraft deviates a threshold amount from a straight-line trajectory. This maneuver information in today's terminal automation system is used by the safety functions.

2.3.2 Future Sources

In the future, the aircraft, including the pilot and automated airborne equipment, can be a direct source of intent information and maneuver occurrence information via the use of new technologies. ADS-B can provide an invaluable source of information to the ground systems. Also, automating air/ground communications through the use of electronic CPDLC can provide a way of communicating intent and changes in intent.

These sources are discussed below. Potential uses of this information are discussed in Section 3.

2.3.2.1 Automatic Dependent Surveillance Broadcast (ADS-B)

Based on the current Minimum Aviation System Performance Standards (MASPS), ADS-B provides the receiving ground DSS with intent and maneuver occurrence information as follows.

2.3.2.1.1 Turn Indication

The ADS-B turn indicator designates an aircraft as turning right, turning left, or not turning.

2.3.2.1.2 Horizontal Velocity

A horizontal velocity vector is provided. Its magnitude contains information useful in monitoring speed change maneuvers, and its direction contains information useful in monitoring turn maneuvers.

2.3.2.1.3 Altitude Change Rate

The altitude change rate designates the aircraft as climbing or descending with a particular rate, reported in feet per minute (fpm).

2.3.2.1.4 Trajectory Change Points

ADS-B provides the next trajectory change point (TCP) and the one following the next (TCP+1). Short-term intended maneuvers can be determined from the TCP and TCP+1. The intended end of a turn, or destination heading also can be determined from the TCP and TCP+1. Also the intended level-off altitude at the end of a climb descent can be determined from the TCP and TCP+1.

2.3.3.2 Controller/Pilot Data Link Communications

The CPDLC, when available, can go a step beyond ADS-B in terms of intent detail. Data link communications between the air and ground provides a means of transmitting detailed intent information in the form of detailed routes such as RNAV routes. Detailed routes can be precisely followed by an aircraft via use of automated cockpit equipment. Operational benefits can be achieved if the automated ground system functions are cognizant of the same route details. The ground functions can monitor aircraft progress on detailed routes and predict any potentially hazardous situations. Likewise, future airborne situation displays, if cognizant of the detailed intended routes of neighboring aircraft, can display the intent and use it to predict hazardous situations.

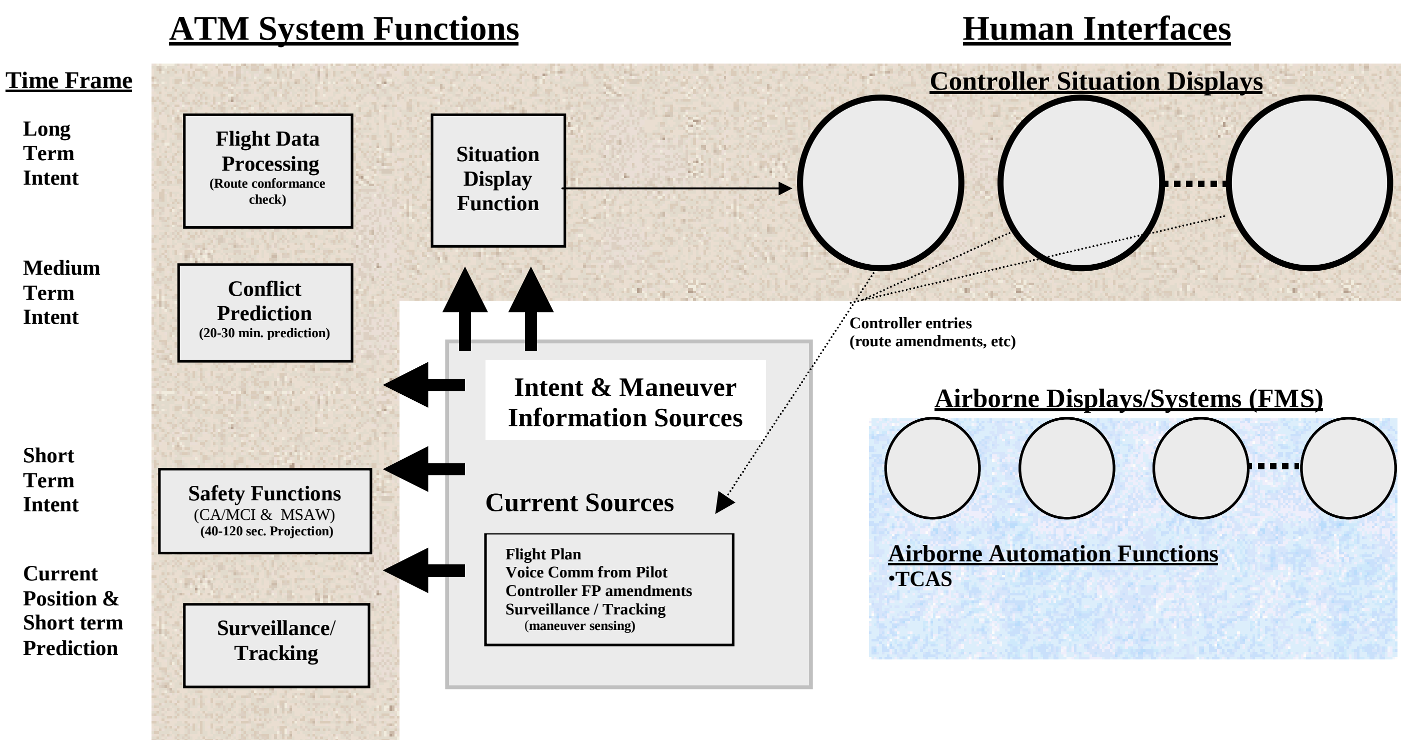

Figure 2-1. ATM Environment with Current Sources of Intent and Maneuver Information

Section 3

Use of ADS-B Intent and Maneuver Information in DSS Automation Functions

Intent and maneuver information available from ADS-B equipped aircraft can be used beneficially in ground-based DSS automation functions. Uses of this information range from simply displaying the information to the controller on his or her situation display, to use of the information by automated functions to improve the performance (and hence the usefulness) of the function to controllers. Figure 3-1 is a high-level diagram of a future ATM environment showing sources of intent information including the current sources available today and the additional future sources of ADS-B and CPDLC. A new function called the intent monitoring function is recommended. Candidate functions for improvement include the situation display function, the surveillance and tracking function, a medium-term conflict prediction function, a metering function, the safety functions (the conflict alert [CA], mode C intruder [MCI], and the minimum safe altitude warning [MSAW] functions), and a surface safety function.

Table 3-1 lists these candidate improvement areas, along with a short description of each function as improved by the availability of intent and/or maneuver information, the operational benefits of the each function, and research areas and issues associated with the function. Following the table, a subsection for each function describes these table columns in more detail. For each of these improvement areas, an overriding issue (not shown in Table 3-1) concerns the "concept of use" of the improved function, the software design to match this concept, the development and testing of this software, and the method of transition from the old to the new improved function.

Conflict prediction is included as a representative of a function that depends on medium-term intent information. Other than this one, Free Flight functions are not covered specifically and should be included in follow-on research.

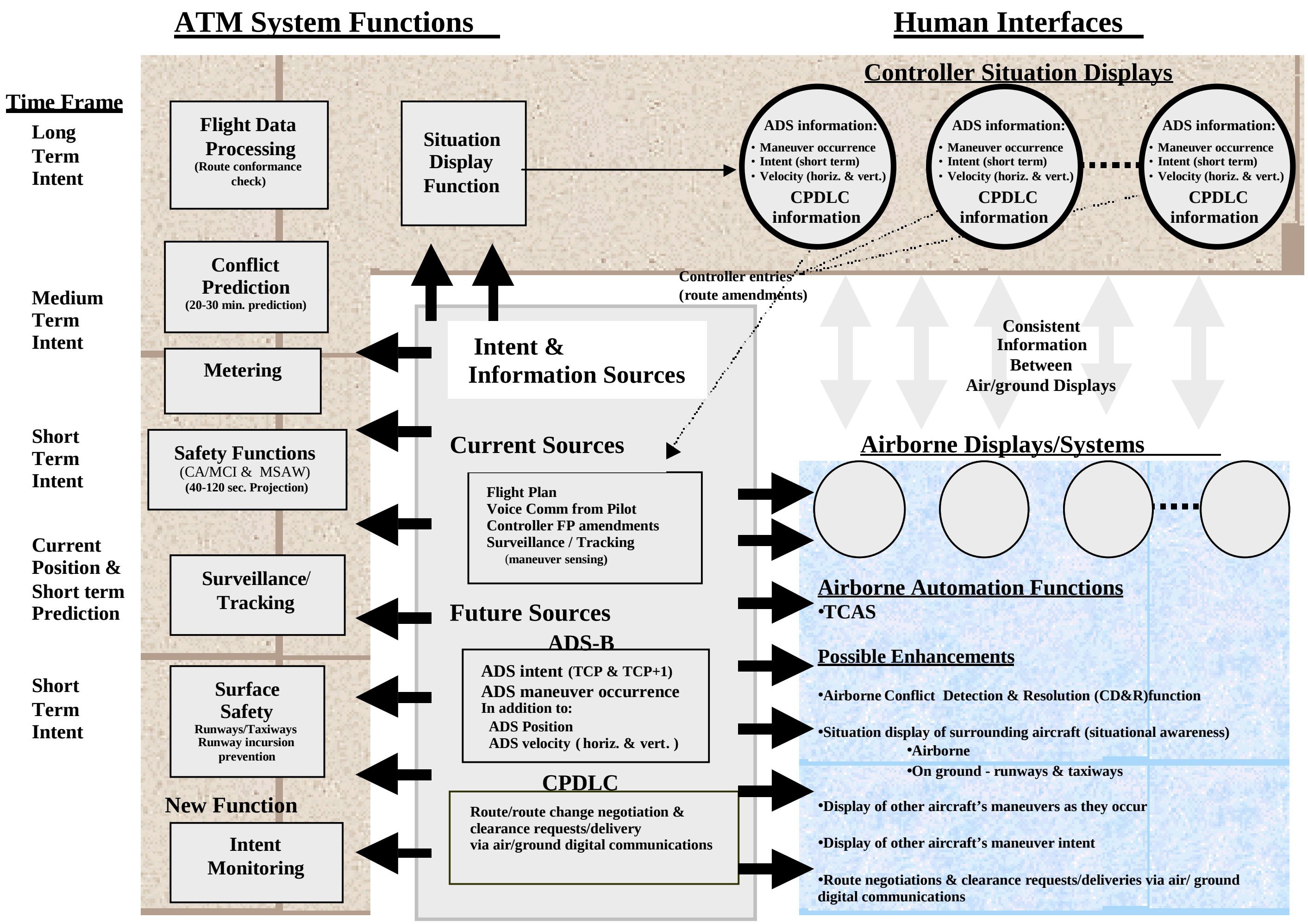

Figure 3-1. ATM Environment with Current and Future Sources of Intent and Maneuver Information

Table 3-1. Candidate Improvements

Candidate Automation Improvement Area	Improvement Description	Operational Benefits	Research Areas/Issues
Intent Monitoring **(see Section 3.1)**	Use of maneuver occurrence & intent information to monitor aircraft movement along its intended route This is needed for other automated functions, e.g. : Flight Data Processing Conflict Prediction RNAV route following Metering Safety Functions Surface Safety	Integrity checks on pilot intent information contained in ground system database to ensure aircraft stay on intended routes. Notify controller and automation functions if aircraft movement is non-conformant with database Comparison checks on sequentially received ADS-B intent information (TCPs) to notify controller of intent changes	Intent monitor design For each function, determine the thresholds for declaring non-conformance to intent Address mixed equipage environment Some aircraft with & some without ADS-B Quality of ADS-B information needed to perform intent monitoring Ways to ensure updating of intent data in response to controller actions

Table 3-2. Candidate Improvements (Continued)

Candidate Automation Improvement Area	Improvement Description	Operational Benefits	Research Areas/Issues
Situation Display Function **(see Section 3.2)** **(see Appendix A)**	Display of: 1. ADS-B maneuver occurrence information: Horizontal maneuvers Vertical maneuvers 2. Intent information: a. ADS-B TCP & TCP+1 b. RNAV routes via CPDLC	Earlier and more positive controller awareness of: Start of a maneuver Projected end of a maneuver Future intended routes	Is there an operational benefit to displaying this information to controllers? Quality of ADS-B maneuver and intent information needed Computer/Human Interface (CHI) Design Design of Computer Human Interface for controller selectable display of maneuver occurrence and intent information Address mixed equipage environment Some aircraft with & some without ADS-B
Surveillance & Tracking **(see Section 3.3)**	Use of ADS-B maneuver occurrence information in track predictions Use of ADS-B TCP intent information to determine end of maneuver	Improved tracker accuracy -more accurate speed & heading display Improved safety function performance.	Tracker Design Design of tracker to accept mixed surveillance data sources (radar & ADS-B) and new ADS-B intent and maneuver information. Quality of ADS-B maneuver and intent information needed Address mixed equipage environment Some aircraft with & some without ADS-B

Table 3-3. Candidate Improvements (Continued)

Candidate Automation Improvement Area	Improvement Description	Operational Benefits	Research Areas/Issues
Conflict Prediction **(Medium Term)** **(see Section 3.4)**	Use of maneuver occurrence and/or intent information to notify controller and/or automatically trigger new conflict probe if out of conformance with FP Use of ADS-B TCP and TCP+1 intent for conflict probes Use of ADS-B altitude change rate information in conflict predictions	New conflict prediction in response to an unexpected maneuver More timely and more accurate conflict predictions	Software modifications to existing software (e.g., URET) to utilize ADS-B information Determine route to use for new prediction. Determine if new prediction should be automatic or if controller approval is needed. Address mixed equipage environment Some aircraft with & some without ADS-B Quality of ADS-B information needed
Metering Function **(see Section 3.5)**	Use of RNAV route as intended route to runways Intent monitor checking using this intended route and received ADS-B information Use of intended RNAV route in metering calculations	More accurate arrival time calculations Better spacing and sequencing	Software modifications to existing metering software Quality of ADS-B information needed Address mixed equipage environment Some aircraft with & some without ADS-B Determine intent monitor thresholds to use to declare non-conformance with intended route

Table 3-4. Candidate Improvements (Continued)

Candidate Automation Improvement Area	Improvement Description	Operational Benefits	Research Areas/Issues
Safety Functions **(Short Term)** **(see Section 3.6)**	Use of ADS-B maneuver occurrence information (horizontal & vertical) for more timely alerts Use of intent information in a two-level alert safety function design	Improved safety function performance in hazardous maneuvering situations Better functional response to maneuvers Possible increased warning times and less nuisance alerts Display of ADS-B information complements this function (see Section 3.2)	Fully develop design for new safety functions to take advantage of ADS-B information Quality of ADS-B information needed Address mixed equipage environment Some aircraft with & some without ADS-B Determine intent monitor thresholds to use to declare non-conformance with intended route

Table 3-5. Candidate Improvements (Continued)

Candidate Automation Improvement Area	Improvement Description	Operational Benefits	Research Areas/Issues
Surface Movement Safety **(see Section 3.7)**	Use of ADS-B information as part of an integrated surface and air situation display for use by controllers, pilots, and surface vehicle operators. Display of vehicles and aircraft on the ground, and airborne aircraft in the vicinity of the airport Display of airborne aircraft intent and maneuver information on surface system situation displays Display of intended taxi routes and use of ADS-B information for intent monitoring of taxi routes	A much safer surface operation if both controllers and pilots have a display of air and surface movement	Need to fully develop a design for ground operations using ADS-B and other new capabilities Quality of ADS-B information needed to support this operation CHI design of air/ground situation displays Address mixed equipage environment Some aircraft with & some without ADS-B

3.1 Intent Monitoring Function

The proposed new intent monitoring function can be viewed as an integrity check on pilot intent information. It can be used within several existing functional areas as well as new areas. The performance of automated functions that rely on an aircraft staying on its intended route can be improved with intent monitoring. This function is needed to detect departures from current intent that are large enough to nullify the current intent information. *It should not be confused with, for example, the conformance monitoring function in the User Request Evaluation Tool (URET), which looks for departures from current intent for the purpose of recalculating medium-term trajectories for conflict detection purposes.*

Controllers mentally perform intent monitoring by remaining vigilant over the movement of each aircraft under their control. The objective is to make sure each aircraft proceeds along its cleared route of flight and doesn't violate the protected space of another aircraft. If an aircraft deviates from its cleared route, the controller can contact the pilot before a hazardous situation arises.

With the advent of Free Flight and increased user flexibility in choice of routes, aircraft will be flying more non-standard routes. This is a benefit to the users, but it makes the controller's monitoring task more difficult without additional automation. The anticipated increased traffic is an additional problem. A growing number of aircraft will be flying non-standard routes. As Free Flight becomes more prevalent and traffic levels rise, an automated intent monitoring function will need to know each aircraft's intent in detail so it can monitor the aircraft's conformance to that intent.

Various checks on the fidelity with which an aircraft is following its intent generally require either different parameterizations for their different purposes, or totally different algorithms. There are a number of ways a new intent monitoring function can perform its monitoring checks:

- Position monitoring

  In an automated intent monitoring function, deviations from an intended route of flight can be determined by aircraft position. The track or radar position of an aircraft can be used to detect lateral deviations from the planned (intended) route of flight. This is done today in the en route system's Flight Data Processing (FDP) function. With the introduction of ADS-B, the ADS-B position information can be used by the intent monitoring function in addition to radar/tracking data. In the future when the use of RNAV routes is commonplace, the details of the RNAV route may replace the flight plan route in the intent monitoring process.

- Maneuver monitoring

  Additionally, with ADS-B, intent monitoring can be extended to include maneuver occurrence information. Maneuvers indicated by ADS-B maneuver occurrence information can be used to check for conformance with the intended route of flight in the ground system. If a maneuver occurs that is not in the intended route of flight, the controller can be notified. He or she can then make a decision on further action.

- Maneuver Intent monitoring

  This is similar to maneuver monitoring. Maneuver intent information can be used to monitor conformance to the intended route of flight. The maneuver intent information contained in ADS-B returns in the form of TCP and TCP+1 can be checked against the intended route of flight in the ground system. The controller can be notified if there is a discrepancy between the TCP information and the intended route of flight stored in the ground system.

- Monitoring change of intent

  This feature is different and does not depend on an intended route of flight. This intent monitoring feature could be a TCP comparison check. If for a given aircraft, successively received TCP information is different (not because the aircraft has reached a TCP point), the controller could be notified in some manner. This could be used to either verify a change in the intended route of flight that has been negotiated between the pilot and the controller and cleared by the controller, or to indicate to the controller that an aircraft is intending to fly a different flight path without notifying the controller.

3.1.1 Description of Improvement

Potentially, the intent monitoring function can monitor aircraft movement for several automation functions. These are aircraft movement monitoring along routes in the FDP function, along routes in the Medium Term Conflict Prediction Function, along RNAV routes, and along routes used in modified safety function algorithms using negotiated RNAV routes that are loaded into airborne avionics systems. Additionally, the intent monitoring function can be used to monitor received ADS-B TCP information, looking for changes in the successively received TCP information and notifying the controller if a change is found.

3.1.1.1 Intent Monitoring for the Flight Data Processing Function

Today, certain intent monitoring is performed on flight plan route information in the en route domain. This is done in the en route system’s Flight Data Processing function using position data derived from the tracking function. Its purpose is twofold. First, if a track is deviating laterally by an amount significant enough to exceed an adapted parameter value, then the track classification is changed from “FLAT (Flight Plan Aided Tracking)” to “Free.” A Free track does not qualify for automatic fix time updating of printed flight strips. Second, if a track is not deviating laterally but is deviating longitudinally (based on time), then automatic time updates are generated if specific criteria are satisfied.

When it is available, more can be done with ADS-B information. First, ADS-B position information can be used as well as radar/tracking position information to perform the deviation checks. For the deviation check, the ADS-B data can be used directly or used as input to a redesigned tracker that merges radar and ADS-B data.

Second, the ADS-B maneuver occurrence and maneuver intent information can also be used to check the conformance of the aircraft's movement with the intended flight plan route. If the ADS-B maneuver occurrence indicator or the ADS-B TCP intent information indicate a maneuver that is occurring or soon will be occurring and this maneuver does not conform to the intended flight plan route, then the aircraft can be declared out of conformance. This out of conformance declaration can result in suspension of a function such as automatic time updates. The controller could also be notified of the non-conformance on his display.

3.1.1.2 Intent Monitoring for RNAV Routes

A good example of a future service that could take advantage of ADS-B information is "Flexible Terminal Routing," which is presented in more detail in Appendix B. This can be used in both en route and terminal domains. More advanced versions of this future service require the implementation CPDLC. However, an initial version could be implemented by use of voice communications instead of CPDLC. Aircraft systems and ground systems each would have an identical library of pre-defined routes. In this initial version, route negotiation and selection would be conducted by voice much like it is today. A route would be selected from the library of routes and would be loaded into the airborne system, and then be used by the ground system for intent monitoring. The selected route becomes the intended route of the aircraft.

Once it became available, CPDLC would be used to negotiate and transmit routes electronically from the ground to the air and vice versa. This would allow route selection from a larger number and more diverse set of routes. It would also allow routes that are created dynamically in response to wind direction, moving weather systems or changing traffic patterns. As in the initial, non-CPDLC version, in the CPDLC version a pre-defined route is loaded into the airborne avionics systems and the aircraft follows the route. The pre-defined route becomes the intent of the pilot.

In either the non-CPDLC or the CPDLC version, the intent monitoring function in the ground system will monitor the aircraft's progress, ensuring that the aircraft is flying along the intended RNAV route. It will do this using one or more of the monitoring methods mentioned above. This includes position monitoring, maneuver monitoring, and maneuver intent monitoring.

RNAV routes can be used as intended routes in several ground system functions. This includes the safety functions (see sections 3.1.1.3 and 3.6) and the metering function (see section 3.5).

3.1.1.3 Intent Monitoring for the Safety Functions

The Conflict Alert/Mode C Intruder (CA/MCI) terminal safety function can take advantage of the service provided in the previous subsection in which a negotiated arrival or departure RNAV route in the terminal area is loaded into airborne automation equipment and the aircraft avionics follows that route. An RNAV route can define a pathway all the way to/from the runway threshold. For the CA/MCI terminal safety function, the route would define short-term intent. Section 3.6 defines a redesigned terminal safety function that would utilize the intended maneuvers in an RNAV route to reduce nuisance alerts. Intent monitoring is needed as an integral part of this design to ensure that the aircraft is following its intended route. If the aircraft stops conforming to its intended route, CA/MCI use of the intent information will be suspended until the aircraft returns to its intended route.

3.1.1.4 Intent Monitoring of ADS-B TCP Changes

This intent monitoring feature could be described as a TCP comparison check. It does not depend on an intended route of flight being stored in the ground system. If for a given aircraft, successively received TCP information is different (not because the aircraft has reached a TCP point), the controller could be notified in some manner. The controller could use this notification to either verify a change in the intended route of flight that has been negotiated between the pilot and the controller and cleared by the controller, or as an indication to the controller that an aircraft is intending to fly a different flight path without notifying the controller. Old and new TCPs could be displayed at the request of the controller.

3.1.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

When a controller notices that an aircraft is in a position and on a flight path that will cause the aircraft to deviate from its protected airspace area, the controller should notify the pilot. If necessary, the controller should assist the pilot to return to his assigned protected airspace. Refer to the following sections of the Federal Aviation Administration's "Air Traffic Control" manual, document FAAO 7110.65M, dated 24 February 2000, that are relevant to this particular improvement:

Chapter 2, General Control, Section 1, General, subsection:

2-1-26, entitled, " PILOT DEVIATION NOTIFICATION"

Chapter 5, RADAR, Section 1, General, subsection:

5-1-10, entitled, "DEVIATION ADVISORIES"

3.1.3 Operational Benefits

Intent monitoring is an operational aid to the controller and to automation functions to ensure that each aircraft is following its intended route of flight. The need for this function will increase as Free Flight becomes more widespread. It provides timely notification to the controller that the aircraft is not flying its intended route. Automation functions that depend on aircraft flying their intended routes, will rely on the intent monitor for this information.

3.1.4 Research Areas/Issues

For each function that will utilize intent monitoring, the rules and parameters of non-conformance need to be defined. In other words, for each function, under what conditions should an aircraft be considered out of conformance? This includes determining the method of monitoring (i.e., position, maneuver occurrence, and/or maneuver intent monitoring) most appropriate for the function. Also, for each method chosen, the non-conformance threshold needs to be determined.

If not chosen correctly, thresholds used by the function to determine non-conformance may not reflect how aircraft actually fly in practice. If thresholds are chosen incorrectly, it could cause too many nuisance or missed non-conformance alerts. Therefore, a fast and easy way for the controller to suspend and then re-engage intent monitoring on an aircraft by aircraft basis will be needed. This will be especially useful when the controller wants to do things such as vector the aircraft, or in the future when the pilot is performing self-separation.

There is a need to find ways to ensure that intent data is updated in response to controller actions.

3.2 Situation Display Function

Situation displays used by controllers in ATC facilities can be improved through the display of ADS-B intent and maneuver occurrence information. Display of this information would be optional and selectable by the controller. Also, on the airside, airborne situation displays available to pilots in the future can be improved through the use of ADS-B intent and maneuver occurrence information.

3.2.1 Description of Improvement

Display of ADS-B maneuver occurrence information and maneuver intent information on a controller’s situation display can be very helpful when controllers are performing their tasks.

3.2.1.1 Maneuver Occurrence Display (Ground System)

In today's system, when controllers issue clearances to aircraft in either the horizontal or vertical direction they are responsible for monitoring and making sure the clearance is executed. For vertical maneuvers, they do this by monitoring changes in the numerical value of the displayed mode C altitude data. For horizontal maneuvers, they monitor the displayed positions of the aircraft over several radar scans to detect a turn.

Display of ADS-B maneuver occurrence information on a controller displays will aid controllers in their overall duties. By observing maneuver occurrence information, a controller can immediately confirm the execution of clearances given to pilots. Also, the controller will have better knowledge of the current maneuvers of aircraft in the vicinity of a conflict situation, or just in any normal situation.

An ADS-B equipped aircraft will send out the following information: turn right, turn left, climb, descend, turn stop, climb/descent stop, no maneuver. Meaningful symbols should be used for display of this information. In the absence of a maneuver for a particular aircraft, it may be desirable to display a symbol that means "no maneuver".

3.2.1.2 Maneuver Intent Display (Ground System)

Display of intent information on the controller display based on the ADS-B TCP information can indicate the near-term destination altitude or destination heading of an aircraft. Display of the start of a maneuver occurrence can be accompanied by the destination altitude and/or heading contained in the TCP. The intent monitoring function could be employed to make sure the aircraft reaches its reported destination. If not, the controller would be alerted. During a conflict situation the controller would have better knowledge of the intended future maneuvers of aircraft involved and better knowledge of the intent of aircraft not involved but in the vicinity of the conflict situation.

Besides ADS-B intent information, intent information based on negotiated routes (e.g., RNAV routes) can be displayed on the controller's display. These are routes that are loaded into airborne Flight Management System (FMS) equipment and executed. This applies whether or not the route is transmitted to the cockpit via CPDLC, or loaded into the cockpit automation from an airborne database of standard routes.

3.2.1.3 Future Airborne Situation Displays

The same ADS-B information seen by controllers can be displayed to pilots on airborne situation displays. This airborne display can provide a pilot with information on surrounding aircraft including maneuver occurrences and the future intent of each pilot. This promotes consistency between airborne and ground situation displays since aircraft can receive the same information from other surrounding aircraft that the ground systems receive.

3.2.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

Display of intent and/or maneuver occurrence information can potentially aid controllers in performing tasks associated with particular controller responsibilities. It gives the controller more information from which to make decisions. Appendix A provides detailed information on this improvement. Individual subsections of Appendix A discuss controller responsibilities relative to this improvement, the sections of the Federal Aviation Administration's "Air Traffic Control" manual (document FAAO 7110.65M) that are applicable to those controller responsibilities, and the specific improvement that could have a beneficial impact on those responsibilities.

The controller tasks outlined in individual subsections in Appendix A are:

- Flight Progress Strip Marking
- Altitude Verification
- Issuing Wake Turbulence Advisories
- Issuing Traffic Advisories
- Issuing Hazardous Weather Advisories
- Maintaining Separation
- Issuing and Confirming Clearances
- Forwarding Information to Non-approach Towers
- Issuing Traffic Information to Aircraft With Merging Targets
- Relaying and Verifying Information During Transfer of Radar Identification
- Maintaining Required Separation Minima
- Vectoring Aircraft
- Issuing Necessary and Appropriate Speed Adjustments
- Vectoring Departing Aircraft
- Vectoring and Separating Aircraft to Final Approach
- Guiding Aircraft on Final Radar Approach
- Guiding Aircraft on Final Surveillance Approach
- Guidance to Aircraft on a PAR Approach
- Monitoring Precision/Non-precision Approaches

- Responding to a CA/MCI or MSAW Alert– En Route
- Monitoring Aircraft Movements During Handoff
- Responding to a CA/MCI Alert– Terminal
- Responding to an MSAW Alert– Terminal

3.2.3 Operational Benefits

Display of ADS-B maneuver occurrence information on a controller's situation display provides an immediate positive identification of maneuver occurrences. Today, after issuing a clearance to a particular aircraft, the controller watches the situation display for several scans looking for a change in the aircraft's trajectory or change in the aircraft's mode C altitude display. With ADS-B, the controller will see a positive indication that the aircraft has started a maneuver. Additionally, if ADS-B TCP intent information is displayed, the controller will also see the destination heading and/or destination altitude, allowing him or her to verify the clearance that was issued.

An early candidate for use of ADS-B information will be the display function. Once ADS-B information is available to ground systems, it should be relatively simple to display the information contained in the ADS-B messages.

3.2.4 Research Areas/Issues

Several research areas need investigation relative to display of ADS-B information on the controller situation display.

3.2.4.1 Quality of Maneuver and Maneuver Intent Information

The following are questions related to the quality of maneuver occurrence and maneuver intent information that need to be researched:

What is the quality of the maneuver and maneuver intent data needed for this display function to be feasible? What are the accuracy, integrity, continuity, availability, and latency needed? What update rate is needed for this data?

What architecture modifications are needed to provide this information on the controller display?

What are the threshold criteria for indicating a maneuver occurrence? Airborne systems set the indicator in an ADS-B message that indicates a turn (right or left) is occurring. This becomes candidate information for use by ground systems and by other aircraft. What is the ideal threshold for the aircraft to use? In other words, what minimum heading change should cause the ADS-B turn indicator to be set? Should a turn be indicated only if an intended route with a turn is activated in the

FMS by the pilot? How should an intended route, based on TCP, be indicated on the controller's situation display? Should it be displayed only if the controller requests it? Should controllers be able to request display of TCP information for all aircraft on their displays?

3.2.4.2 Display of ADS-B Maneuver Occurrence and Maneuver Intent on the Situation Display

It needs to be determined whether there is a sufficient operational benefit to displaying ADS-B maneuver occurrence and maneuver intent information. If it turns out to be so, the following are questions related to the display of ADS-B information that need to be researched:

What is the methodology for displaying maneuver occurrence and maneuver intent information to the controller?

What display options should be available for a viable operational concept?

What is the design of the CHI for display and use of maneuver occurrence and intent information?

How can this design preclude the possibility of controller information overload?

What are the best design features to make display of this information easily selectable by the controller?

Are display inhibits needed?

What are the best methods of display and what are the best display symbols to use for indicating maneuver occurrence and maneuver intent?

When a maneuver begins, how can the end of the maneuver be indicated, if it is known? (Display of the start of a maneuver occurrence could be accompanied by the destination altitude and/or heading.)

3.2.4.3 Mixed Equipage Environment

During the transition period to full ADS-B equipage, some aircraft will be equipped with ADS-B and some will not be equipped. This environment of mixed equipage is likely to exist for many years. Controllers will need to be able to recognize immediately, aircraft equipped with properly functioning ADS-B equipment.

The following question related to the mixed environment of ADS-B equipped and non-ADS-B equipped aircraft needs to be researched:

> What CHI display should be used in a mixed environment of ADS-B equipped and non-ADS-B equipped aircraft? The display should make controllers immediately aware of which aircraft have properly functioning ADS-B equipment.

Meaningful symbols should be used. One possibility is to continuously display one of several symbols for an aircraft that has functional ADS-B equipment. When the aircraft is maneuvering, a specific maneuvering symbol would be displayed. In the absence of a maneuver a symbol that means "no maneuver" would be displayed. Display of a "no maneuver" symbol would indicate ADS-B equipage; i.e., the "no maneuver" symbol would be displayed whenever the information received from an ADS-B equipped aircraft contains a "not turning" turn indication **and** an altitude change rate of zero.

3.3 Surveillance and Tracking Function

In ATC systems the surveillance and tracking function is necessary for maintaining aircraft identity on the controller's display. This function is also necessary for providing input to functions such as the safety functions.

3.3.1 Description of Improvement

Using surveillance data, the tracking function initiates and maintains aircraft identity for use by controllers on their situation displays. To do this, the tracking function uses successive aircraft radar reports to predict near-term aircraft locations. By doing this, the function calculates the speed and heading of each aircraft. This tracker-derived speed and heading information can be displayed to controllers.

Being dynamic in nature, trackers are designed to adjust to changing conditions. A tracker has to be "tuned" to track in both straight lines and turns, or in both level flight and climb/descent maneuvers. For example, designing a horizontal tracker results in a trade-off between tracking accurately in straight lines and tracking accurately in turns. Straight-line tracking performance is sacrificed in order to have adequate tracking performance in turns and adequate turn sensing for functions such as the safety functions. Even with this sacrifice, several scans are sometimes needed for the tracker to recognize and declare that an aircraft is in a turn (or ending a turn). Likewise, the vertical tracker has similar trade-offs.

Trackers attempt to predict where aircraft will be within a certain short period of time in the future. This is complicated by the fact that trackers are performing dynamic guesswork and so need to be flexible in order to respond to maneuvers that can occur at any time.

ADS-B maneuver information transmitted down from airborne equipment will help eliminate some of this tracker guesswork and also could provide 'future' information. It will provide a positive indication of the start of a maneuver; but just as important, it will provide a positive indication of the end of a maneuver. The end of a maneuver in the horizontal direction is most important for improving tracking. Overshooting a turn and sometimes losing a track at the end of a turn have been problems in the past. In the vertical direction, use of the ADS-B altitude rate and vertical TCP information can result in better tracking accuracy in the vertical direction.

Also, if ADS-B could downlink turn rate information, it could be used by the tracking function. Instead of linearly predicting (predicting in a straight line) when an aircraft is turning, the tracker could predict on a curvilinear path using the downlinked turn rate. Knowing the intended end of the turn from the ADS-B TCP would be important in this case.

In addition to providing aircraft identity for the situation display, tracking makes the terminal and en route ground-based safety functions possible. This is because the tracking function determines velocity in the horizontal and vertical directions for each aircraft. The effectiveness of these safety functions relies heavily on the performance of the trackers. If use of ADS-B maneuver information improves tracking performance, then the performance of the safety functions will be improved.

3.3.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

Before providing service to an aircraft a controller must establish and maintain radar identification of the aircraft. A controller can use the output of the en route and terminal automation systems to provide this identity. Refer to the following sections of the Federal Aviation Administration's "Air Traffic Control" manual, document FAAO 7110.65M, dated 24 February 2000, that are relevant to this particular improvement:

Chapter 5, RADAR, Section 3, Radar Identification, subsections,

5-3-1, entitled, "APPLICATION"

5-3-3, entitled "BEACON IDENTIFICATION METHODS"

5-3-4, entitled "TERMINAL AUTOMATION SYSTEMS IDENTIFICATION METHODS"

5-3-8, entitled "TARGET MARKERS"

5-3-9, entitled "TARGET MARKERS"

3.3.3 Operational Benefits

During aircraft maneuvering situations, use of ADS-B maneuver occurrence information will result in improved tracking in both the horizontal and the vertical directions. This will in turn result in improved information displayed to controllers. While improved track position accuracy probably will not be noticeable to controllers on the situation display, other data displayed to controllers will be more accurate. Speed information displayed in the data blocks will be more accurate since the velocity information calculated by the tracker will be more accurate. Also, any velocity vector displayed to the controller will be more accurate during maneuvers.

In addition to improved controller display information, improved tracker performance from use of ADS-B maneuver information will result in more accurate data for input to advanced functions such as the safety functions. During maneuvering situations, more accurate velocity data will help alleviate nuisance alarms and could contribute to longer warning times in situations that are hazardous.

It must be noted that ADS-B information contains aircraft velocity information as well as maneuver information. The option exists to use this ADS-B cockpit-derived velocity in place of tracker-derived speed for a display of speed to the controller. This cockpit-derived velocity information could be used instead of tracker velocity to display a velocity vector to the controller. It could also be used by the safety functions. In addition, faster and more accurate track initiations and aircraft identifications may be possible by using this ADS-B velocity and/or TCP information. This would also result in quicker use of track information by automated functions such as safety functions since a track for a particular aircraft needs to be of sufficient quality before track data is used for the safety functions. Confidence in the tracker could be accomplished sooner if velocity data were in the first data report received from the aircraft.

3.3.4 Research Areas/Issues

Using ADS-B data would necessitate a tracking function that is more complex. Also, the tracker would have to deal with an environment of aircraft with mixed equipage. Algorithms would need to be sensitive to this and so would have to expect maneuver occurrence information from some aircraft and none from others. It would have to sense turns for some aircraft and not sense turns for others. Also, the tracker may need to retain the turn sensing capability for ADS-B equipped aircraft as a backup in case the aircraft does not send maneuver information to the ground for a particular maneuver and the aircraft goes into a maneuver. This would be a failure condition, so the tracker would have to be able to respond to failed ADS-B equipment, or missing ADS-B data.

Finally, the controller would have a display of speeds derived from different sources. If an aircraft were not ADS-B equipped, its displayed speed would be derived from the tracker only; however, if it were equipped, its displayed speed would be derived by the tracker with input from ADS-B.

The following are questions related to the use of maneuver occurrence and maneuver intent information by the tracking function that need to be researched:

> How can the tracking function be designed to accept maneuver occurrence information for some aircraft but not for others? Would there be a significant and noticeable performance difference? What is the accuracy improvement in the

horizontal direction? In the vertical direction? How much would this be expected to improve the safety functions?

Would the tracker still need to retain a turn sensing capability for ADS-B equipped aircraft?

What speed should be displayed to the controller: the speed derived by the tracker, or that derived from ADS-B velocity data? The same question can be posed for a velocity vector display. If ADS-B velocity data is used for speed display, some aircraft will still have speed derived by the tracker. What inconsistencies or differences could arise in speed displayed for different aircraft, and would this impact the controller's ability to control?

Should the tracker-derived velocity data or the ADS-B cockpit-derived velocity data be used by the safety functions? In a mixed equipage environment, would it be practical to use velocity derived from different sources?

Can ADS-B downlink turn rate information? If the tracker were to use this information, how much would tracking in turns improve? How much better would velocity information be during the turn if turn rate information is used? Would it be better to use the ADS-B velocity data in turns and have the tracker derive turn rate from the ADS-B velocity? Should the ADS-B velocity data be used directly by the tracker instead of the tracker-derived velocity?

Use of ADS-B intent information seems less important for the tracking function than for other functions. Can it be used by the tracking function to any great benefit? Can it be used to indicate the end of a turn or climb/descent?

3.4 Conflict Prediction (Medium Term) Function

The medium term conflict prediction function is a decision support system automation function that will facilitate the safe clearance of direct routes and non-standard routes in the airspace within and immediately adjacent to en route center airspace. Use of this automation function to assist air traffic specialists with timely detection of predicted problems, as well as with managing workload and planning, is expected to enable the system to support a greater number of user-preferred trajectories, increased flexibility, and increased capacity.

3.4.1 Description of Improvement

The conflict prediction function is an en route domain function and uses real-time data inputs from both the FDP and tracking functions. These data are combined with site adaptation, key aircraft performance parameters, and winds and temperatures from the National Weather Service in order to build four-dimensional flight profiles, or trajectories. These trajectories are used to predict conflicts between aircraft in the medium term time frame. A 30-40 minute projection along each aircraft's intended route of flight is used to predict the conflicts between aircraft up to 20 minutes in advance. The flight plan route used in FDP or an amended flight plan route can be used as the intended flight path of the aircraft. Conflict prediction also allows a trial plan to be probed along a potentially new route in order to test for conflicts prior to entering an amendment to include that new route in the intended flight path of the aircraft.

Conflict prediction adapts itself to the observed behavior of aircraft, dynamically adjusting predicted speeds, climb rates, and descent rates based on the performance of each individual flight as it is tracked through en route airspace.

One issue is the extent to which ADS-B intent information can be used by an enhanced version of the conformance monitoring function in medium-term conflict prediction (URET). One potential use of ADS-B maneuver and intent information in the conflict prediction function is in its conformance monitoring logic. The conformance monitoring logic is an integrity check on each aircraft's movement versus its intended route of flight for purposes of FP based conflict prediction. Conformance monitoring ensures that an aircraft is in conformance with its intended FP route before a conflict probe is performed. Such probes are valid as long as the aircraft remains in conformance.

If ADS-B maneuver occurrence or ADS-B TCP intent information indicates a new maneuver or new route that is not in conformance with the FP route, then the controller could be notified. In response, a new conflict probe could be conducted based on a recalculated trajectory that uses the ADS-B TCP and TCP+1 maneuver intent information.

Another potential use of ADS-B information lies in the vertical dimension. Accurate conflict predictions in the vertical direction are difficult. Knowing the climb rate of an aircraft makes predictions more accurate. However, there are significant differences in climb rates within aircraft types, different weights of aircraft within aircraft types, and different airlines with the same aircraft type (for example, South West Airlines is known for climbing faster). Knowing the weight of an aircraft would be helpful in a conflict prediction, since then the climb rate of the aircraft can be better estimated. However, knowing the current actual climb rate of the aircraft should yield much better predictions. ADS-B provides the ground with actual climb rate information as well as TCP intent and maneuver information. This information could be used to more accurately predict conflicts when vertical maneuvers are involved.

Finally, a more detailed RNAV route can be used for all or for particular segments of the intended flight path used by conflict prediction. This is discussed in section 3.1.1.2. When RNAV routes are used as part of the intended route of an aircraft, conflict predictions will be more accurate. RNAV routes can be very detailed and the ground system can be more assured the aircraft is following these routes since the avionics is using this route to guide the aircraft. When CPDLC becomes available, RNAV route negotiation and exchange between the ground and the air will make the controller's job easier, because controllers would no longer need to take the time to update the database when adjustments are made to an aircraft's route. Updating the ground system's route intent database will be much easier and will keep it more current. A more current aircraft route database on the ground will improve conflict prediction performance.

3.4.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

When a controller notices that an aircraft is in a position and on a flight path that will cause it to merge with another aircraft, the controller has a responsibility to notify the pilot. If necessary, the controller should assist the pilot in returning to a non-merging condition. Also, the controller has a responsibility to issue a safety alert to an aircraft if he or she is aware the aircraft is in a position/attitude which, in the controller's judgment, places it in unsafe proximity to terrain, obstructions, or other aircraft. The controller also has a responsibility to issue traffic advisories to all aircraft on his or her frequency when, in the controller's judgment, their proximity may diminish to less than the applicable separation minima. If no separation minima apply, the controller should issue traffic advisories to those aircraft when in his or her judgment their proximity warrants it.

Refer to the following sections of the Federal Aviation Administration's "Air Traffic Control" manual, document FAAO 7110.65M, dated 24 February 2000, that are relevant to this particular improvement:

Chapter 2, General Control, section 1, General, subsections:

2-1-6, entitled, "SAFETY ALERT"

2-1-21, entitled, "TRAFFIC ADVISORY"

Chapter 5, RADAR, Section 1, General, subsection:

5-1-8, entitled, " MERGING TARGET PROCEDURES"

3.4.3 Operational Benefits

The use of ADS-B information can make controllers aware that aircraft are not in conformance with their intended FP route. When this happens, more accurate conflict predictions may be achieved if the ADS-B TCP intent information is used in place of the FP route.

Use of ADS-B vertical maneuver information (altitude change rate) has the potential of making conflict predictions involving altitude transitions more accurate.

When CPDLC becomes available, route exchange between the ground and the air will be much easier and will become routine. This will improve compatibility between intended route information in airborne avionics databases and ground system databases. This will in turn decrease the workload on controllers and pilots since CPDLC can be used for route information exchange with less reliance on controller and pilot entries.

3.4.4 Research Areas/Issues

The following are questions related to the use of ADS-B information by the conflict prediction function that need to be researched:

> Is it beneficial for the currently fielded en route conflict prediction function (URET) to utilize ADS-B information? Would significant changes be needed in URET's conflict prediction software for it to use specific ADS-B information? How can ADS-B altitude change rate information be used to improve conflict predictions in altitude transition situations?

If ADS-B maneuver occurrence and/or ADS-B maneuver intent information is used to monitor the conformance of aircraft movement along intended routes, what are the thresholds for declaring that an aircraft is in non-conformance for purposes of FP-based conflict prediction? Should a new conflict probe action be automatically initiated when an aircraft is found to be in non-conformance or should controllers be notified so they can make a decision on initiating a new prediction? Should a change in the received ADS-B intent information from the intended route in the ground system database initiate a new probe action? Or should the controller simply be notified?

3.5 Metering Function

Metering is an automation tool that prescribes the sequencing and spacing of aircraft.

3.5.1 Description of Improvement

Metering is a tool that is useful in both en route and terminal airspace, especially around high-density airports. In the vicinity of an airport a metering function sequences and spaces aircraft approaching the airport from different directions. Aircraft are merged into a steady arrival stream or streams for arrival fixes associated with one or more runways. This balances use of runways, increases traffic flow efficiency and helps aircraft conserve fuel.

Aircraft arriving and departing at large airports usually follow published routes. These published routes are defined between fixes in en route airspace and fixes located in terminal airspace. The routes are defined using fixed ground-based navigational aids (NAVAIDS) and are limited in number since they are constrained by a limited number of NAVAIDS. Also, the published routes are generally not defined all the way to/from the runways. In airspace close to the runways, this frequently requires vectoring of aircraft by the controller, increasing controller workload and decreasing the number of aircraft controllers can handle.

The concept of “Flexible Terminal Routing," described in Appendix B, takes advantage of new navigational capabilities such as RNAV, Global Positioning System (GPS), and FMS.

This creates in theory an almost unlimited number of possible airport arrival and departure routes. It also allows dynamic definition of routes in response to dynamic situations such as weather systems, runway changes and missed approaches. It allows definition of routes all the way to the runway thresholds. It enables aircraft to follow routes more precisely.

Once an aircraft is cleared to fly one of these new routes, its route can be considered to be the intent of the aircraft. The FMS will be “flying the route." Intent monitoring can be performed on the aircraft’s movement along this route, and ADS-B intent and ADS-B maneuver occurrence information received from the aircraft can be checked against this route as described in Section 3.1.1.2. The controller can be notified if the aircraft moves off its intended route.

In addition, the intended route assigned to each aircraft can be used by the metering function to calculate more accurate arrival times, and arrival spacing and sequencing. Altitude change rate information received from ADS-B equipped aircraft could also be used in metering calculations.

Finally, the intended route can be coupled with a newly revamped conflict alert function (as described in Appendix C) for a safer control environment with less nuisance alerts.

3.5.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

The controller is required to establish the sequence of arriving and departing aircraft by requiring them to adjust flight or ground operation, as necessary, to achieve proper spacing.

Refer to the following section of the Federal Aviation Administration’s “Air Traffic Control” manual, document FAAO 7110.65M, dated 24 February 2000, that are relevant to this particular improvement:

Chapter 3, Airport Traffic Control, Section 8, Sequencing and Spacing, subsection:

3-8-1, entitled, “SEQUENCE/SPACING APPLICATION”

3.5.3 Operational Benefits

Use of the concept of “Flexible Terminal Routing” described in section 3.1.1.2 and Appendix B, and use of these routes in a modified metering function could result in more accurate arrival time calculations and better arrival spacing and sequencing. ADS-B maneuver occurrence and maneuver intent information could be used to help aircraft conform to their cleared routes.

Use of ADS-B altitude change rate information in metering calculations has the potential to make the results more accurate.

3.5.4 Research Areas/Issues

The following are questions related to the use of ADS-B information by the metering function that need to be researched:

> What changes are needed to the metering software in the currently fielded metering functions to utilize ADS-B information? Are significant changes needed to use specific ADS-B information? For example, it may be relatively easy to modify the software to use ADS-B altitude change rate information in metering calculations.

> Relative to the metering function, if ADS-B maneuver occurrence and/or ADS-B maneuver intent information are used to monitor the conformance of aircraft movement along intended routes, what are the thresholds for declaring that an aircraft is in non-conformance? Should a new metering calculations be automatically initiated when an aircraft is found to be in non-conformance or should the controller be notified so he or she can make a decision?

The environment of mixed equipage is likely to exist for many years. During this period controllers will need an immediate way to recognize on their situation display, aircraft equipped with functioning ADS-B equipment. There will also be a need for a very immediate way for the ground to know that cockpit systems are operating properly on board an ADS-B equipped aircraft.

The metering function will need to perform metering calculations on a mixture of non-ADS-B equipped aircraft and ADS-B equipped aircraft during the transition to full equipage.

3.6 Safety Functions

Two ground-based safety functions are currently implemented in each terminal and en route ATC system. These are the CA/MCI function and the MSAW function. These functions are short-term safety functions and should not be confused with the Conflict Prediction function (see Section 3.4) which is a medium-term planning function.

3.6.1 Description of Improvement

The currently implemented CA/MCI function detects and warns controllers of hazardous situations between two aircraft. The currently implemented MSAW function detects and warns controllers of single-aircraft hazardous situations, usually aircraft versus terrain situations. CA/MCI depends on input from the horizontal and vertical tracking functions to determine dangerous proximity situations between pairs of aircraft. In certain situations it depends on the horizontal tracker to detect the start of a turn maneuver. Likewise, the MSAW function depends on input from the horizontal and vertical trackers to determine dangerous situations based on adapted terrain information. Potential improvements to these safety functions via use of the ADS-B maneuver occurrence and maneuver intent information are discussed in the following two subsections.

3.6.1.1 Use of Maneuver Occurrence Information for the Safety Functions

ADS-B maneuver occurrence information provides an aircraft's current maneuvering situation in both the horizontal and the vertical directions. This information could be used by the terminal and en route safety functions to improve performance. Maneuver occurrence information, since it is cockpit derived, provides a better indicator of an aircraft's current maneuvering situation than the output of a tracker. A tracker always has a time lag in determining the occurrence of a maneuver. Additionally, more confidence can be placed in the maneuver occurrence information since it represents something that is occurring in the present, not something intended to happen in the future.

The ADS-B turn indicator indicates whether the aircraft is currently turning right, turning left, or not turning. The altitude rate (altitude velocity) indicates whether the aircraft is currently flying level, climbing, or descending. Since it is an altitude "rate," it provides the speed of the climb/descent in feet per minute. All of this information could be used by the safety functions to improve performance. Using this information could increase alert warning times in hazardous situations where maneuvers play a role in causing a hazard. Also, nuisance alerts could be reduced.

The safety functions need modification to accept the new ADS-B maneuver occurrence information. CA/MCI maneuver logic, similar to the terminal system's (Module for Maneuvering and Maneuvering Sensitive [MFMAMS] aircraft pairs) logic, would be needed to accept and process the information and detect hazardous maneuvering situations in the horizontal and vertical directions. A hazardous situation such as those caused by one aircraft turning into another or two aircraft turning into each other should be detected sooner by using ADS-B information. Also, hazardous situations such as those caused by a climb or descent of one aircraft into another or two aircraft into each other should be detected sooner. This new maneuver logic would be in addition to the linear projection logic present in today's safety function algorithms and would use input from both the tracking function and ADS-B. The performance advantage of the maneuver logic over the linear projection logic would be a longer warning time.

The new maneuver logic would detect hazardous situations based on maneuver occurrence information and would generate display alerts to controllers. Besides the alert, controllers would also see an indication of the ADS-B maneuver occurrence information on their situation displays if the improvement to the display function described in Section 3.2 were implemented. Indications of maneuvering aircraft in the proximity of the hazardous situation would also be displayed. This would provide the controller with additional information for quicker recognition of the problem and more information to resolve the problem.

An additional performance gain may be possible if turn rate information were sent down from the cockpit along with the ADS-B maneuver occurrence indicator. The CA/MCI maneuver logic could then use the turn rate to perform curvilinear projections for more accurate conflict predictions. In curvilinear projecting, knowledge of the end of a turn is vital. The ADS-B TCP information might provide this end of turn information, however, use of intent information is risky, as described section 3.6.1.2.

3.6.1.2 Use of Maneuver Intent Information for the Safety Functions

The ADS-B intent information, in the form of TCP information, should be used with caution by the safety functions.

3.6.1.2.1 Safety Function use of Intent Information

Use of maneuver intent information by the ATC terminal and en route safety functions is less straightforward than use of the maneuver occurrence information described above. Intent information must always be used with caution since intent information is something intended to happen in the future and there is no absolute guarantee that it will happen.

Even in the past, the use of maneuver intent information in the ground-based safety functions, especially in the CA/MCI function, has been controversial. Currently the terminal CA/MCI program does not use intent information, but the en route CA/MCI program does. The en route CA/MCI uses an aircraft's flight plan assigned altitude as the aircraft's intended altitude. The program assumes that a climbing aircraft will level off at its intended assigned altitude, and so it suppresses an alert between the climbing aircraft and another aircraft flying at a higher altitude. The purpose of this logic is to cut down on nuisance alerts.

However, it must always be considered what happens if the aircraft doesn't level off at its assigned altitude. If the aircraft doesn't level off, a situation even more hazardous than the original alert situation could ensue. The program is assuming that something is going to happen, which is not a sufficiently conservative approach to the design of a safety function.

Cockpit-derived data is a more trustworthy source of maneuver intent than the ground system's flight plan database. But since it is still not absolutely reliable, cockpit-derived ADS-B intent information, in the form of TCP information, probably should not be used directly by the CA/MCI safety functions to suppress alerts. For the same reasons, it should not be used to suppress MSAW alerts.

3.6.1.2.2 A Safety Function Design with Two Alert Levels

Using the terminal ATC CA/MCI function as an example, Appendix C presents a feasible CA/MCI redesign that uses intent information and presents two different types of alerts to controllers. This design assumes that the pilot and the controller have negotiated a detailed route clearance, perhaps in the form of a detailed RNAV route (see Appendix B). Furthermore, the ground system safety function knows the route details, and the avionics systems on board the aircraft are guiding the aircraft along the cleared route of flight. Hence, both the ground and airborne systems have detailed knowledge of the cleared route, and this route would be considered to be the "intended" route. The intent monitoring function described in Section 3.1 would be active and periodically checking to see if the aircraft is flying the intended route. If the CA/MCI function detected that the aircraft was in a potentially hazardous situation, a normal CA alert would be issued to the appropriate controller. However, if the intended route of the aircraft contained an intended maneuver that would nullify the hazardous situation, the alert would not be suppressed, but a "Maneuver must occur" alert would be issued to the appropriate controller. Appendix C gives some detailed examples of situations using this design.

As part of the intent monitoring function, the ADS-B TCP intent information could be used to declare conformance/non-conformance with the route of flight. If TCP does not agree at any time with the cleared route of flight, the aircraft would be declared out of conformance and the safety function would discontinue use of the cleared route as intent information. The same would apply for the other intent monitoring checks described in Section 3.1.

The en route CA/MCI function and the other safety function, MSAW, could use this same design approach and use two different types of alert.

3.6.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

When an en route or terminal CA or MCI alert is displayed, the controller is required to evaluate the reason for the alert without delay and take appropriate action. The controller can use displayed ADS-B maneuver occurrence information to aid in the evaluation of the conflict situation. The maneuver information can also be used by the CA/MCI algorithms to improve functional performance.

Refer to the following sections of the Federal Aviation Administration's "Air Traffic Control" manual, document FAAO 7110.65M, dated 24 February 2000, that are relevant to this particular improvement:

Chapter 2, General Control, section 1, General, subsections:

2-1-6, entitled, "SAFETY ALERT"

2-1-21, entitled, "TRAFFIC ADVISORY"

Chapter 5, RADAR, Section 14, Automation – En Route, subsection:

5-14-1, entitled, "CONFLICT ALERT (CA) AND MODE C INTRUDER (MCI) ALERT"

Chapter 5, RADAR, Section 15, Automated Radar Terminal Systems (ARTS)-Terminal, subsection:

5-15-6, entitled, "CA/MCI"

When an en route MSAW or terminal MSAW alert is displayed, the controller is required to immediately analyze the situation and, if necessary, take the appropriate action to resolve the alert. The controller can use displayed maneuver information to aid in the evaluation of the low altitude situation. Refer to the following subsections of FAAO 7110.65M that are relevant to this particular improvement:

> 5-14-2, entitled, “EN ROUTE MINIMUM SAFE ALTITUDE WARNING (E-MSAW)”
>
> 5-15-7, entitled, “INHIBITING MINIMUM SAFE ALTITUDE WARNING (MSAW)”

3.6.3 Operational Benefits

Use of ADS-B maneuver occurrence information will improve safety function performance in hazardous situations involving maneuvers. Alert warning time to the controller could be increased.

Use of intent information in redesigned ground safety functions could result in a lower nuisance alert rate. The redesigned functions will remind controllers to make sure aircraft perform planned maneuvers that are necessary to prevent hazardous situations.

Additionally, other potential improvements described in this document can potentially help in hazardous conflict situations. Safety function performance should be improved with the improved tracking function performance described in Section 3.3. Also, controllers will have more information to use during resolution of hazardous conflict situations if maneuver occurrence and maneuver intent information from ADS-B are made available for display on the controller’s situation display as described in Section 3.2.

3.6.4 Research Areas/Issues

A new design for the CA/MCI and MSAW safety functions needs to be developed to take advantage of the new information available in ADS-B. Appendix C discusses a potential new design for CA/MCI. New functions should perform well in a mixed environment of ADS-B equipped and non-equipped aircraft. Studies are needed to quantify the operational benefits of the new safety function designs.

Relative to the safety functions, if ADS-B maneuver occurrence and/or ADS-B maneuver intent information is used to monitor the conformance of aircraft movement along intended routes, the thresholds for declaring that an aircraft is in non-conformance need to be determined. The new CA/MCI design described in Appendix C assumes that use of intent information will be suspended when one or both aircraft are found to be in non-conformance with their intended route of flight.

3.7 Surface Safety Function

Today the FAA is focusing on ground surface safety and prevention of hazardous situations on the ground at airports around the country. Preventing runway incursions is of prime concern, as well as improving controller information on aircraft location and movement at night and during bad weather situations. Airport Surface Detection Equipment (ASDE) model 3, or ASDE-3, is installed at 34 of the busiest airports in the country. ASDE is a ground radar that provides controllers with images of aircraft and vehicles on the airport surface. New versions of ASDE are being deployed at 25 additional airports to provide improved information on aircraft and other vehicles that use the airport surface. Future plans include the use of ADS-B information for surface control.

3.7.1 Description of Improvement

In the future, ADS-B can contribute greatly to the continued safety of aircraft operations on the ground and in the vicinity of airports. Future government/industry plans for surveillance include creation of a common surveillance data set that will provide information on all aircraft and surface vehicles in the airport movement area. ADS-B is envisioned to be a major source of this information. ADS-B can provide position information on aircraft on the ground (taxiways, runways, gate areas, etc) and can also provide information on airborne arriving and departing aircraft in the vicinity of the airport. A situation display that integrates aircraft both on the ground and in the air will become possible. Surface vehicle movement can also be displayed. Such a display can be made available to controllers on the ground and to pilots, both in the air and taxiing on the ground, as well as to surface vehicle operators.

Safety can be increased in airport operations if controllers have situation displays that display aircraft both on the ground and in the air as well as surface vehicle traffic. On the situation display a controller can monitor aircraft ground movement on taxiways and runways as well as airborne arrival aircraft approaching runways and departure aircraft leaving runways.

If provided with the same situation display as controllers, pilots on the ground and in the air can monitor other aircraft. A pilot on the ground can monitor airborne arrival and departures. The pilot can monitor the movement of airborne approaching aircraft to make sure a runway is clear before entering or crossing it. Likewise, a pilot in the air can monitor the ground movement of aircraft in the vicinity of the arrival runway. The pilot can monitor movement on the runway before landing on the runway.

In addition to position information, other ADS-B information can be made available for display. This includes maneuver occurrence and intent information of airborne aircraft. Maneuver intent can show runway arrival intent for arriving aircraft, and departure routes for departing aircraft currently on the ground or airborne.

If detailed RNAV routes are used for the intended arrival and departure routes for aircraft in the airport vicinity (see section 3.1.1.2 and Appendix B), these intended routes can be made available for display on the controller and pilot situation displays.

Similarly, if aircraft are assigned to specific airport surface taxi routes (intended taxi routes) using CPDLC (or another communications vehicle), the intended taxi routes of all aircraft can be made available to controller, pilot, and surface vehicle operator displays. In this way pilots on the ground and in the air can monitor the intended ground routes of all aircraft. Using the ADS-B position information, an intent monitoring function could also monitor the ground movement of all aircraft to assure they are following their assigned taxi routes. The intent monitor would notify the controller, and possibly the pilot, if an aircraft moved off its assigned route.

3.7.2 Controller Responsibilities and Applicable Sections of FAAO 7110.65M

The controller is responsible for determining the position of an aircraft before issuing taxi instructions or takeoff clearance. The aircraft's position may be determined visually by the controller, by pilots, or through the use of the ASDE. The controllers should use the ASDE to augment visual observation of aircraft and/or vehicular movements on runways and taxiways, and other components of the movement area. Controllers should use ASDE information to assist with formulating clearances and control instructions to aircraft and other vehicles on the movement area.

Controllers are responsible for monitoring compliance with control instructions by aircraft and vehicles on taxiways and runways. They are also responsible for confirming pilot reported positions. The controller is responsible for issuing, as required or requested, the route for the aircraft/vehicle to follow on the movement area in concise and easy-to-understand terms. When a taxi clearance to a runway is issued to an aircraft, the controller should confirm that the aircraft has the correct runway assignment. When an aircraft is authorized to taxi into takeoff position to hold, the controller should inform its pilot of the closest traffic that is cleared to land, touch-and-go, stop-and-go, or unrestricted low approach on the same runway.

Refer to the following sections of the Federal Aviation Administration's "Air Traffic Control" manual, document FAAO 7110.65M, dated 24 February 2000, that are relevant to this particular improvement:

Chapter 2, General Control, Section 1, General, subsection:

2-1-16, entitled, "SURFACE AREAS"

Chapter 2, General Control, Section 10, Team Responsibilities, subsection:

2-10-3, entitled, "TOWER TEAM POSITION RESPONSIBILITIES"

Chapter 3, Airport Traffic Control--Terminal, Section 1, General, subsections:

3-1-7, entitled, "POSITION DETERMINATION"
3-1-9, entitled, "USE OF TOWER RADAR DISPLAYS"

Chapter 3, Airport Traffic Control--Terminal, Section 6, Airport Surface Detection Procedures, subsections:

3-6-1, entitled, "EQUIPMENT USAGE (Surface equipment ASDE)"
3-6-2, entitled, "INFORMATION USAGE"

Chapter 3, Airport Traffic Control--Terminal, Section 7, Taxi and Ground Movement Procedures, subsection:

3-7-2, entitled, "TAXI AND GROUND MOVEMENT OPERATIONS"

Chapter 3, Airport Traffic Control, Section 8, Sequencing and Spacing, subsections, subsection:

3-8-1, entitled, "SEQUENCE/SPACING APPLICATION"

Chapter 3, Airport Traffic Control, Section 9, Departure Procedures and Separation, subsection:

3-9-4, entitled, "TAKEOFF POSITION HOLD"

3.7.3 Operational Benefits

A safer and more efficient airport surface situation can be achieved if everyone involved can "see" everyone else. It will be much safer if both controllers and pilots involved in the airport surface operations and nearby airborne operations can see (on one display) all aircraft and all ground vehicles on the ground as well as all airborne aircraft in the vicinity of the airport. With universal equipage, ADS-B can provide position information on all vehicles (aircraft and ground vehicles) on the ground and all airborne aircraft in the vicinity of the airport. Use of ADS-B maneuver occurrence information and maneuver intent information for airborne aircraft will add to the safety by displaying maneuvers and intended maneuvers to everyone involved in the surface operations.

If taxi routes and runway assignments are made part of each aircraft's intent database information, then display of each aircraft's intended taxi route can be displayed to everyone else, and an intent monitoring function can monitor all aircraft movement on the ground and detect any deviations from intended routes.

3.7.4 Research Areas/Issues

The new capabilities provided by ADS-B and other sources of surface movement information will allow, in the mature state, surface operations to be conducted in near-zero or fully-zero visibility conditions as if conditions were Visual Flight Rules (VFR).

Research is needed on the quality of ADS-B information and other-source information to support these operations. Research also is needed on the design of an appropriate display showing all ground movement and airborne movement in the vicinity of the airport.

A viable operational concept for ground operations needs to be developed using the new capabilities and new information available with ADS-B and other sources of surveillance information. The operational concept needs to ensure that the display design is useful to all users and that a safe and efficient operation can be achieved. The CHI for each particular user of the information (controller, pilot, surface vehicle operator, etc.) needs to be developed based on the operational concept. Roles and responsibilities of controllers, pilots, and others should be evaluated to ensure the operational concept is valid.

The viability of maintaining a taxi route and runway assignment database needs to be determined. The workload and time necessary to maintain and update this database needs to be quantified.

To be totally effective, universal ADS-B equipage on all aircraft and all ground vehicles is needed. During the transition to full ADS-B equipage, the users of situation displays will need to be able to immediately distinguish ADS-B equipped aircraft from non-ADS-B equipped aircraft.

Information displayed on the situation display may present an “information overload” when the roles and responsibilities of users are examined.

The roles and responsibilities of pilots when in the terminal phase of flight may not allow enough time for use of a situation display.

The workload and time necessary to update and maintain a taxi route and runway assignment database may be prohibitive.

Section 4

Conclusions and Recommendations

The ADS-B is new technology that delivers new information to both controllers and pilots by providing information to automation functions in ground-based and cockpit-based systems. ADS-B provides very accurate and timely aircraft position and velocity vector information that can be used in ground-based systems in conjunction with existing radar sensor position information. In cockpit-based systems, ADS-B position information can provide a pilot with a situation display of aircraft in his or her immediate area regardless of whether they are airborne or on the ground.

In addition to position and velocity information, ADS-B provides pilot intent, and maneuver occurrence information. Horizontal and vertical maneuvers that an aircraft is presently conducting are part of the ADS-B information. Use of this maneuver information in the ground and cockpit systems can be an important supplement to the use of intent information.

4.1 DSS Improvements

In order to safely handle the expected increase in future traffic levels while providing users with more flexibility in choosing routes, it will be advantageous to use pilot intent and other available ADS-B information.

However, ADS-B pilot intent is part of a more comprehensive view of intent. This comprehensive view includes other sources of intent, such as flight plans and CPDLC, as well as ADS-B maneuver occurrence information. This more comprehensive view of intent is used in this document as a basis for discussing potential ground-based DSS functional improvements.

The document discusses the use of intent information to make improvements in several existing ground-based DSS functional areas. These functional areas include the controller display function, surveillance and tracking, medium-term conflict prediction, metering functions, short-term safety functions, and surface movement safety. A proposed new function called intent monitoring that would be used to monitor aircraft movement versus the intended routes of aircraft is also discussed.

Potential benefits enabled by these improvements are derived from the increase in information made available to controllers and to the automation functions that aid controllers. These benefits include:

- Enhanced controller awareness of current aircraft situations as well as enhanced awareness of future situations

- Improved tracker accuracy and better speed and heading information
- Improved safety function performance in maneuvering situations with more warning time and less nuisance alerts
- More accurate medium-term conflict predictions
- More accurate spacing and sequencing, and arrival time calculations in metering functions
- A safer surface operation with both controllers and pilots viewing the same airborne and ground movement situations on their respective situation displays.

Most of these improvements will require extensive development work. However, the controller display function improvement has the potential to provide significant benefits simply by displaying ADS-B maneuver occurrence information to controllers. A timelier and more definitive indication of the beginning and end of aircraft maneuvers could reduce a controller's workload.

For each improvement, significant work is needed in developing an operational concept, a detailed functional design including an acceptable CHI design and any needed airside design, all with a government/industry consensus. A determination of the quality of ADS-B data needed to support each improvement is also needed. (Data quality includes the time horizon, availability, reliability, integrity, and resolution of the data needed.) Estimates of the expected benefits (as a function of the quality of ADS-B data) should be prepared.

4.2 Issues

Significant issues raised in the Section 3 discussion of the functional improvements are recounted here:

1. ADS-B Equipage. The transition period to full ADS-B equipage will take many years. During this transition functional improvements that use ADS-B information will have to be designed to cope with partial equipage. This will make functions more complicated. For example, a tracking function modified to use ADS-B maneuver occurrence information will still need to sense turns for non-ADS-B equipped aircraft. Also, controller (and pilot) situation displays will have to make identification of ADS-B equipped aircraft immediately obvious.
2. ADS-B equipment operational/non-operational. Like any equipment, ADS-B equipment can be turned off or can malfunction. Functions that use ADS-B information need to be able to detect ADS-B equipment that is not functioning properly and treat that particular aircraft as a non-ADS-B equipped aircraft. This means that even after full ADS-B equipage has been achieved, functions that use ADS-B information will still need to cope with aircraft that are effectively unequipped.

3. Intent information must be used with caution, because it pertains to the future and intent can change before it actually occurs. In fact, long-term intent for a particular flight is liable to change throughout the life of a flight. The design of automation functions must consider this fact and therefore intent information should be used conservatively. The design needs to be flexible enough to accommodate change of intent. A proposed new function called intent monitoring is recommended in Section 3. The intent monitoring function would monitor the movement of aircraft and detect non-conformance with intended routes (changes in intent). When non-conformance is detected, the intent monitoring function would notify controllers and the relevant automation functions.
4. Intent thresholds. The intent thresholds that determine conformance/non-conformance of an aircraft's movement along its intended route of flight need to be determined for each improved function.
5. Information overload. Display of maneuver and maneuver intent information on the controller's situation display could potentially result in controller information overload. Display of this information should be optional and selectable by the controller. The CHI design should preclude the possibility of controller information overload

4.3 Recommendations

Using some example improvements to ATM DSS functions, this document developed ideas for use of ADS-B intent and other information. These examples represent initial ideas and the recommendations listed below are for continued work in this area:

1. Address the questions raised within the "Research Areas" subsection of each improvement discussed in Section 3.
2. This FY00 work should be extended by addressing all of the Free Flight Phase 1 (FFP1) functions and by adding more detail to the functional descriptions. As Free Flight Phase 2 (FFP2) functionality is defined, use of intent information in FFP2 functions should be considered.
3. A wide-ranging quantitative benefits assessment is needed. For each function, determine the "payoff" in benefits as a function of the quality of ADS-B data available. "Quality" of the data includes data time horizon, availability, reliability, integrity, and data resolution. This could be accomplished by paper studies, or by test bed simulations.
4. Use Human-In-The-Loop laboratory evaluations to:

- Refine details of how the new maneuver/maneuver intent information would be used in the each automation function, accounting for how each function will perform in a mixed environment of ADS-B and non-ADS-B equipped aircraft
- Develop a detailed operational concept for the use of ADS-B data by each automation function
- Conduct tests to evaluate alternative CHI features for each automation function
- Determine possible interaction of automation functions with other system functions

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Appendix A

Display of ADS-B Intent and Maneuver Information as an Aid to Controllers

This Appendix complements Section 3.2 (Situation Display Function) of this document. Display of ADS-B maneuver occurrence information and maneuver intent information on a controller's situation display can be very helpful when controllers are performing their tasks. Display of intent and/or maneuver occurrence information can potentially aid controllers in performing tasks associated with particular controller responsibilities. Each of the following subsections discusses a particular controller task that is described in the Federal Aviation Administration's "Air Traffic Control" manual (document (7110.65). Discussed in each subsection are the controller responsibilities associated with the task, the sections of 7110.65 that are applicable to those responsibilities, and the specific improvement that could have a beneficial impact on helping a controller meet those responsibilities.

A.1 Flight Progress Strip Marking

A.1.1 Controller Responsibilities

After giving an aircraft a clearance to a different altitude level the controller has the task of marking strips when the aircraft leaves its present altitude.

A.1.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapters 2, General Control, section 3, Flight Progress Strips, subsection 2-3-1, entitled "GENERAL," paragraph a.2.

A.1.3 Specific Improvement

An ADS-B altitude maneuver occurrence indication on the controller's display can be a positive indication that the altitude transition is beginning and, when observed by the controller, can trigger the marking of the appropriate strip. Also, display of the information associated with the ADS-B TCP can indicate the destination altitude of the aircraft, serving as a verification of the altitude clearance.

A.2 Altitude Verification

A.2.1 Controller Responsibilities

When instrument flight rules are in effect, controllers have the responsibility of separating aircraft using specific altitude minima between aircraft. They must clear aircraft to specific altitude levels and verify that each aircraft reaches and maintains its assigned altitude. They generally verify altitudes by observing displayed mode C altitude data for each aircraft.

A.2.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 4, IFR, section 5, Altitude Assignment and Verification, subsection 4-5-1, entitled "VERTICAL SEPARATION MINIMA."

A.2.3 Specific Improvement

Display of altitude maneuver occurrence information and intended destination altitudes can make the controller's verification task easier and more expedient.

A.3 Issuing Wake Turbulence Advisories

A.3.1 Controller Responsibilities

Controllers have the responsibility of issuing cautionary information to any aircraft if in their opinion, wake turbulence may have an adverse effect on it. When traffic is known to be a "heavy" aircraft, include the word heavy in the description issued to the pilot.

A Controller is responsible for issuing wake turbulence cautionary advisories and the position, altitude if known, and direction of flight of the heavy jet or B757 to:

1. TERMINAL VFR aircraft not being radar vectored but behind heavy jets or B757's.

2. IFR aircraft that accept a visual approach or visual separation.

3. TERMINAL arriving VFR aircraft that have previously been radar vectored and the vectoring has been discontinued.

A.3.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 2, General Control, section 2-1, General, subsection 2-1-20, entitled, “WAKE TURBULENCE CAUTIONARY ADVISORY."

Chapter 7, Visual, section 4, Approaches, subsection 7-4-1, entitled, “VISUAL APPROACH."

A.3.3 Specific Improvement

Display of the information associated with the ADS-B TCP can indicate on the controller’s display the intended short-term route of an aircraft. The controller can use this as an aid in determining if an aircraft is intending to fly behind and below an aircraft (a heavy) and thus possibly coming in danger of flying through wake turbulence. If the controllers have the ability to momentarily display the TCP for all ADS-B equipped aircraft in their area, they can tell at a glance whether any ADS-B equipped aircraft will pass through a turbulent wake area.

An ADS-B maneuver occurrence indication on the controller’s display may also help to show that an aircraft is maneuvering into a possible wake turbulence area.

A.4 Issuing Traffic Advisories

A.4.1 Controller Responsibilities

Unless an aircraft is operating within Class A airspace or omission is requested by the pilot, controllers are responsible for issuing traffic advisories to all aircraft (IFR or VFR) on their frequencies when, in their judgment, their proximity may diminish to less than the applicable separation minima.

A.4.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA’s ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 2, General Control, section 1, General, subsection 2-1-21, entitled “TRAFFIC ADVISORIES."

A.4.3 Specific Improvement

Controllers can use the displayed ADS-B maneuver occurrence and maneuver intent (TCP) information or other displayed intent information to determine what maneuvers aircraft are performing, if any, during a traffic advisory situation.

A.5 Issuing Hazardous Weather Advisories

A.5.1 Controller Responsibilities

Controllers are responsible for issuing pertinent information on hazardous weather and observed/reported weather and chaff areas and provide radar navigational guidance and/or approve deviations around weather or chaff areas when requested. In areas of significant weather, the controller should plan ahead and be prepared to suggest, upon pilot request, the use of alternative routes/altitudes.

A.5.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 2, General Control, section 6, subsections:

2-6-2, entitled , "HAZARDOUS INFLIGHT WEATHER ADVISORY SERVICE."

2-6-3, entitled , "PIREP INFORMATION."

2-6-4, entitled , "WEATHER AND CHAFF SERVICES."

A.5.3 Specific Improvement

The single factor that has the greatest impact on system safety and capacity is hazardous weather. Accurate and up to date weather information displayed to both controllers and pilots in a consistent manner, provides the means to minimize delays, prevent aircraft from entering areas of hazardous weather and allows controllers, Airline Operations Centers (AOCs) and pilots to formulate strategic plans rather than relying on tactical responses.

If a tactical response is necessary, controllers can use their accurate weather display along with the displayed ADS-B maneuver occurrence and maneuver intent (TCP) information or other displayed intent information (e.g., RNAV route information) to determine if an aircraft will penetrate areas of bad weather or chaff. Intent information can also be used to determine where an aircraft is going before giving guidance around weather or chaff.

In future systems, an automation function could use the ADS-B maneuver and maneuver intent information, along with accurate weather information to predict potential penetrations of hazardous weather systems and warn controllers and/or pilots of the situation.

A.6 Maintaining Separation

A.6.1 Controller Responsibilities

Controllers located at most En Route, Terminal, and Tower team positions have a responsibility of ensuring separation between aircraft.

A.6.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 2, General Control, section 10, Team Position Responsibilities, subsections:

2-10-1, entitled, "EN ROUTE SECTOR TEAM POSITION RESPONSIBILITIES" (separation).

2-10-2 , entitled, "TERMINAL RADAR/NONRADAR TEAM POSITION RESPONSIBILITIES" (separation).

2-10-3, entitled, "TOWER TEAM POSITION RESPONSIBILITIES" (separation).

A.6.3 Specific Improvement

Controllers at these positions can use the displayed ADS-B maneuver occurrence and maneuver intent (TCP) information or other displayed intent information as a tool to help maintain separation between aircraft.

A.7 Issuing and Confirming Clearances

A.7.1 Controller Responsibilities

Controllers are responsible for issuing clearances for aircraft under their control. A clearance is an authorization by air traffic control for an aircraft to proceed under specified traffic conditions within controlled airspace. The pilot-in-command of an aircraft may not deviate from the provisions of a VFR or Instrument Flight Rules (IFR) air traffic clearance except in an emergency or unless an amended clearance has been obtained.

A.7.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 4, IFR, section 2, Clearances, subsections:

4-2-1, entitled, "CLEARANCE ITEMS."

4-2-2, entitled, "CLEARANCE PREFIX ".

4-2-3, entitled, “DELIVERY INSTRUCTIONS."

4-2-4, entitled, “CLEARANCE RELAY."

4-2-5, entitled, “ROUTE OR ALTITUDE AMENDMENTS."

4-2-6, entitled, “THROUGH CLEARANCES."

4-2-7, entitled, “ALTRV CLEARANCE."

4-2-8, entitled, “IFR-VFR AND VFR-IFR FLIGHTS."

4-2-9, entitled, “CLEARANCE ITEMS."

Also Chapter 4, section 4 Route Assignments, subsections:

4-4-1, entitled, “ROUTE USE."

4-4-2, entitled, “ROUTE STRUCTURE TRANSITIONS."

4-4-3, entitled, “DEGREE-DISTANCE ROUTE DEFINITION FOR MILITARY OPERATIONS."

4-4-4, entitled, “ALTERNATIVE ROUTES."

4-4-5, entitled, “CLASS G AIRSPACE."

A.7.3 Specific Improvement

Controllers can use ADS-B TCP to see where an aircraft is going before specifying a new or changed route to the pilot or before issuing a clearance. Also, to confirm an assignment/clearance, controllers can use ADS-B TCP to display where an aircraft is going after a route assignment/clearance is issued.

A.8 Forwarding Information to Non-approach Towers

A.8.1 Controller Responsibilities

Prior to relinquishing control, an en route or terminal controller is responsible for forwarding specific aircraft information to non-approach control towers or to a Flight Service Station (FSS) soon enough to allow adjustment of the traffic flow for accommodating the aircraft.

A.8.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA’s ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 4 IFR, Section 7, Arrival Procedures, subsections:

4-7-6, entitled, “ARRIVAL INFORMATION” (en route).

4-7-11, entitled, “ARRIVAL INFORMATION BY APPROACH CONTROL FACILITIES” (terminal).

The information to be transferred includes:

5. Aircraft identification.
6. Type of aircraft.
7. ETA.
8. Type of instrument approach procedure the aircraft will execute; or
9. For Special VFR Operations (SVFR)*, the direction from which the aircraft will enter Class B, Class C, Class D, or Class E surface area and any altitude restrictions that were issued; or
10. For aircraft executing a contact approach the position of the aircraft.

* An SVFR is an aircraft operating in accordance with clearances within Class B, C, D, and E surface areas in weather conditions less than the basic VFR weather minima. Such operations must be requested by the pilot and approved by ATC.

A.8.3 Specific Improvement

Controllers can use ADS-B maneuver occurrence and maneuver intent information to determine or verify where an aircraft is going before forwarding arrival information to the non-approach control tower or FSS.

A.9 Issue Traffic Information to Aircraft With Merging Targets

A.9.1 Controller Responsibilities

Controllers are responsible for issuing traffic information to those aircraft whose targets appear likely to merge unless the aircraft are separated by more than the appropriate vertical separation minimum. They are also responsible for providing vectors if the pilot requests vectors to avoid merging with another aircraft. Controllers are also responsible for detecting any aircraft that stray outside a holding pattern area or protected airspace area, and are responsible for assisting it to return.

A.9.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA’s ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5 RADAR, Section 1, General, subsections:

5-1-8, entitled, “MERGING TARGET PROCEDURES."

5-1-9, entitled, “HOLDING PATTERN SURVEILLANCE."

5-1-10, entitled, “DEVIATION ADVISORIES."

A.9.3 Specific Improvement

Controllers can make use of the display of maneuver occurrence and maneuver intent information to determine if aircraft are likely to merge or stray from a holding pattern, or to stray from their intended course. They can use this information to help the aircraft return to its intended course.

The intent monitoring function described in subsection 3.1 could also be used to warn a controller that an aircraft is straying outside a holding pattern area or protected airspace area.

A.10 Relaying and Verifying Information During Transfer of Radar Identification

A.10.1 Controller Responsibilities

During a transfer of radar identification, certain information concerning the aircraft is to be communicated between the sending and the receiving controllers.

A.10.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA’s ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5 RADAR, Section 4, TRANSFER OF RADAR IDENTIFICATION, subsection:

5-4-3, entitled, “METHODS," paragraph b.

A.10.3 Specific Improvement

The sending and receiving controllers could make use of the display of maneuver occurrence and maneuver intent information to determine if the aircraft is maneuvering vertically or horizontally before, during, and after the transfer.

A.11 Maintaining Required Separation Minima

A.11.1 Controller Responsibilities

Controllers are responsible for maintaining the required separation minima between each radar identified aircraft and other aircraft (radar-identified or not), from obstructions and from adjacent airspace as specified in the 7110.65M sections identified below.

A.11.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5 RADAR, Section 5, RADAR SEPARATION, subsections:

5-5-1, entitled, "APPLICATION."

5-5-2, entitled, "TARGET SEPARATION."

5-5-3, entitled, " MINIMA."

5-5-4, entitled, "VERTICAL APPLICATION."

5-5-5, entitled, "EXCEPTIONS."

5-5-6, entitled, "PASSING OR DIVERGING."

5-5-7, entitled, "ADDITIONAL SEPARATION FOR FORMATION FLIGHTS."

5-5-8, entitled, "SEPARATION FROM OBSTRUCTIONS."

5-5-9, entitled, "ADJACENT AIRSPACE."

5-5-10, entitled, "EDGE OF SCOPE."

5-5-11, entitled, "BEACON TARGET DISPLACEMENT."

5-5-12, entitled, "GPA 102/103 CORRECTION FACTOR."

A.11.3 Specific Improvement

The controller could make use of the display of maneuver and maneuver intent information to aid in the separation of a radar-identified aircraft and other aircraft, obstructions or adjacent airspace.

A.12 Vectoring Aircraft

A.12.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65, controllers have the responsibility of vectoring aircraft for separation, safety, noise abatement, operational advantage, or when a pilot requests. As much as possible, a controller should allow aircraft operating on a RNAV route to remain on their own navigation.

A.12.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 6, Vectoring, subsections:

5-6-1, entitled, "APPLICATION."

5-6-2, entitled, "METHODS."

5-6-3, entitled, " VECTORS BELOW MINIMUM ALTITUDE."

A.12.3 Specific Improvement

The controller can make use of the display of maneuver occurrence and maneuver intent information to aid in the vectoring of aircraft. These can be used to verify vectoring aircraft movement after issuing vectoring instructions.

A.13 Issuing Necessary and Appropriate Speed Adjustments

A.13.1 Controller Responsibilities

Based on the details of the following sections of 7110.65M, controllers are required to keep speed adjustments to the minimum necessary to achieve or maintain required or desired spacing. They are to avoid adjustments requiring alternate decreases and increases and they must permit pilots to resume normal speed when previously specified adjustments are no longer needed.

A.13.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 7, Speed Adjustment, subsections:

5-7-1, entitled, “APPLICATION."

5-7-2, entitled, “METHODS."

5-7-3, entitled, “MINIMA."

A.13.3 Specific Improvement

The controller could make use of the display of maneuver occurrence and maneuver intent information to aid in the speed adjustment of aircraft.

A.14 Vectoring Departing Aircraft

A.14.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65M, controllers are required to use standard departure routes and channelized altitudes whenever practical to reduce coordination. They are to provide separation minima as specified in these sections.

A.14.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA’s ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 8, Radar Departures, subsections:

5-8-1, entitled, “PROCEDURES."

5-8-2, entitled, “INITIAL HEADING."

5-8-3, entitled, “SUCCESSIVE OR SIMULTANEOUS DEPARTURES."

5-8-4, entitled, “DEPARTURE AND ARRIVAL."

5-8-5, entitled, “DEPARTURES AND ARRIVALS ON PARALLEL OR NONINTERSECTING DIVERGING RUNWAYS."

A.14.3 Specific Improvement

The controller could make use of the display of maneuver occurrence and maneuver intent information to aid in the vectoring of departure aircraft. The controller can use this information to monitor aircraft maneuvers in real time and to verify assigned headings.

A.15 Vectoring and Separating Aircraft to Final Approach

A.15.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65M, controllers are required to vector aircraft to final approach courses. In doing so, they are to provide minimum separation as specified in these sections.

A.15.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 9, Radar Arrivals, subsections:

5-9-1, entitled, "VECTORS TO FINAL APPROACH COURSE."

5-9-2, entitled, "FINAL APPROACH COURSE INTERCEPTION."

5-9-3, entitled, "VECTORS ACROSS FINAL APPROACH COURSE."

5-9-4, entitled, "ARRIVAL INSTRUCTIONS."

5-9-5, entitled, "APPROACH SEPARATION RESPONSIBILITY."

5-9-6, entitled, "PARALLEL DEPENDENT ILS/MLS APPROACHES."

5-9-7, entitled, "SIMULTANEOUS INDEPENDENT ILS/MLS APPROACHES- DUAL & TRIPLE."

5-9-8, entitled, "SIMULTANEOUS INDEPENDENT DUAL ILS/MLS APPROACHES- HIGH UPDATE RADAR."

A.15.3 Specific Improvement

The controller can make use of the display of maneuver occurrence and maneuver intent information to aid in the vectoring of arrival aircraft and in maintaining separation minima. The controller can use this information to monitor aircraft maneuvers in real time and to verify assigned headings.

A.16 Guiding Aircraft on Final Radar Approach

A.16.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65M, controllers are required to perform certain tasks when guiding aircraft on final approach courses.

A.16.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 10, Radar Approaches-Terminal, subsections:

5-10-1, entitled, "APPLICATION."

5-10-2, entitled, "APPROACH INFORMATION."

5-10-3, entitled, "NO-GYRO APPROACH."

5-10-4, entitled, "LOST COMMUNICATIONS."

5-10-5, entitled, "RADAR CONTACT LOST."

5-10-6, entitled, "LANDING CHECK."

5-10-7, entitled, "POSITION INFORMATION."

5-10-8, entitled, "FINAL CONTROLLER CHANGEOVER."

5-10-9, entitled, "COMMUNICATIONS CHECK."

5-10-10, entitled, "TRANSMISSION ACKNOWLEDGMENT."

5-10-11, entitled, "MISSED APPROACH."

5-10-12, entitled, "LOW APPROACH AND TOUCH-AND-GO."

5-10-13, entitled, "TOWER CLEARANCE."

5-10-14, entitled, "FINAL APPROACH ABNORMALITIES."

5-10-15, entitled, "MILITARY SINGLE FREQUENCY APPROACHES."

A.16.3 Specific Improvement

The controller could make use of the display of maneuver occurrence and maneuver intent information to aid in guiding aircraft on final approach courses. The controller can use this information to monitor aircraft maneuvers in real time and to verify the aircraft is remaining on its final approach course.

A.17 Guiding Aircraft on Final Surveillance Approach

A.17.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65M, controllers are required to provide certain information when guiding and monitoring aircraft on final approaches. The controller provides guidance to the pilot by providing recommended altitudes and course guidance. The controller informs the pilot of any deviation from the approach course in both the horizontal and vertical dimensions.

A.17.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 11, Surveillance Approaches-Terminal, subsections:

5-11-1, entitled, "ALTITUDE INFORMATION."

5-11-2, entitled, "VISUAL REFERENCE POINT."

5-11-3, entitled, "DESCENT NOTIFICATION."

5-11-4, entitled, "DESCENT INSTRUCTIONS."

5-11-5, entitled, "FINAL APPROACH GUIDANCE."

5-11-6, entitled, "APPROACH GUIDANCE TERMINATION."

A.17.3 Specific Improvement

The controller can make use of the display of maneuver occurrence and maneuver intent information to aid in the guidance of ADS-B aircraft on final approach courses. The controller can use this information to monitor aircraft maneuvers in real time and to verify that the aircraft is remaining on its final approach course. Controllers can also monitor the maneuvers of ADS-B equipped aircraft in the vicinity of the approach zone.

A.18 Guidance to Aircraft on a PAR Approach

A.18.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65M, controllers are required to provide precise guidance to aircraft on a PAR approach. The controller provides precise guidance in both the horizontal and vertical dimensions, informing pilots that they are either on course or deviating from the approach course.

A.18.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 12, PAR Approaches-Terminal, subsections:

5-12-1, entitled, "GLIDEPATH NOTIFICATION."

5-12-2, entitled, “DECISION HEIGHT (DH) NOTIFICATION."

5-12-3, entitled, “DESCENT INSTRUCTION."

5-12-4, entitled, “GLIDEPATH AND COURSE INFORMTION."

5-12-5, entitled, “DISTANCE FROM TOUCHDOWN."

5-12-6, entitled, “DECISION HEIGHT."

5-12-7, entitled, “POSITION ADVISORIES."

5-12-8, entitled, “COMMUNICATION TRANSFER."

5-12-9, entitled, “ELEVATION FAILURE."

5-12-10, entitled, “SURVEILLANCE UNUSABLE."

A.18.3 Specific Improvement

The controller may be able to make use of the display of maneuver occurrence information to aid in the guidance of aircraft on a PAR approach course. However, the usefulness may be questionable since the PAR equipment should immediately indicate a deviation.

A.19 Monitoring Precision/Non-precision Approaches

A.19.1 Controller Responsibilities

Based on the specifics of the following sections of 7110.65M, aircraft making precision/non-precision approaches can be monitored by a controller using PAR equipment. During monitoring, the controller acts primarily as a safety observer and does not actually guide the aircraft. The controller informs the pilot of any deviation from the approach course.

A.19.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA’s ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 13, Use of PAR for Approach Monitoring (Terminal), subsections:

5-13-1, entitled, “MONITOR ON PAR EQUIPMENT."

5-13-2, entitled, “MONITOR AVAILABILITY."

5-13-3, entitled, “MONITOR INFORMATION."

A.19.3 Specific Improvement

The controller may be able to make use of the display of maneuver occurrence information to aid in the monitoring of aircraft on an approach course. However, the usefulness may be questionable since the PAR equipment should immediately indicate a deviation.

A.20 Responding to a CA/MCI or MSAW Alert (En Route)

A.20.1 Controller Responsibilities

When a Conflict Alert (CA) or Mode C Intruder (MCI) alert is displayed on an en route display, the controller is required to evaluate the reason for the alert without delay and take appropriate action.

Also, when an En Route Minimum Safe Altitude Warning (E-MSAW) alert is displayed, the controller is required to immediately analyze the situation and, if necessary, take the appropriate action to resolve the alert.

A.20.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 14, Automation – En Route, subsections:

5-14-1, entitled, "CONFLICT ALERT (CA) AND MODE C INTRUDER (MCI) ALERT."

5-14-2, entitled, "EN ROUTE MINIMUM SAFE ALTITUDE WARNING (E-MSAW)."

A.20.3 Specific Improvement

The controller can use displayed maneuver occurrence information to aid in the evaluation of the conflict situation. Displayed intent information for the aircraft involved in the potentially hazardous situation and also for aircraft in the vicinity, may be helpful in resolving the situation and expediting a resolution.

A.21 Monitoring Aircraft Movements During Handoff

A.21.1 Controller Responsibilities

ARTS/STARS may be used for identifying aircraft assigned a discrete beacon code, maintaining identity of targets, and performing handoffs of these targets between controllers.

A.21.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 15, Automated Radar Terminal Systems (ARTS)-Terminal, subsections:

5-15-1, entitled, "APPLICATION."

5-15-3, entitled, "FUNCTIONAL USE," paragraph c., Handoff.

A.21.3 Specific Improvement

The controller can use displayed maneuver occurrence information to monitor aircraft movements during handoffs. The receiving controller also can use the displayed aircraft maneuver intent to verify the intended route of an aircraft in handoff.

A.22 Responding to a CA/MCI Alert-Terminal

A.22.1 Controller Responsibilities

When a Conflict Alert (CA) or Mode C Intruder (MCI) alert is displayed, evaluate the reason for the alert without delay and take appropriate action.

A.22.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 15, Automated Radar Terminal Systems (ARTS)-Terminal, subsections:

5-15-6, entitled, "CA/MCI."

A.22.3 Specific Improvement

The controller can use displayed maneuver occurrence information to aid in the evaluation of the conflict situation. Displayed intent information for the aircraft involved in the potentially hazardous situation and also for aircraft in the vicinity, may be helpful in resolving the situation and expediting a resolution.

A.23 Responding to an MSAW Alert– Terminal

A.23.1 Controller Responsibilities

When a terminal Minimum Safe Altitude Warning (MSAW) alert is displayed, the controller should analyze the situation and, if necessary, take the appropriate action to resolve the alert.

A.23.2 Applicable FAAO 7110.65M Sections

Refer to the following sections of the FAA's ATC Manual, document FAAO 7110.65M, dated 24 February 2000:

Chapter 5, RADAR, Section 15, Automated Radar Terminal Systems (ARTS)-Terminal, subsection:

5-15-7, entitled, "INHIBITING MINIMUM SAFE ALTITUDE WARNING (MSAW)."

A.23.3 Specific Improvement

The controller can use displayed maneuver occurrence information to aid in the evaluation of the conflict situation. Displayed intent information for the aircraft involved in the potentially hazardous situation and also for aircraft in the vicinity, may be helpful in resolving the situation and expediting a resolution.

Appendix B

Flexible Terminal Routing

The description below serves as an example of what can be done in the future to bring together the ground and airborne systems and use intent information to create an efficient and beneficial ATM operation that will be safer and allow more aircraft to be handled in the future. It describes a potential service that could be available to controllers and pilots in the future. The description applies to the terminal domain but could also be applied to the en route ATM environment.

Problem Statement

The tactical workload for controlling arriving and departing aircraft in terminal airspace, including the voice communication workload, limits the amount of traffic that can be handled safely in the terminal area. The requirement for aircraft to fly dynamic random departure and arrival routes (severe weather, traffic saturation, etc) significantly adds to the complexity of the traffic in the terminal area. This workload and route complexity can result in inefficiencies that can cause unwanted delays and higher than normal fuel burns.

Solution

This service will ultimately allow controllers to use two-way addressed data link (the initial implementation does not require data link) to communicate to FMS-equipped aircraft the clearances that are necessary to follow a precise RNAV path into or out of a terminal area. It also allows a pilot to originate a route choice and communicate the choice to a controller in the form of a route request. This service will enable gains in airport throughput by responding to dynamic conditions and by allowing the execution of more complex routes in the terminal area without additional voice communication workload and errors. It will increase safety, decrease both pilot and controller workload, and decrease inefficiencies. The data linked route can be, but does not need to be, referenced to ground based navigation devices making route selection more flexible. Routes are chosen in response to dynamic traffic and/or weather situations, or in an attempt to match or closely match a user preferred trajectory (UPT) requested by a pilot.

A controller or pilot can originate a route selection. When a controller originates the route selection, the selected route is negotiated with the pilot via data link. The route, with any negotiated changes, then becomes a clearance to the pilot. The route is then autoloaded into the FMS after being either uplinked from the ground or retrieved from FMS storage. When a pilot rather than a controller makes a route selection, the selected route is sent to the controller in the form of a data linked clearance request. This allows the pilot to include any user preferred route characteristics. After negotiation, the controller data links a route clearance, including any negotiated changes, to the pilot and the pilot autoloads the route into the FMS.

Several developmental spirals are envisioned for this service. Over time, these spirals introduce more technical complexity, more route definition flexibility and a higher level of efficiency.

In the first developmental spiral, for selected airports, the same set limited of pre-defined published RNAV routes are resident in both ground and airborne systems. These pre-defined published routes will be defined by a sequence of waypoints and altitudes, and routes such as STARs and SIDs can be included in the set. Each published route will have a short, unique identifier understood by both the ground and the flight deck. Simply by using the route's unique identifier, a terminal arrival or departure route can be selected. Data link can be used for communication of the unique identifier, but voice could be used as well.

In developmental spiral 2, the set of available routes is expanded to include many more 3D routes. Since airborne route storage capacity is limited, these additional routes will be stored in the ground systems and uplinked to the pilot during route selection and negotiation. At each terminal facility as many routes as needed can be pre-defined in order to anticipate any conceivable situation that may arise due to traffic and weather conditions, and different runway configurations at that facility.

In developmental spiral 3, routes can be dynamically created. In response to changing weather or traffic situations, the route can be defined dynamically by the pilot or the controller. Special software aids can be used to help create the route by taking into consideration dynamic conditions such as weather or traffic constraints. These aids include functions such as the En-route Descent Advisor (E/DA) function or the Expedite Departure Path (EDP) function, which can provide definition of 3D RNAV routes with specific constraints caused by weather and/or traffic conditions.

In development spiral 4, time, the fourth dimension, is introduced into dynamically calculated random routes, initiated by airside or ground based automation. Any constraints required by traffic flow management (TFM) would be added. For arrivals, the use E/DA for descent information and constraints would be included in the route message. This will also work in conjunction with a Final Approach Spacing Tool (FAST) for the final approach alignment and spacing. For departures, the use of EDP function will allow for more direct routings out of terminal airspace, in addition to any constraints for TFM. The 4D routes including required time of arrival (RTA) and multiple RTAs, will be provided to and used by FMS equipment. Software aids can be used to help create a 4D route that will consider both timing constraints and flight path constraints caused by weather and/or traffic conditions.

Appendix C

Potential Terminal Conflict Alert Use of Maneuver and Maneuver Intent

The current design of the short term (tactical) terminal Conflict Alert/Mode C Intruder (CA/MCI) safety function bases alerts on surveillance data, tracking of surveillance data and adaptation. Currently hazardous situations between two aircraft are identified using surveillance position data. The prediction of hazardous situations is accomplished by tracking surveillance data and using track velocity information for straight line projections and by attempting to sense the starts of turns for horizontal maneuver hazardous conditions. Adaptation allows adjustment of the safety function logic via parameterization and geographically sensitive logic. New aircraft movement data, including maneuver occurrence and intent data, would be available in the future with ADS-B. Also new avionics allows an aircraft to accurately follow more detailed routes such as RNAV routes. This leaves the door open for use of this new information in the ground based safety functions. Section 3.6 of this document discusses the safety functions in greater detail.

Use of intent information in the terminal CA/MCI safety function can be beneficial if the function is redesigned and aircraft involved in a conflict are flying RNAV routes. The new design creates a two-level alert algorithm. It works on the premise that a normal CA/MCI alert will be issued if a potentially hazardous situation exists and there is no intended maneuver within the relative time period of the hazard. However, if the intended route of the aircraft (based on the RNAV route) contains an intended maneuver that will nullify the hazardous situation, the alert would not be suppressed, but a "maneuver must occur" alert would be issued to the appropriate controller. It tells the controller that the aircraft must perform the maneuver in order to avoid a hazardous situation.

The intent monitoring function will be needed to ensure that the aircraft remains on its intended RNAV route, otherwise the CA/MCI function would suspend use of intent information and revert back to the current design.

Three examples that demonstrate the new design that uses intent information contained in RNAV routes are shown in the three figures contained on the following pages.

Example 1 shows two aircraft, A/C 1, flying in a Northeasterly direction, and A/C 2 flying in a Northwesterly direction. Both are flying RNAV routes and both are at the same altitude. A/C 1 intends to make a turn to the left and A/C 2 intends to make a turn to the right. If A/C 1 were not to turn, the two aircraft would reach the potential collision point shown in the figure. For this situation, the current terminal CA/MCI function would issue a normal conflict alert two scans after the point that is 40 seconds before the conflict situation. This is the point where the aircraft are separated by 3.6 nm.

With the new design that uses intent information, a “maneuver must occur” alert will be issued for A/C 1 in place of the normal alert. When the controller receives this alert, it becomes necessary to make sure that A/C 1 begins its left turn in time to avoid the conflict situation.

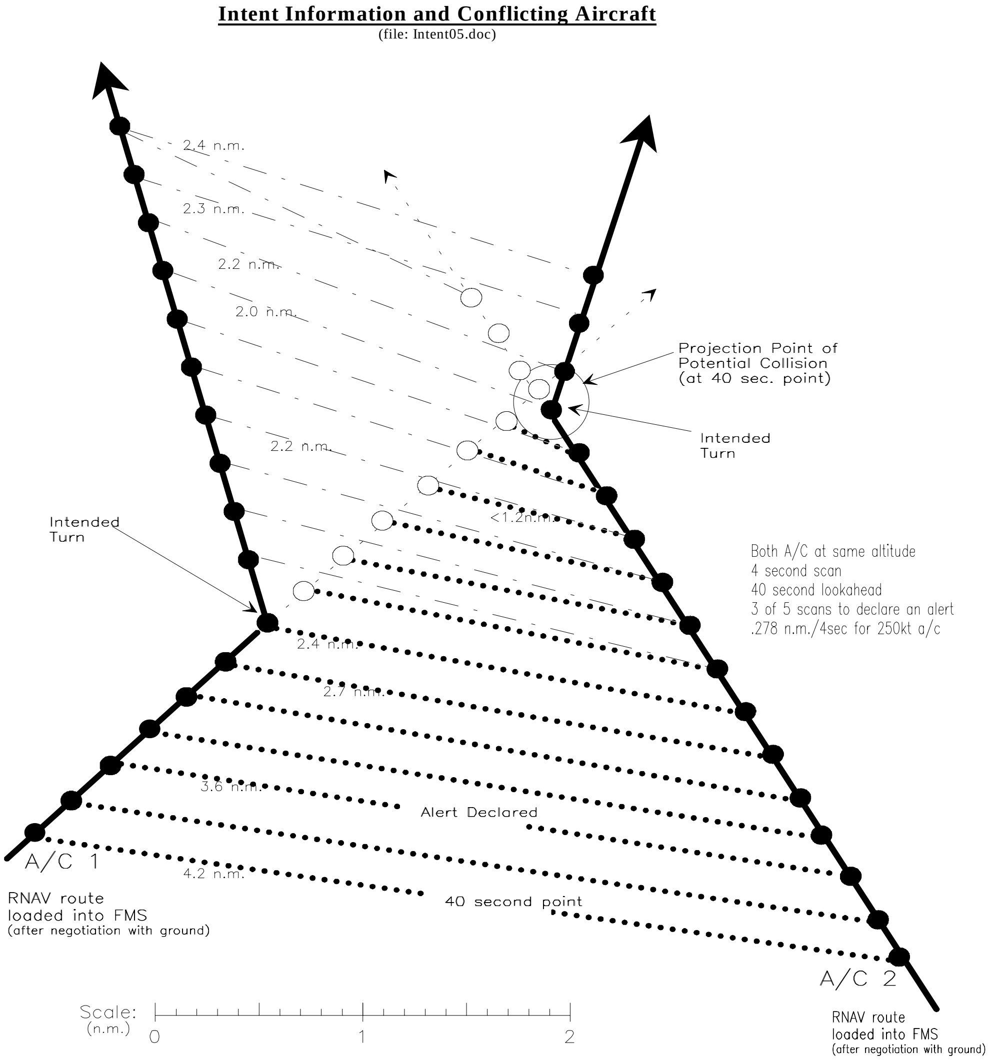
Example 2 shows the same situation as in Example 1 except that A/C 1 in this case does not intend to make a left-hand turn. With the new CA/MCI design, a normal CA/MCI alert will be issued to controllers involved when the separation between the two aircraft is 3.6 nm.

Example 3 shows the same situation as in Example 2 except that A/C 1 intends to climb from 5000 feet to 7000 feet at a rate of 1000 feet/minute. A/C 2 intends to remain at a level altitude of 5000 feet. With the new CA/MCI design, a “maneuver must occur” alert for A/C 1 will be issued to controllers involved when the separation between the two aircraft is 3.6 nm. When receiving this alert, the controller should make sure that A/C 1 begins its climb soon enough to avoid the conflict.

If at any time during these conflict situations the intent monitoring function determined that either of the aircraft were in non-conformance with its intended route, then only normal conflict alerts would be issued.

Example 1:
Intent Information and Conflicting Aircraft
(Two intended turns; both aircraft at same altitude)

ACTION: Issue a "maneuver-must-occur" alert for A/C 1 to controllers involved.

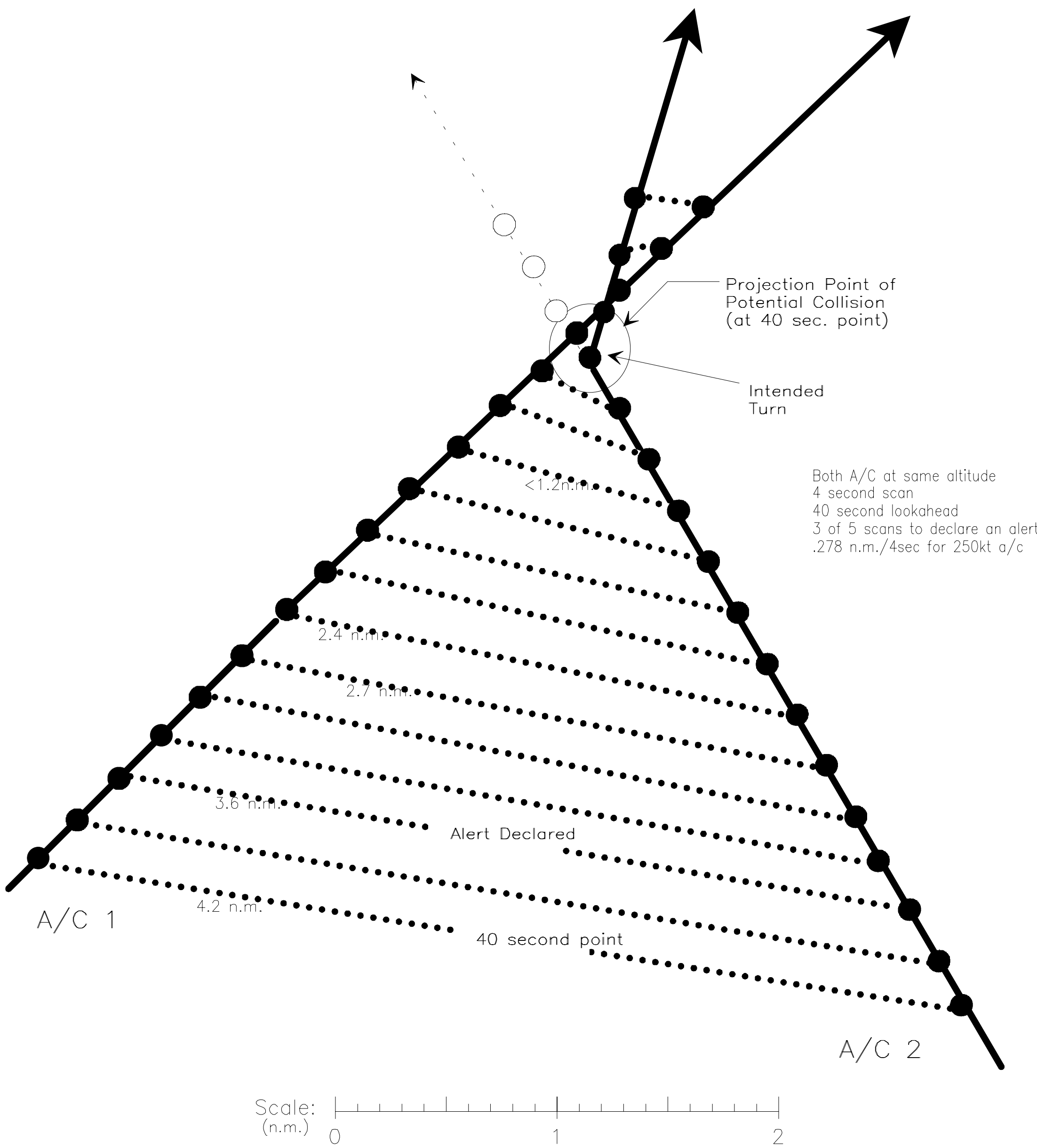


Example 2:

Intent Information and Conflicting Aircraft

(One intended turn; both aircraft at same altitude)

ACTION: Issue a normal conflict alert for controllers involved.

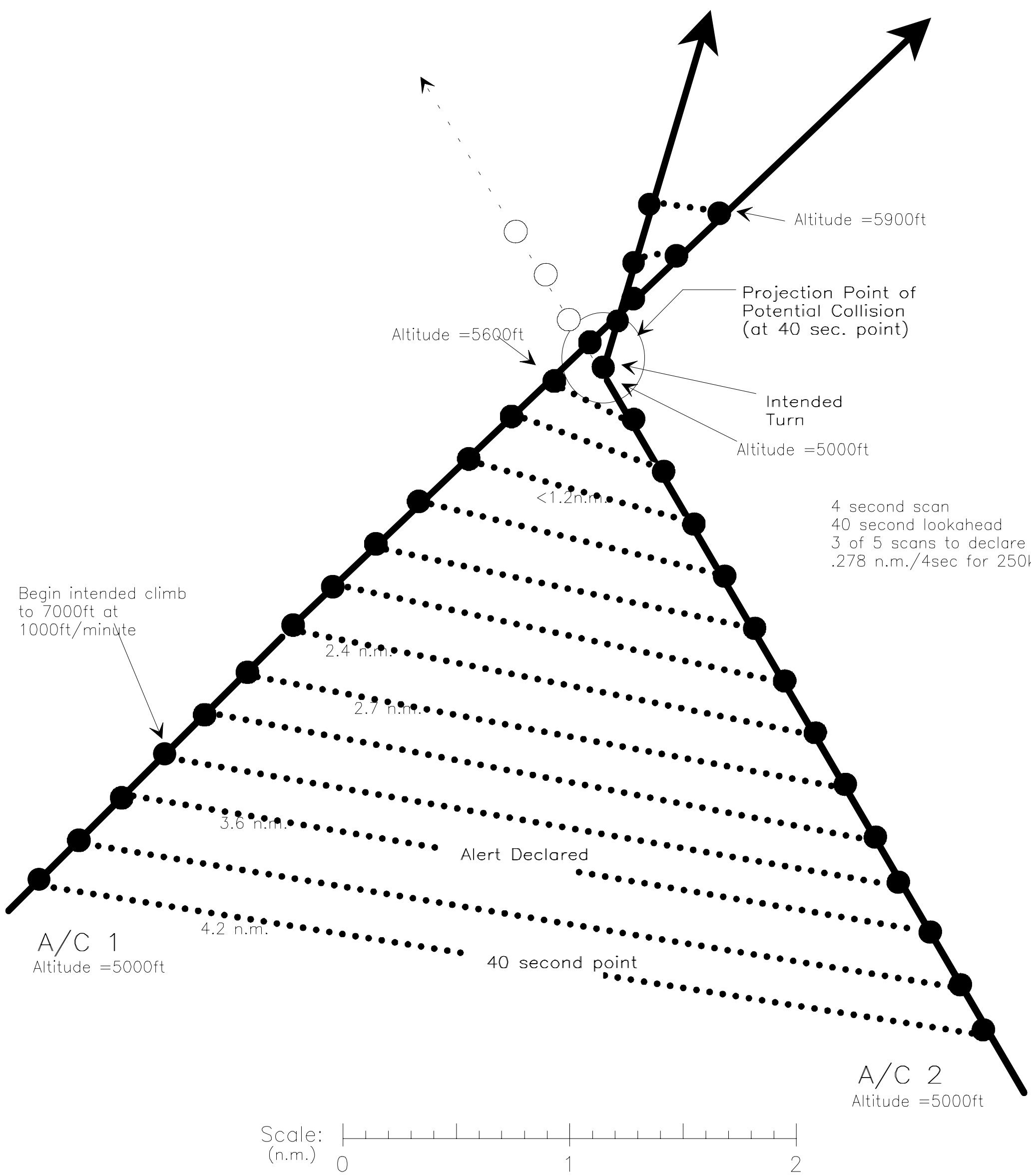


Example 3:

Intent Information and Conflicting Aircraft

(One intended turn; plus one intended altitude maneuver)

ACTION: Issue a “maneuver-must-occur” alert for A/C 1 to controllers involved.



Glossary

ADS-B	Automatic Dependent Surveillance Broadcast
ARTS	Automatic Radar Terminal Systems
ASDE	Airport Surface Detection Equipment
ATC	Air Traffic Control
ATM	Air Traffic Management
CA	Conflict Alert
CA/MCI	Conflict Alert/Mode C Intruder
CAASD	Center for Advanced Aviation System Development
CHI	Computer/Human Interface
CPDLC	Controller Pilot Data Link Communication
DSS	Decision Support Systems
E/DA	En-route Descent Advisor
EDP	Expedite Departure Path
E-MSAW	En Route Minimum Safe Altitude Warning
FAA	Federal Aviation Administration
FAST	Final Approach Spacing Tool
FDP	Flight Data Processing
FFP1	Free Flight Phase 1
FFP2	Free Flight Phase 2
FLAT	Flight Plan Aided Tracking
FMS	Flight Management System
FP	Flight Plan

FSS	Flight Service Station
GPS	Global Positioning System
IFR	Instrument Flight Rules
MASPS	Minimum Aviation System Performance Standards
MFMAMS	Module for Maneuvering and Maneuvering Sensitive
MSAW	Minimum Safe Altitude Warning
NAVAIDS	Navigational Aids
nm	Nautical Mile
RTA	Required Time of Arrival
SVFR	Special VFR Operations
TCP	Trajectory Change Point
TCP+1	Trajectory Change Point + 1
UPT	User Preferred Trajectory
URET	User Request Evaluation Tool
VFR	Visual Flight Rules