

Air Traffic Management Technology Demonstration – 3 (ATD-3) Operational Concept for the Integration of ATD-3 Capabilities Version 1.0

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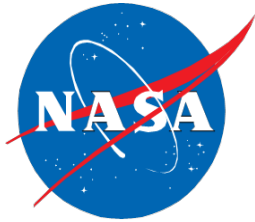
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Airspace Technology Demonstration- 3 (ATD-3)

Operational Concept for the Integration of Airspace Technology Demonstration -3 (ATD-3) Capabilities

V1.0

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1 INTRODUCTION

The Airspace Technology Demonstration 3 (ATD-3) sub-project is sponsored by the National Aeronautics and Space Administration (NASA) ATD Project as part of NASA's Airspace Operations and Safety Program (AOSP). ATD-3 addresses AOSP Technical Challenge #3 aiming to reduce weather-induced delays through integration of weather information to better manage aircraft, traffic flow, airspace and schedule constraints by delivering air/ground procedures and user-tool technologies. To address this technical challenge, the goal of ATD-3 is to develop and demonstrate advanced integrated air/ground automation technologies and procedures that enable strategic user-preferred routes to be identified and executed. The primary objective of ATD-3 is to develop integrated air/ground automation tools that:

- Reduce impact of uncertainty in weather in domestic airspace
- Enable continuous searching for more efficient routes for individual flights in domestic airspace
- Enable continuous searching for more efficient routes for groups of flights in domestic airspace
- Efficiently share route correction options between traffic managers, pilots, dispatchers, and controllers in domestic airspace.

ATD-3 has developed four capabilities to address the goal and objectives stated above. The four ATD-3 capabilities include:

- **Dynamic Weather Routes (DWR):** an airline operations center (AOC) decision support capability to identify and propose reroutes to efficiently avoid weather and airspace constraints.
- **Multi-Flight Common Routes (MFCR):** a traffic flow management decision support capability to identify opportunities for time-saving reroutes of individual and multiple aircraft around weather, or to more dynamically update routing-related Traffic Management Initiatives (TMIs) during changing weather conditions.
- **Traffic Aware Strategic Aircrew Requests (TASAR):** a flight deck decision support capability to identify, coordinate, and request flight-optimizing reroutes taking into account traffic, weather, and airspace constraints.
- **Dynamic Routes for Arrivals in Weather (DRAW):** a traffic flow management decision support capability to enable more efficient terminal area arrival flow metering and management in response to dynamic weather conditions.

NASA, the Federal Aviation Administration (FAA), and industry partners have defined the scope and expectations of simulation and demonstration activities as a part of ATD-3. The service-provider capabilities in ATD-3 are planned for technology transfer to the FAA with supporting documentation for operational deployment. The airspace-user capabilities in ATD-3 are currently being developed and tested by NASA and their partner airline under operational evaluations with revenue flights and are intended for tech transfer to the user community and industry. See Appendix B for more information about ATD-3 research activities.

This document describes the long-term, mature vision for the use and incorporation of the ATD-3 capabilities into the National Airspace System (NAS). This vision describes their complementary interaction and the benefit capture that accrues from use. Recognizing that all

capabilities are unlikely to be implemented in unison, each of the capabilities are currently designed and prototyped to be able to be implemented independently. As discrete portions of the integrated capabilities are planned, additional integration efforts should be undertaken to validate the complementary interactions and benefit pool are realized from the selected subset.

1.1 PROBLEM STATEMENT

Adverse weather is responsible for roughly 70% of the total NAS delays in U.S. operations [1]. Convective weather is one of the most difficult forms of adverse weather constraints to mitigate due to its dynamic and unpredictable nature. Traffic Flow Management (TFM) Decision Support Tools (DSTs) are available to traffic managers and airspace users to help identify and apply strategic mitigations, such as Severe Weather Avoidance Plans (SWAPs). Strategic weather-avoidance routes are often planned two or more hours in advance of departure and help mitigate the impacts of hazardous weather. However, these routes often result in large deviations from user preferred trajectories. Automation is not available today to notify traffic managers and airspace users when weather constraints have changed and avoidance routes (or segments of them) may no longer be necessary. Consequently, circuitous Playbook routes may remain in effect much longer than required and result in unnecessary delays, fuel consumption, operating costs, and environmental impacts. The ATD-3 Integrated Concept addresses this problem through the integration of the ATD-3 capabilities – TASAR, DRAW, MFCR, and DWR.

1.2 INTEGRATED CONCEPT OVERVIEW

The ATD-3 Integrated Concept describes the seamless, complementary interactions of NASA's dynamic rerouting capabilities – DWR, MFCR, TASAR, and DRAW. The integration of these capabilities will improve trajectory efficiency in the en route and arrival phases of flight, improve TFM coordination and productivity, respond to changes and uncertainty in demand and constraint predictions, accelerate the recovery from outdated Traffic Management Initiatives (TMIs), and reduce the need to issue airspace related TMIs. ATD-3 capabilities identify and suggest time-and/or-fuel-saving alternate reroutes taking convective weather and other airspace constraints into account consistent in accordance with airspace user preferences.

As such, the integrated system is heavily reliant on sharing complete, timely, and accurate constraint information and predictions. Current and planned Air Navigation Service Provider (ANSP) and airspace user constraints and preferences are shared with the ATD-3 capabilities to provide complete and timely information. Each of the ATD-3 capabilities continuously searches for and identifies efficient reroutes accounting for weather. Using Systems Wide Information Management (SWIM) the candidate reroutes are reviewed and coordinated across the ATD-3 capabilities, engaging in automated negotiation as necessary. Following a successful automated negotiation, the proposed reroute is communicated to the respective controller, who then communicates the route change clearance to the flight crew.

Enhancements to digital communications, data sharing, and system integration through the implementation of SWIM and other communication conduits will enable fluid communication between the integrated ATD-3 capabilities and the users, helping to increase system performance and benefits over time.

1.3 DOCUMENT ORGANIZATION

This concept document consists of eight sections. Section 1 provides the background and rationale for the integration of the ATD-3 capabilities. Section 2 provides an understanding of today's current operations. Section 3 provides an outline of the shortfalls of today's operations during adverse weather scenarios and justifications for changes and enhancements to the current operations. Section 4 provides a description of each of the ATD-3 capabilities, as currently developed and prototyped by NASA, a description of the integrated concept, and associated guiding principles and assumptions. Section 5 outlines enhancements to the current functions of the ATD-3 capabilities that would be required in order to enable the integrated concept. Section 6 provides example operational scenarios and describes the interactions of the ATD-3 capabilities and the users. Section 7 provides a summary of operational impacts resulting from integration of the ATD-3 capabilities. References can be found in section 8. Appendix A provides a glossary and definition of terms table. Appendix B describes the research and work being conducted under ATD-3 and outlines additional research that will need to be conducted. Appendix C explains the technology and automation dependencies and integration with other non-NASA systems as part of the integrated concept. Appendix D describes the integration of the ATD-1, ATD-2, and ATD-3 functions. Appendix E outlines the support and collaboration of the ATD-3 work in line with the FAA's vision and operational improvements.

2 CURRENT OPERATIONS

2.1 DESCRIPTION OF USERS IN CURRENT OPERATION

Figure 1 on the following page, outlines the key players in the National Airspace System. The traffic managers, air traffic controllers, airline air traffic control coordinators, dispatchers, and flight crews all work together for efficient airspace operations.

Traffic Managers: Air Traffic Control System Command Center (ATCSCC) Traffic Managers (TM) use weather forecasts to identify areas of predicted adverse weather that may require Traffic Management Initiatives (TMIs), and work with Air Route Traffic Control Centers (ARTCCs) to develop a plan when needed. ATCSCC identifies which flights should be included in the Ground Delay Program (GDP) and/or Playbook routes, and publishes notices and details of the plan. ARTCC Traffic Management Coordinators (TMCs) coordinate Severe Weather Avoidance Plan (SWAP) routes with ATCSCC. TMs use the Traffic Flow Management System (TFMS) to monitor NAS status and SWAP effectiveness and Time-Based Flow Management (TBFM) to monitor arrival demand, TMs impose TMIs and tactical demand mitigations.

Air Traffic Controllers: Air traffic controllers are responsible and inter-separating aircraft spacing that is consistent with safe airspace operations and expediting traffic flow, providing information to aircraft about weather conditions, and handling unexpected events, emergencies and unscheduled traffic.

Airline Air Traffic Control Coordinators and Dispatchers: Coordinators work with ATCSCC Traffic Managers to coordinate schedules, substitutions, and weather avoidance routes that best service company needs, and coordinate reroutes with ARTCC TMCs. Dispatchers manage flight plans and fueling, monitor progress and crew/passenger connections, and coordinate changes with flight crews.

Flight Crews: Flight crews conduct flights, monitor weather along the route of flight, and request changes that keep aircraft clear of hazardous weather and achieve company flight objectives.

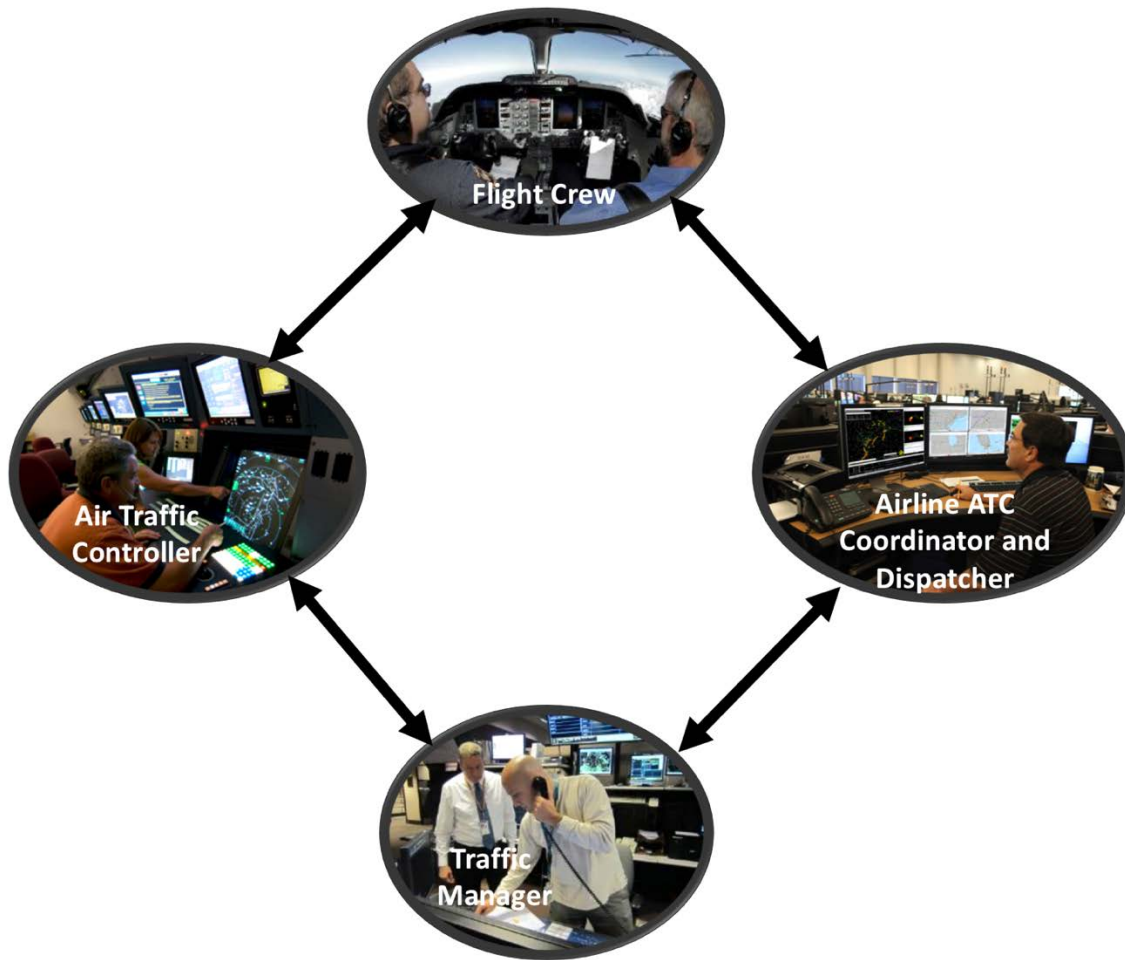


Figure 1: Primary Users in Current Operations

2.2 OPERATIONAL OVERVIEW

ATD-3 capabilities begin operations at the conclusion of the departure route and extends to the arrival meter fix at the destination airport. Figure 2 is a graphical depiction of the operational environment addressed by the ATD-3 capabilities .

Today, traffic flow is managed by the ATCSCC and 20 ARTCCs, large TRACONs and select Towers across the contiguous U.S. The ATCSCC assesses forecast weather and traffic demand throughout the day, and coordinates with ARTCC and Terminal Radar Approach Control (TRACON) facilities to implement strategic TMIs. These TMIs generally involve metering departures by imposing delays, rerouting traffic around hazardous weather, or metering the flow of traffic through flow constrained airspace. Strategic TMIs include SWAP routing, Miles-in-Trail (MIT) restrictions, Airspace Flow Programs (AFP), and Ground Delay Programs (GDP). The ATCSCC and ARTCCs propose and execute the strategic TMIs, provide feedback on their effectiveness, and recommend alternatives. ARTCC TMCs and controllers make tactical adjustments for airborne flights throughout the day, through airborne holding, radar vectors, and speed control/miles-in-trail (MIT) restrictions, in order to meter demand to match airport capacity.

Organized weather fronts that contain large, well-developed lines of convective weather impose a requirement for strategic traffic flow management mitigations to safely route flights around hazardous weather and to meter demand in areas where deviating flights contribute to excess demand. The FAA uses a combination of Flow Control Areas (FCA), Playbook routes, and GDPs to manage traffic flows in such scenarios. FCAs are areas through which demand must be controlled due to demand/capability imbalance within the affected airspace, which may be caused by weather or excess traffic demand. The TMIs, including appropriate Playbook routes, are tailored to each weather and traffic scenario, and are used as part of a SWAP, the FAA's primary means of strategically managing large-scale weather constraints.

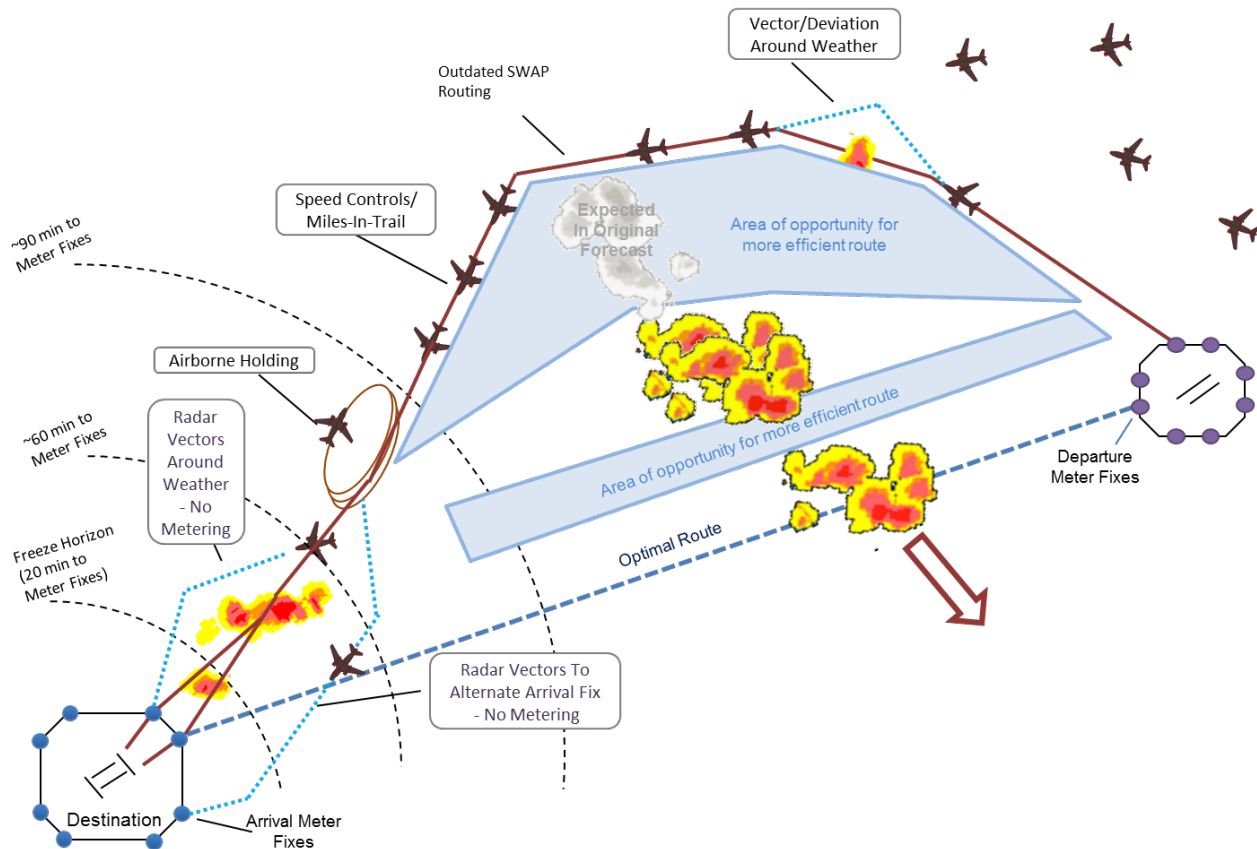


Figure 2: Operational Environment for ATD-3

During significant en route weather events, ATCSCC evaluates weather forecasts for areas of potentially severe weather. For areas identified as major obstructions to traffic flow, alternatives are discussed with affected ARTCC facilities and airspace users. Based on available information, and judgment based on experience, ATCSCC develops a proposed strategy that includes a SWAP made up of selected Playbook routes that traffic managers believe best address the weather and best serve traffic demand. Airspace users amend flight plans with SWAP routes that best fit the objectives for each flight and may rearrange their flights by substituting assigned departure times of one flight for another to minimize the impact on operating costs and schedules. Impacted flights that have not filed a SWAP route will be issued a route before departure or while airborne. Rerouted flights will increase congestion on available sectors closest to the weather. This may require flights currently planned to transit those sectors to also be

rerouted in order to distribute delay more evenly among airspace users, and to manage demand across remaining sector capacities. The ATCSCC will reassess the demand profile once flight plans are updated and may expand the number of flights subjected to reroutes. Alternatively, the ATCSCC may issue GDPs through an AFP to avoid creating excessive demand in surrounding airspace sectors. The revised demand profile will extend to destination airports and may influence GDPs.

During the initial arrival phase of flight, up to the TRACON boundary, TBFM is used to manage arrival flows to many major airports, utilizing radar-track data and 4-D trajectory predictions, to create Estimated Times of Arrival (ETA) for arrival flights within its planning horizon. These ETAs are used to calculate a flight sequence and Scheduled Times of Arrival (STA) at the assigned arrival meter fix and runway for each arriving flight. For arriving flights that will be departing from an airport within the TBFM planning horizon, scheduled departure times are used to calculate STAs (including any planned delay). TBFM continuously updates flight ETAs, STAs, and the sequence at the arrival meter fix and runway, until flights cross the freeze horizon, at which point the flight is considered too close to the approach phase to make changes. The freeze horizon is typically 20 minutes out from arrival meter fixes (30-40 minutes from the airport), but varies for each airport configuration, and can be as much as two hours out, equating to roughly 600 nautical miles. Any assigned delay for a flight is distributed to upstream sectors through which the flight will traverse, and controllers apply that delay through radar vectors or speed controls. Any interruption in the intended trajectory up to the meter fix, such as radar vectors to avoid convective weather or other airspace constraints, or differences from predicted ground speed, will result in inaccurate ETAs and metering schedules that are suboptimal or even unworkable.

2.3 SUPPORTING CAPABILITIES

Today's operations are primarily supported by FAA automation to improve the consistency and quality of information flow among users, and to enhance situation awareness. The sections below describe supporting systems used in today's operations.

2.3.1 Traffic Flow Management System (TFMS)

TFMS is a suite of automation tools that assist in the planning and implementation of TMIs to address demand/capacity imbalances in the NAS. TFMS integrates with systems used by more than 30 FAA, military, industry, public, and international stakeholders, and is implemented in more than 80 air traffic management sites. TFMS monitors demand and capacity information, assesses the impact of system constraints, provides alerts, and helps determine appropriate adjustments. This enables increased predictability, flexibility, efficiency, and capacity in the system, and contributes to decreases in delay, safety risks, and cost. TFMS is comprised of a collection of capabilities enabled by custom applications running on commercial hardware., and TFMS data are processed at the FAA William J. Hughes Technical Center in Atlantic City, NJ.

2.3.2 Time-Based Flow Management (TBFM)

TBFM is deployed to all domestic ARTCCs, selected TRACONs and towers, and many major airports. It uses time instead of distance to help controllers sequence air traffic, and compared to the traditional miles-in-trail process to separate aircraft, TBFM provides a more efficient traffic flow that reduces fuel burn, lowers exhaust emissions, and increases traffic capacity and

throughput. TBFM metering creates a time slot for fixed metering points along an aircraft's route, and controllers use speed advisories or vectors to direct an aircraft to cross the metering points at their assigned times. An adjacent-center metering capability provides time-based management capabilities to neighboring centers to better manage arrivals. An integrated departure/arrival capability automates the process of monitoring departure demand, identifying departure slots, and assigning them to aircraft. It coordinates departure times between airports and provides situational awareness to air traffic control towers so they can select from available departure times and plan their operations to meet these times.

2.3.3 System Wide Information Management (SWIM)

SWIM replaces the multiple stand-alone computer interfaces that connect point-to-point with a data-exchange format interface through a single connection. SWIM is the digital data delivery platform needed to fully realize many NextGen operational improvements. SWIM contributes to the FAA's goal of time-based management and enables trajectory-based operations through integration and data sharing among pilots, airline Air Traffic Control (ATC) coordinators and dispatchers, controllers, and air traffic managers. This increased access to common air traffic management data and information increases efficiency and helps with planning, while reducing delays, cancellations, fuel consumption, and aircraft exhaust emissions.

3 SHORTFALLS AND JUSTIFICATION OF CHANGES

3.1 SHORTFALLS

Adverse weather, in the form of convective storms, winds, turbulence, snow and ice, low visibility, and low ceilings, is consistently responsible for nearly 70% of the total NAS delays in U.S. operations, and of these, 60% are caused by convective weather. Summer convective storms can increase that figure. For example, weather-related delays were responsible for 85% of delays for a total of 1.8 million minutes of delay in the NAS during the summer of 2016 [1].

Convective weather impacts both en route and terminal operations, and current mitigations can cause excessive delays due to the inability of strategic initiatives to address dynamic changes in weather conditions [2]. Response to dynamically changing weather conditions and movements is often reactive due to the lack of integrated automation and decision support tools. The tactical amendments that are applied are largely manual exercises that place heavy workload demands on TMCs, controllers and airspace users, and are cumbersome and time-consuming to employ. This contributes to the conservative nature of strategic traffic management initiatives.

3.1.1 En Route Delays

TMIs are necessary to ensure that aircraft safely avoid areas of adverse weather or other airspace constraints and to address demand/capacity imbalances when demand exceeds capacity, while maximizing throughput. However, TMIs can be overly conservative due to uncertainty in weather forecasts, demand profiles, and airspace capacity limitations impacted by weather. In some cases, nominally assigned routes may be inefficient due to the use of legacy route structures or other system constraints.

When significant convective activity is forecast to develop in an area of the NAS, FAA traffic managers may designate those areas as FCAs, and they may implement SWAP routes to safely divert traffic around the weather-impacted regions.

There are a number of challenges associated with route selection and timing for SWAP implementation, cancelation, and recovery. The root of the problem is the inability to predict precisely where and when convective cells will develop and dissipate, and the resulting demand distribution. To provide traffic managers and flight operators with ample time to prepare and assign the necessary resources where needed, SWAP routes are identified two to eight hours prior to the time the flow constraint is predicted to develop. Airline flight dispatchers must file flight plans at least 45 minutes before push-back from the gate based on their best available weather forecasts. In practice, flight plans are typically filed one to two hours before take-off. When SWAP routes are in effect, dispatchers will determine which SWAP routes are applicable to a flight's planned route, and they will file a revised route accordingly.

Due to the uncertainty in convective forecasts with such lead times, convective weather may not materialize as expected. Consequently, selected routes may be very inefficient (as illustrated in Figure 2), or they may be implemented earlier than required. Conversely, convective weather may develop on selected routes after flights depart, requiring numerous in-flight reroutes. Identifying, coordinating, and communicating a large number of reroutes imposes a heavy workload on traffic managers, controllers, and flight dispatchers during a time when they are already experiencing high workload managing weather-related constraints and delays. Excessive

workload can result in SWAP routes remaining in effect longer than needed and/or flights remaining on those routes when no longer required, thereby incurring costly and unnecessary delays, fuel consumption, and emissions.

There is little automation in the current system to help airspace users identify and coordinate workable opportunities for time- and fuel-saving corrections to weather avoidance routes. This includes the lack of up-to-date traffic flow and airspace constraint information, and decision support tools to identify more efficient routes that will avoid congested airspace or conflicts with other aircraft. Although flight crew can identify more efficient weather-avoidance trajectories using flight management systems and weather radar, they are unable to see convective weather anywhere beyond the limits of their on-board weather radar without broadband convective-weather products. Even then, broadband weather products may not include detailed convective forecasts like Corridor Integrated Weather System (CIWS). The flight crew must consult the controller or airline dispatcher about alternate trajectories that may avoid large areas of adverse weather and flow restrictions. The crew must then request the alternate trajectory from the controller to effect the change en route. Airspace users also lack access to all TFM and ATC restrictions that may impact alternate routes (i.e., Letters of Agreement (LoA) between facilities, sector boundaries, etc.), and the flight operator must therefore coordinate with controllers and TMCs. Coordinating such route changes and related flight priorities beyond a few flights is very time consuming and workload intensive.

3.1.2 Arrival Delays

Arrivals can experience similar delays related to weather or demand/capacity imbalances, and may have fewer alternatives than en route flights, especially in metroplex environments. Delays in the terminal area often back up into the en route environment, requiring demand metering using MIT restrictions, speed controls, delay vectors, and airborne holding. In more severe cases, MIT and speed restrictions may extend beyond the host Center and/or require the implementation or extension of GDPs.

The FAA's existing time-based metering tool, TBFM, facilitates efficient traffic flow when arrival demand approaches or exceeds airport capacity. Due to the current TBFM system's inability to adjust its predicted times of arrival when controllers vector aircraft off nominal arrival routes to avoid weather, arrival metering is not currently maintained when significant convective weather impacts arrival routes and the destination airport. Because vectors are dynamic and not defined, TBFM has no trajectory intent information and is therefore unable to accurately predict ETAs at the meter fixes. In these scenarios, controllers normally apply MIT restrictions, path stretching via vectors, speed control, or airborne holding to manage arrivals, resulting in greatly increased delays and controller workload, consequently increasing fuel burn and emissions.

In order to preempt potential disruption in the arrival flow and metering, hours before a flight would arrive (i.e., at a time when weather forecasting error is high) it may be routed to a different, but often less efficient, arrival route to avoid forecasted weather. Even if weather does not impact the arrival route or fails to materialize as forecasted, arrival flights will often continue to fly these less efficient arrival routes, even though there may be other arrival routes available that avoid the weather and maintain arrival throughput. The workload to coordinate and communicate such route changes for a multitude of flights can be excessive and impractical for traffic managers and controllers to implement for fast-moving weather. Automation tools are not

available to quickly identify and provide more efficient distribution of traffic across available arrival routes. Consequently, flights often remain on the current arrival route and are vectored around the constraint to the initial or intermediate approach fix, reducing the arrival rate and causing delays to back up into the en route phase of flight.

Improved automation tools are needed can continuously monitor real-time and short-term weather forecasts and dynamically identify opportunities for time- and fuel-saving corrections to weather avoidance routes tools can significantly improve the efficiency of flights in en route airspace.

3.2 JUSTIFICATION FOR CHANGES

The following table describes changes to be implemented through the introduction of integrated ATD-3 capabilities and the justification for those changes, relating to the shortfalls described in the previous section. The specific changes addressing the en route phase shortfalls described in Section 3.1 above are justified in the first row of Table 1.

Table 1: Justification of Changes

Change	Justification	Shortfall
Continuously evaluate, identify, and coordinate time-saving route alternatives around convective weather and other airspace constraints for individual and groups of flights to better meet airspace user objectives, constraints, and preferences.	<ul style="list-style-type: none"> • Delay recovery • Improves reroute efficiency based on time-savings metrics and leveraging RNAV capabilities • Improves coordination across ARTCCs, AOC, Flight Deck and ATCSCC • Increased TMC, controller, dispatcher, and flight crew productivity • Improves responsiveness to changes in convective weather and other airspace constraints • Improves TFM and airspace constraint information sharing and collaboration • Enables more rapid recovery from outdated playbook routes • Reroutes support downstream metering • Incorporates airspace user preferences into reroute decisions • Increases fuel and emissions savings. • Reduces operating costs 	<ul style="list-style-type: none"> • Unnecessary route delays • Lack of ability to trial plan reroute alternatives • Limitations in convective weather forecasting and planning • Limited ability to respond to convective weather changes • Slow recovery from route TMIs • Dynamic radar vectors interfere with downstream metering • Limited ability to consider airspace user preferences in rerouting decisions • Limited ability to capitalize on opportunities for more efficient routes • Limited situational awareness of TFM and ATC constraints • Limited ability to inject airspace user preferences in rerouting decisions

Change	Justification	Shortfall
Continuously evaluate, identify, and coordinate weather avoidance routes on arrival to support arrival metering during convective weather and arrival meter fix balancing	<ul style="list-style-type: none"> • En route and arrival delay reduction • Increased controller productivity during adverse weather • Enables longer sustained time-based arrival metering • Reduces controller workload during adverse weather • Improves utilization of airport capacity 	<ul style="list-style-type: none"> • Potentially unnecessary arrival delays • Interruption of arrival metering during convective weather • Arrival delays due to demand-capacity imbalance at arrival meter fixes

4 ATD-3 INTEGRATED CONCEPT AND CURRENT CAPABILITIES

The ATD-3 capabilities continuously and automatically analyze flight trajectories and airspace constraints to find opportunities for flight time- and fuel-saving reroutes. These reroutes are route and/or altitude changes that reduce the overall delays in the airspace system by avoiding weather and other airspace constraints. Each of the ATD-3 capabilities uses information from ground-based weather and NAS status information networks to identify constraints.

Although they provide similar functions, the ground and flight deck capabilities differ in fundamental ways due to the platforms on which they are implemented and the data to which they have access. The flight deck capability attempts to optimize the trajectory of the aircraft on which it is installed, whereas the ground capability attempts to balance the optimization of all flight trajectories within en route airspace with the most efficient use of limited airspace resources. The flight deck capability, in addition to using available ground-based data, also uses onboard avionics systems to identify other constraints known to the flight deck.

The airspace user systems generally have more information about aircraft performance and company objectives preferences, while the service provider systems are more connected to traffic management networks and local facility information. Enhancements to digital communications, data sharing, and system integration through the implementation of the FAA's System Wide Information Management (SWIM) reduces these differences and enables the integrated ATD-3 capabilities to increasingly improve system performance and benefits over time.

4.1 CAPABILITY DESCRIPTIONS

Descriptions of the four ATD-3 capabilities, as currently developed and prototyped by NASA, are provided in the following sections. Although ATD-3 capabilities will provide the greatest benefits during convective weather events, they will also provide route savings benefits any time more efficient routes are available, regardless of weather conditions.

4.1.1 Dynamic Weather Routes (DWR)

The Dynamic Weather Route (DWR) capability is utilized by flight dispatchers and ATC coordinators in AOCs. DWR continuously searches each en route flight trajectory for a given airline and recommends (time time-saving) lateral reroutes for individual flights that avoid convective weather or other airspace constraints. These airspace constraints include SUAs and TFRs. DWR detects, but does not avoid, congested sectors that are approaching or have reached their monitor alert parameter (MAP) threshold. If a congested sector is detected, DWR notifies the user that the reroute conflicts with a congested sector. DWR also notifies the user of flights effected by FAA issued TMIs [3].

When the system determines that a flight could save more than a user-set time threshold (e.g., 5 minutes) by flying a more efficient route and still avoid the applicable constraint(s), it will suggest a new route segment for that flight. The new route segment is defined by two or more waypoints (as shown in Figure 3). It begins with a Maneuver Start Point (MSP) along the current route and ahead of the aircraft's current position by a user-set time period (e.g., 5 minutes). This feature provides sufficient time to review and coordinate the route amendment when necessary. The end of the route amendment is defined by the Return Capture Fix (RCF), located downstream along the original flight plan route. The RCF reflects current operational practice on how far downstream a route clearance can typically be issued, and do not extend beyond the arrival meter fix. To avoid interfering with arrival metering and approach operations at the destination airport, the RCF is subject to additional limits on distance or time from arrival meter fixes, based on Center or TRACON constraints.

The system inserts up to two auxiliary waypoints between the MSP and RCF when needed to avoid the applicable airspace constraint(s) or to ensure operationally acceptable clearances. Auxiliary waypoints may be the nearest named waypoint or geographic coordinates. Reroute candidates avoid Special Use Airspace (SUAs) and inform the user when the proposed route is impacted by a route TMI. Once a route correction is found that meets the user-defined time-saving parameter, the reroute is displayed to an airline dispatcher showing the estimated time savings based on predicted ground speed.

DWR limits its search to only the host company's flights. Each implementation may include slightly different user preferences, such as time savings, on which DWR bases route proposals. The AOC will share and coordinate the proposed route with flight crews via digital communication systems. Once agreed upon, a reroute request will be made to the controller using a digital communication capability, or voice communications when this capability is unavailable.

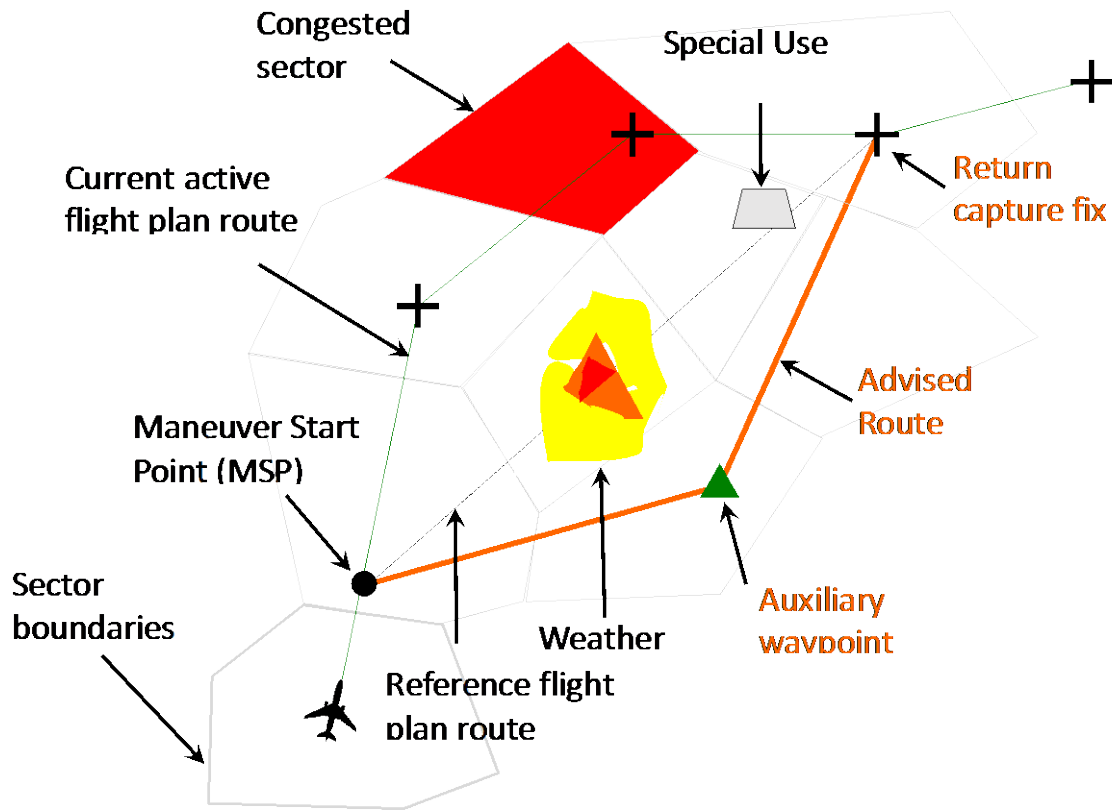


Figure 3: DWR Concept

4.1.2 Multi-Flight Common Routes (MFCR)

The MFCR capability is utilized by Traffic Managers in the Traffic Management Unit of an En route Center or the ATCSCC. The MFCR capability builds on the DWR concept by adding the ability to identify common reroutes for groups of flights on similar trajectories. Common reroutes are generally used when available airspace is constrained and requires multiple flights to share that airspace in an organized fashion. The individual reroute capability searches all trajectories within the designated area of coverage and is used when constraints do not require flights to share common routes [4].

MFCR monitors flight trajectories in all 20 Centers and has the capability to provide route advisories that put multiple flights on a common route around one or more constraints. This allows reroutes for multiple flights to be reviewed and approved all at one time. This capability is particularly useful when options for constraint avoidance are limited and multiple flights need to share route solutions. It is also useful when conditions prompting constraint avoidance routes change and numerous flights in the same vicinity need to be rerouted. MFCR logic identifies a common route that balances constraint avoidance and potential time savings with ATM acceptability to achieve the best compromise for the group of flights (Figure 4).

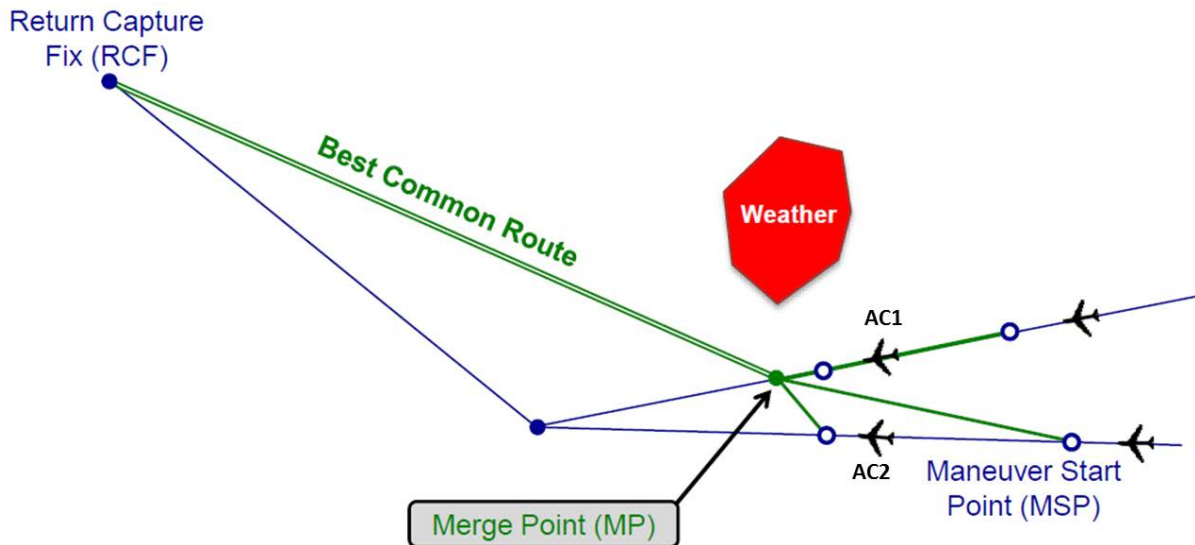


Figure 4: MFCR Concept

Grouping flights in this manner reduces workload required to identify, review, and coordinate separate reroutes for each flight. The time or fuel savings for each flight in the group may be slightly lower than if the reroute were optimized for that individual flight, but it will allow more flights to benefit and increase overall savings and benefits.

MFCR identifies common reroutes sufficiently in advance (user-selectable time parameter) to allow enough time to coordinate with all the flights involved and to provide controllers with enough lead time to deconflict those flights if needed.

4.1.3 Traffic Aware Strategic Aircrew Requests (TASAR)

The flight deck component of ATD-3, TASAR, continuously searches for optimized routes accounting for traffic, weather, and airspace constraints. TASAR leverages connectivity to flight management systems and other data sources to identify wind-optimized routes and altitudes that will save time and/or fuel [5].

TASAR is supported by the emergence of three systems: Electronic Flight Bags (EFB), Automatic Dependent Surveillance Broadcast (ADS-B)-Out/In, and broadband internet connectivity to the flight deck. The EFB provides a platform for powerful applications to use real-time aircraft navigation and performance data, ADS-B traffic data, onboard weather radar, and system-wide information from broadband internet connectivity. Airborne internet and the Aircraft Access to SWIM (AAAtS) provides EFB applications with connectivity to real-time data on the aircraft's operating environment, including airspace constraints, traffic flow restrictions, wind predictions, weather hazards, and SUA status.

TASAR allows greater opportunity for individual flight optimization and provides immediate benefits for equipped flights. Candidate solutions are wind-optimized and clear of known traffic and airspace conflicts before they are presented to the flight crew for requesting a change from ATC. As a result, TASAR saves fuel and/or flight time, provides immediate and ongoing benefits to the airspace user, and can improve flight schedule compliance, passenger comfort, and pilot and controller workload (Figure 5).

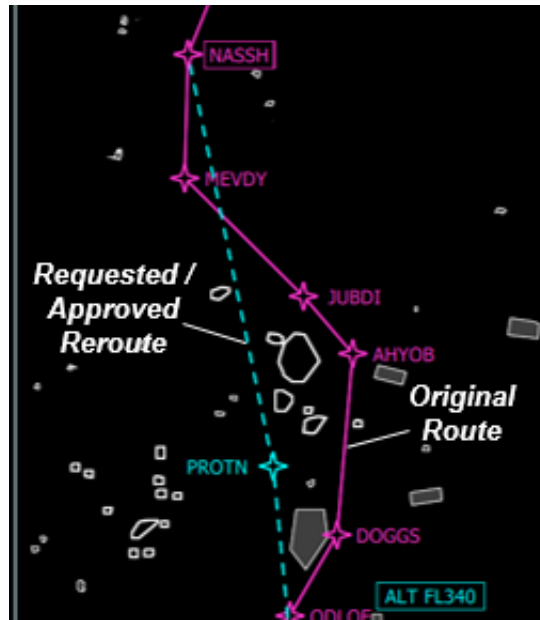


Figure 5: TASAR Concept

4.1.4 Dynamic Routes for Arrivals in Weather (DRAW)

DRAW is a concept and traffic management decision support tool utilized by the TMC in an En Route Center or TRACON. DRAW combines trajectory-based convective weather avoidance technology with integrated route and arrival schedule trial planning capabilities. The DRAW capability facilitates metering operations and enables more efficient routes for arrival flights in the presence of convective weather activity [456].

DRAW will continuously analyze all arrival flights to identify opportunities to reroute flights to more efficient routes and/or around weather on their current flight plans. Figure 6 illustrates two examples of DRAW reroute candidates with corresponding simplified metering timelines. In the first example, DRAW identifies a more efficient route for AC2. The current flight plan for AC2 is representative of a SWAP route that would have been filed pre-departure hours earlier. The SWAP route takes AC2 to the south meter fix (MF2) in anticipation of forecasted weather blockage of the flight's typical north meter fix (MF1). DRAW analyzes trajectories for AC2 against updated weather forecasts. Arrival flight AC2 is identified as a DRAW candidate for more efficient, time-saving reroute to an alternate arrival route and meter fix. DRAW proposes a reroute for AC2 that will save time by taking it back to the MF1. The traffic manager would then trial plan the proposed DRAW route for AC2 with the integrated route and schedule trial planner, evaluate its impact on route and scheduling constraints including its trial ETA/STA (shown in magenta), then implement it if desired.

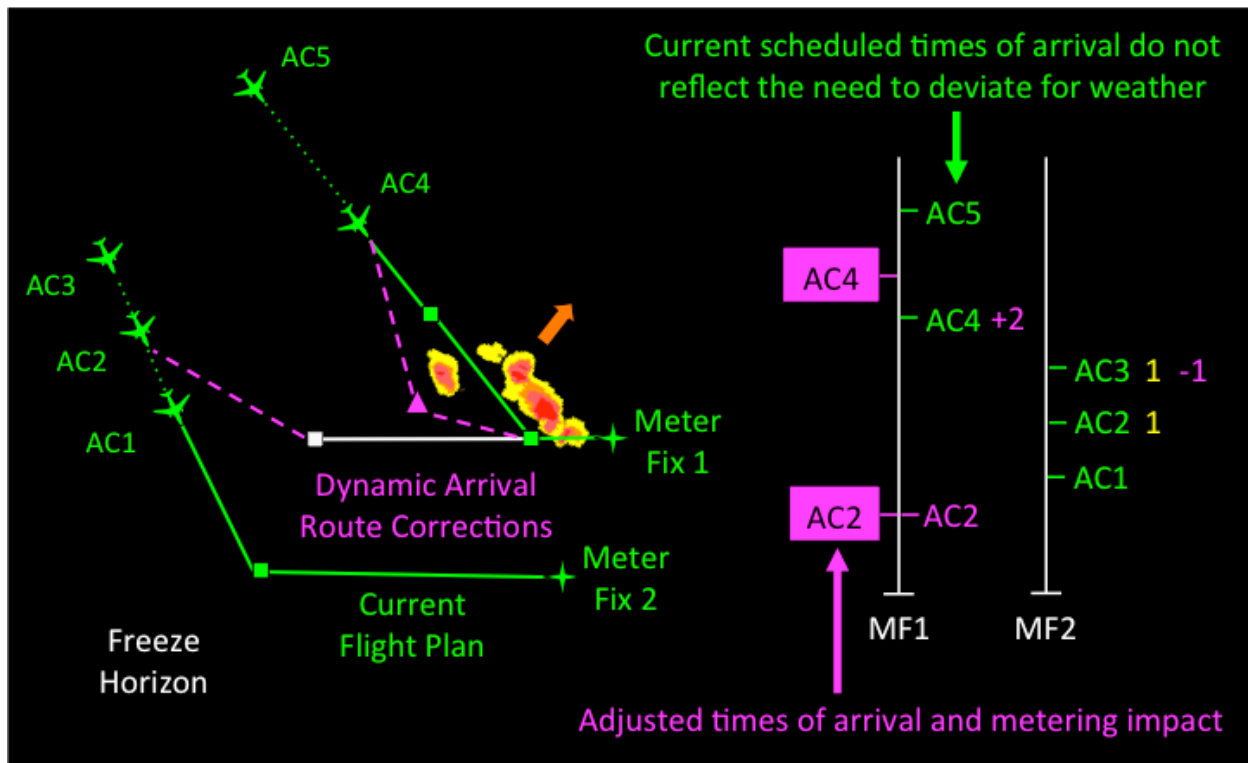


Figure 6: DRAW Concept

The second example outlines the case where DRAW identifies a weather avoidance reroute. DRAW analyzes metered flights for weather conflicts on their current trajectories. In Figure 6, weather is observed on the current flight plan of AC4. DRAW detects a weather conflict on AC4's flight plan and proposes a weather deviation reroute that would take AC4 south to an additional auxiliary waypoint then back to the original arrival route. The trial plan of the proposed DRAW route for AC4 is shown in magenta.

4.2 OPERATIONAL CONCEPT FOR THE INTEGRATION OF ATD-3 CAPABILITIES

The primary objective of the integrated concept is to provide a vision of how the functions of the ATD-3 capabilities can be integrated. By integrating the ATD-3 capabilities, there are opportunities to improve the efficiency of operations through the following:

- Improved trajectory efficiency in the en route and arrival phases of flight
- Improved TFM coordination and productivity
- Responses to changes and uncertainty in demand and constraint predictions
- Accelerated the recovery from outdated TMIs
- Revised long duration TMIs expeditiously

4.2.1 Assumptions

The integrated concept is based on a set of over-arching assumptions that provide a basis for procedures and processes used in the concept.

It is assumed that:

- Relevant human actors across the NAS are provided insight into potential or ongoing changes that affect their operations through appropriate systems to maintain awareness and provide opportunity to adjust constraints or respond to exigent circumstances, if needed.
- Operators will have a variation in deployed ATD-3 capabilities, and those that do have ATD-3 capabilities may not use them at all times. Specifically, airlines may or may not choose to include the DWR system in their airline operations. Similarly, an airline may choose to equip some, all, or none of its fleet with the TASAR system.
- Aircraft will be equipped with ADS-B Out consistent with 14 Code of Federal Regulation (CFR) 91.225 and 14 CFR 91.227 [7,8]. TASAR-equipped aircraft are also assumed to be ADS-B In equipped.
- All ATD-3 capabilities have access to relevant NAS information and airspace user constraints and preferences for maximum effectiveness. This may include, but is not limited to, current and planned ATM constraints, weather, airspace and airport configurations, infrastructure availability, and both fleet-wide and flight-specific constraints and preferences.
- ATD-3 capabilities hosted by the FAA might use different weather products than those operated by users due to operational requirements.
- All ATD-3 capabilities will have access to, and provide input to, other relevant NAS capabilities.
- Digital communication is assumed to be the predominant air/ground exchange mechanism for reroute interactions. Voice communications are assumed to be used for tactical course changes and for aircraft not equipped with a digital communication capability. Reroute proposals and negotiations by voice communications are on a time-permitting basis.

4.2.2 Guiding Principles

The guiding principles below provide a foundation for interaction across ATD-3 capabilities and their users:

- The roles and responsibilities of the individual airspace users, air traffic controllers, and traffic managers remain the same as in today's system, though the mechanisms and capabilities available to discharge those responsibilities continue to evolve.
- Airline operations personnel will continue to manage their fleets safely while sharing their preferences with the ANSP for individual or groups of flights to meet company goals and objectives to maximize efficiency.
- Flight crews will still be responsible for the safe operations of their aircraft while searching for efficiencies for their own flights.
- Air traffic controllers will continue to maintain safe separation between aircraft under their control while trying to accommodate individual flight preferences when practical.
- Traffic managers will still devise plans for overall traffic flow on a temporal basis that maximizes safety and efficiency and accounts for dynamic conditions such as weather and demand and capacity imbalances.
- All of the ATD-3 capabilities will work together to collaboratively support user roles and responsibilities. System users are provided with real-time, accurate information and advisories to assist them in achieving a reliable, efficient, and safe overall traffic flow in the face of changing conditions.

Within the integrated ATD-3 capabilities framework, the following guiding principles apply to the integration and operation of the automation, as well as to the users of the tools:

- Sharing of constraints and preferences between the ATD-3 capabilities and their users is key to increasing common situational awareness and simplifying, and potentially reducing, human workload and the complexity of reroute negotiations.
- Proposed reroute requests from the users or the automation will include the initiator.
- All candidate reroutes submitted will have a time-out window after which the request will expire if the vetting and negotiation process has not been completed. The duration of the time-out will be based on the lead time needed to coordinate and implement the reroute clearance prior to the aircraft reaching the Maneuver Start Point (MSP) or it is determined that the requested reroute is no longer viable due to changes in constraints or lack of savings.
- ATD-3 capability users have the ability to propose reroutes or intervene during automated negotiations.
- All proposed reroutes are reviewed by the controller and flight crew before implementation.
- When a proposed reroute is fully vetted and ready for execution, the proposed route amendment is presented to the controller responsible for issuing the clearance, even if the affected portion of the trajectory occurs downstream of that controller's sector.
- Limits may be placed on the frequency of reroutes beyond the time or fuel savings threshold to manage TMC, controller, dispatcher, and flight crew workload

- The airspace user or automation acts as one agent to the service provider, which implies:
 - When the flight crew using TASAR or the AOC using DWR initiates a request, they negotiate and agree on a single request before sending it to the service provider
 - When feedback is requested by the service provider using MFCR or DRAW on a route, the flight crew using TASAR and the AOC using DWR agree on a single response back to the ANSP.
- The service provider or automation acts as one agent to the airspace user, which implies:
 - When the TMC with MFCR or the TMC with DRAW initiates a request, they negotiate and agree on a single request prior to sending it to the airspace user.
 - When feedback is requested by the airspace user using TASAR or DWR on a route, the TMCs using MFCR or DRAW agree on a single response back to the airspace user.

4.2.3 Concept Description

The integrated concept calls for more robust constraint definition and sharing, as well as expanded integration of the ATD-3 capabilities. Preflight planning and TFM procedures are carried out much the same as they are today. All current and planned ANSP constraints are shared with ATD-3 capabilities to provide complete and timely information. Airspace user constraints and preferences are continuously shared with the ATD-3 capabilities to create reroutes that satisfy the airspace user's objectives for each flight.

The integrated system is heavily reliant on sharing complete, timely, and accurate constraint information and predictions. ANSP constraints are continuously updated as they change. Airspace users utilizing ATD-3 capabilities, update, and share their constraints and preferences for each flight prior to departure, and update them during flight execution when necessary. It is assumed that during initial phases of ATD-3 operations, not all constraints and preferences will be known to the ATD-3 capabilities. In these operational phases, all candidate reroutes must be reviewed by the human user to ensure all constraints are met before being requested from the controller.

Figure 7 shows the ATD-3 Capabilities Block Diagram, which describes the interaction between the various participants, the ATD-3 capabilities and the information flow between them. Reroute requests and negotiations are communicated across the ATD-3 capabilities using SWIM. After negotiation of a reroute request, if a reroute request originates with the airspace user, the flight crew will request the reroute from the controller via digital communications or the dispatcher will request the reroute from the controller via the TMC through SWIM. If a reroute request originates with the ANSP, after negotiation, the TMC will forward the reroute to the respective controller via digital communications, who then issues the proposed route change clearance to the flight crew via digital communications or by voice. The ANSP could also send a reroute request to an AOC via SWIM.

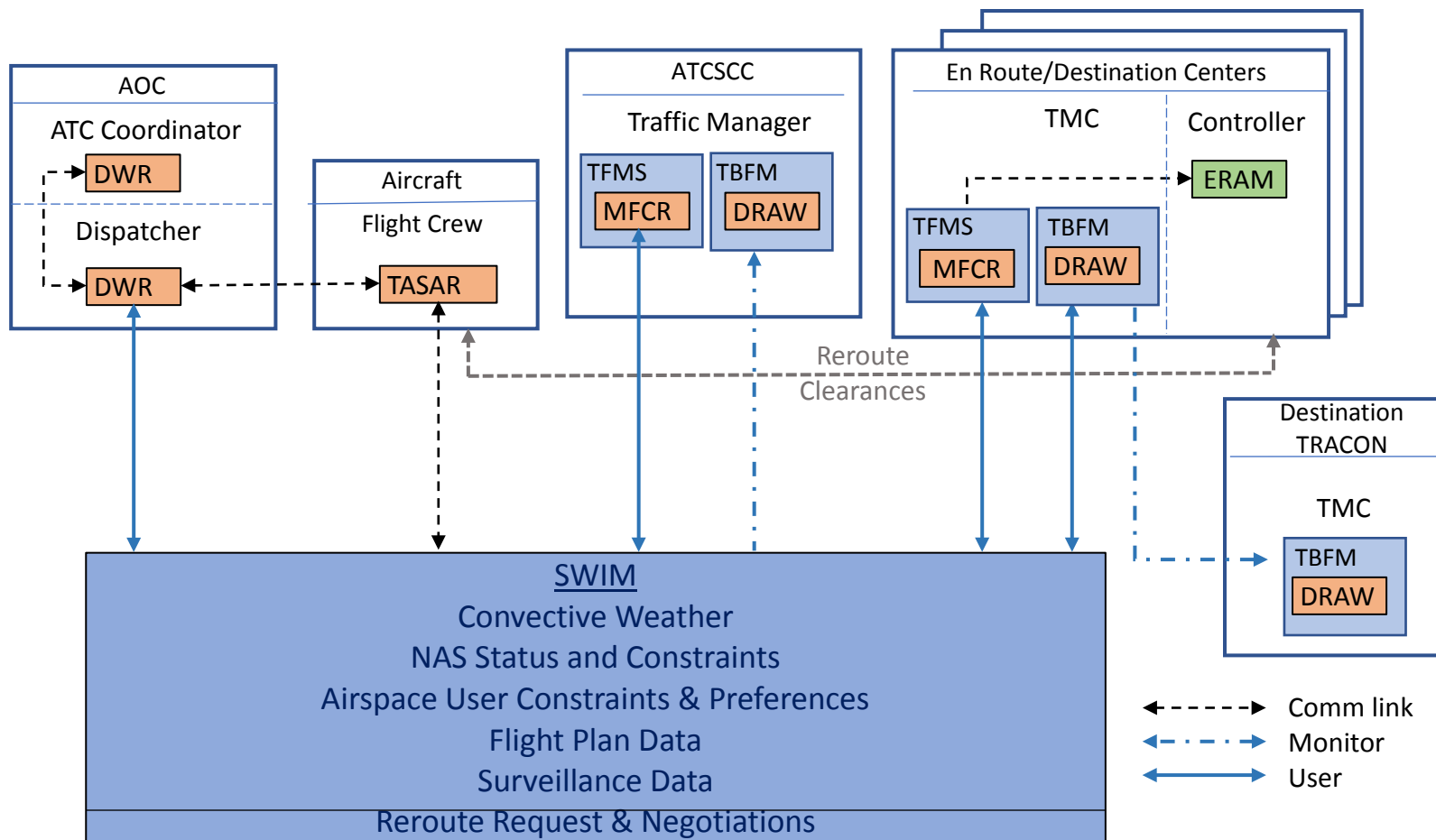


Figure 7: ATD-3 Capabilities Block Diagram

Figure 8 provides an overview of the ATD-3 capabilities and operating environments in which they function. Flights may be rerouted individually to maximize time savings, or on a common route when demand is high, airspace capacity is constrained, or alternative route options are limited.

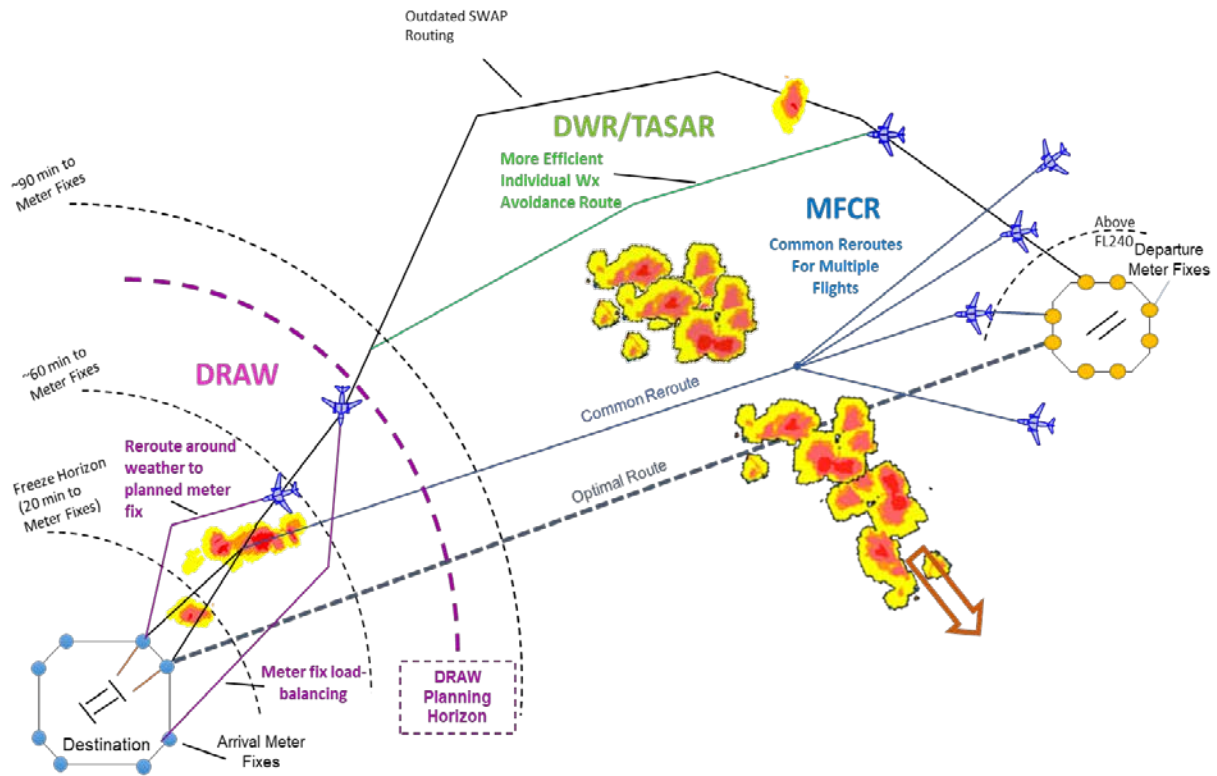


Figure 8: ATD-3 Capability Operating Environment

ATD-3 capabilities identify and suggest time-and/or-fuel-saving alternate routes accounting for convective weather and other airspace constraints in accordance with airspace user preferences. As a flight progresses toward predicted airspace constraints impacting its route, ATD-3 capabilities will use updated weather and constraint data to identify more-efficient avoidance routes.

For ANSP initiated reroutes, candidate reroutes are generated by MFCR for aircraft outside their destination TBFM/DRAW planning horizon. As part of the reroute vetting process, MFCR checks the candidate reroute ETA(s) for downstream flow and Airport Arrival Rate (AAR) constraints to ensure the reroute(s) will not contribute to a predicted demand/capacity imbalance that cannot be managed without causing additional delays.

Candidate reroutes generated for aircraft located within a TBFM/DRAW planning horizon are generated by DRAW. As part of the reroute vetting process, DRAW will check candidate reroutes against arrival flow constraints and ensure that the revised ETA will allow the flight to fit into the arrival stream and can be given a new STA.

If the revised ETA of a candidate reroute cannot be accommodated within TBFM metering constraints, DRAW will provide feedback on available time windows that can be accommodated. The airspace user's ATD-3 capability would incorporate the time window or STAs into its reroute identification logic and attempt to identify a reroute that would fit into that time window or STA slot. There may be times when arrival demand at a destination may be predicted to be high at the proposed ETA, and there is a risk the en route savings may be offset by arrival delays. These risks may be acceptable trade-offs to ensure that available arrival capacity is not wasted when demand profiles are uncertain. The trade-offs may become less acceptable as flights get closer to their destination and demand predictions become more accurate, or predicted demand far exceeds predicted capacity.

Once the reroute is determined to be in compliance with known ANSP constraints and airspace user constraints and preferences, it is presented to the TM/TMC for concurrence. Any refinements needed are made prior to forwarding the reroute(s) to the controller(s) for review and issuance.

For airspace users with an AOC, candidate reroutes are coordinated between the operations center and the flight crew before requesting approval from the service provider. This coordination may be via company voice or digital communications, and/or through DWR/TASAR integration. Airspace users will generally employ policies regarding reroutes that permit flight crews to request reroutes without AOC coordination when the route change remains within a defined set of parameters, or is a matter of flight safety. Such limits may also be set on a flight-by-flight basis using flight preferences. In either case, such policies or preferences are incorporated to avoid conflicting airspace user input to the ANSP.

Once the airspace user decides the candidate reroute meets their needs, they forward it to the ANSP for approval. If requested by the flight crew, the reroute is submitted to the controller via a digital communication capability, or via voice communications if needed. The controller may approve and issue the reroute clearance, or conduct any additional coordination they deem necessary prior to issuing the clearance. If requested by the AOC, the reroute is submitted to the TMC via ground communication. the TMC may review the reroute on the ABRR screen or use the MFCR or DRAW interface to amend it as needed, and forward it to the controller for issuance via ABRR. The same division of MFCR and DRAW domains applies to the reroutes received by the ANSP from airspace users; reroutes received from aircraft outside the TBFM/DRAW planning horizon will appear on the MFCR interface, and those received from aircraft inside the planning horizon will appear on the DRAW interface.

The division of reroute responsibility between MFCR and DRAW, as well as the required coordination within each airspace user's operation, ensures that there is only one reroute requested by the ANSP at any given time.

4.2.4 Contingency Situations

There are a number of ways that the individual or integrated ATD-3 capabilities could become inoperable or compromised. Any one of the capabilities could become inoperable due to significant failures such as power interruption, hardware component failure, corrupted software, etc. They could also be rendered unusable if the systems on which they rely fail or are otherwise unavailable. Because ATD-3 capabilities are not critical to safety, there are minimal safety risks to persons or property. Only failures that lead to hazardous misleading information pose any potential safety risk, such as incomplete or erroneous traffic, hazardous weather or airspace constraint information. For such instances, users should be alerted to ATD-3 capability or related system failures, including data connection interruptions, software errors, or computer hacking, and authentication failures of reroute requests. In cases when constraint and preference information is not available, automated modes may not provide constraint-free reroutes and should revert to human-in-the-loop mode.

Roles and responsibilities do not change. Controllers are still responsible for separating aircraft, and flight crews are still the final authority for the safe operation of an aircraft. Consequently, all reroute requests are reviewed by sector controllers and flight crews prior to acceptance and implementation of the reroute clearance. For example, any of the capabilities that check for potential weather and traffic conflicts do so only to filter candidate reroutes before presenting it to the decision maker for review and acceptance. This does not replace the controller's role in ensuring separation from other traffic, or the flight crew's role in ensuring safe avoidance of hazardous weather.

Conflicts with downstream constraints will be caught by TMCs or sector controllers utilizing other TFM and controller DSTs as well as their own professional judgement in a manner similar to today's operation. Any resulting over-demand scenario caused by uninformed reroutes will be managed as they are today using tactical TMIs, such as miles-in-trail, airborne holding, radar vectors, traditional reroutes, etc.

Integrated ATD-3 operations or failures have no impact on how emergency scenarios are handled by ATC. Reroute prioritization rules could include special rules for priority handling, such as for flights with low fuel, existing operational procedures, are considered adequate.

5 MATURE STATE CAPABILITY ENHANCEMENTS

Enhancements to current ATD-3 prototyped capabilities are needed to fully support the mature state vision. No change is needed in the fundamental weather avoidance or route efficiency logic to support the mature state concept. The mature-state enhancements involve the following:

1. Automated sharing of airspace user constraints and preferences, and a complete set of current and predicted NAS constraints.
2. Communication and coordination of reroutes among the capabilities and participants.
3. Ability to automatically negotiate candidate reroutes and reroute requests.
4. Miscellaneous enhancements to individual functions and infrastructure to support their integration into the NAS.

5.1 CONSTRAINT AND PREFERENCE SHARING

The sharing of constraints and preferences is necessary to in minimize human workload and maximizing system performance. In the mature state, ATD-3 capabilities should have access to a full set of ANSP constraints, as well as airspace user preferences and flight constraints, in order to effectively filter candidate reroutes prior to presenting them to the responsible human actor. Constraint and preference data must be as complete as possible and updated automatically in order to minimize the complexity and timeliness of negotiations. In addition to convective weather, SUAs, and FCAs, constraints should include all active Special Activity Areas (SAA), congested or saturated sectors, blocked arrival and departure routes, choke points, and any other constraints that would cause a reroute request to be denied or modified. Constraints imposed by letters of agreement (LOAs) and standard operating procedures (SOPs) of the Centers should also be included. Assuming some of these constraints will change based on airport/terminal area configurations that are in effect, a change in configurations should trigger a change in the associated constraints against which ATD-3 capabilities evaluate candidate reroutes. Constraints should include time frames for which they are active, and ATD-3 capabilities need to be able to determine when a pending constraint will conflict with a candidate reroute. The sources of these data may be varied, but should include the most current updates.

Some constraints and TMIs are what could be considered “hard constraints,” (i.e., those that aircraft should not be routed through them for safety reasons). Hazardous convective weather, active SUA, or FCAs are examples. However, many constraints or TMIs have some flexibility to them depending on the scenario, and could be considered “soft constraints.” For example, there are a number of TFM constraints that are relaxed by controllers and TMCs on a case-by-case basis, such as adherence to playbook routes, routing through congested sectors (yellow or red sectors, based on the monitor/alert parameters), unused portions of active SUA, etc. Given ATD-3 capabilities are intended to find more efficient routes in the presence of constraints, it will be important to provide better definitions for soft constraints. Without such definition, ATD-3 capabilities must either avoid all constraints, or each reroute will need to be reviewed and potentially modified by a TMC before being forwarded to a controller. This could create unacceptably high workload for TMCs, controllers, dispatchers, and flight crews.

In the TBFM planning horizon, STAs and time availability are assessed when DRAW identifies viable reroutes. The other ATD-3 capabilities should perform a similar check when vetting a candidate reroute. The granularity of the time window being used to determine the viability of a

candidate reroute would depend on the aircraft's distance from the TBFM/DRAW planning horizon and the location of the flight's projected candidate reroute end point. For example, if the flight's reroute point ends inside the TBFM/DRAW planning horizon, DWR/MFCR or TASAR may not propose candidate reroutes, due to the flight's assessment by DRAW, unless the arrival time is essentially unchanged. If the flight's reroute point ends outside the TBFM/DRAW planning horizon, DWR/MFCR or TASAR should propose candidate reroutes, because there is still a lot of uncertainty in STAs (not frozen), and time to sequence and space traffic.

Each capability should also have access to flight constraints and preferences that airspace users are willing to share for the purposes of route changes. This information would originate from sources such as the flight plan/object, SWIM, airline schedules, and potentially the DWR or TASAR applications themselves. Airspace user constraints and preferences would be shared only with the ANSP and within the airspace user's operation, not with other airspace users. When necessary, dispatchers and flight crew may modify constraints and preferences while the flight is airborne. Updates may come through other systems which ATD-3 capabilities access for constraint and preference information.

5.2 REROUTE COMMUNICATION AND COORDINATION

In addition to sharing constraints and preferences, mature state functionality will require that ATD-3 capabilities communicate reroute requests, negotiations, status, and concurrence. There may be a variety of communication conduits that can be used, depending on availability and suitability to the application. With the exception of a digital communication mechanism for communication of route clearances, this ConOps makes no assumptions about specific communication technologies or architecture to be used, but it is assumed that the ATD-3 capabilities can communicate for the purposes of negotiating reroutes, and updating the status of reroute requests. It may be possible for MFCR/DWR and DRAW to be combined into a centralized application that acts as client server, which users access to initiate, negotiate, and concur with reroute requests. This may also be possible through the use of SWIM by airspace users for data exchange. This would offer advantages in terms of application communications and integration among the ATD-3 capabilities, as well as with other data sharing and automation systems.

5.3 AUTOMATED NEGOTIATION

Complete and timely constraint and preference data would provide the foundation for automated negotiation.

The automated negotiation process would be carried out 'behind the scenes' and begin with an ATD-3 capability accessing pertinent constraints and flight preferences to generate a candidate reroute. That candidate reroute would be shared with the other pertinent ATD-3 capabilities to inform them that a reroute request is forthcoming and to obtain feedback on its acceptability. This permits candidate reroutes to be vetted against constraints or preferences known to one of the ATD-3 capabilities. Proposed modifications or alternative reroutes may be exchanged and evaluated by the ATD-3 capabilities involved. Once a reroute has been found acceptable to all the ATD-3 capabilities involved, it is presented to the initiator for concurrence and action. In the case of ANSP generated reroutes, it may be possible for TMs/TMCs to set their MFCR or DRAW systems to automatically initiate or concur with reroute requests that meet certain

parameters once constraint and preference definition and vetting is fully mature. For example, the MFCR user interface could be enhanced to allow a TMC to configure MFCR user settings to automatically vet and request reroutes for flights on stale playbook route segments with a newly prescribed route, without further TMC review. Those vetted reroute requests could go directly to the controller for issuance.

Currently, the ATD-3 capabilities may present more than one option to the user for consideration. A reroute request may also come in from the other user (ANSP or airspace user). Consequently, there could be several from which to choose. Although this may not be a problem if it is an isolated scenario, it may present workload challenges for TMCs dealing with a multitude of flights for which there are more efficient routes available. In this case, it would be helpful for the ATD-3 capabilities to select the candidate reroutes that best fit the situation before presenting it to the user for review. This would also be required if automatic requests were implemented. The following prioritization rules would provide the structure needed to accomplish this goal. These rules, combined with constraint compliance, are intended to provide system stability and prevent excessive workload.

5.3.1 Priority and Preemption Rules for Reroute Negotiations

In auto mode, a set of priority and preemption rules would be applied to select and concur with a single solution, as follows:

- Compliance with arrival metering constraints has the highest priority when negotiating reroutes.
- ANSP-initiated reroutes to cope with TFM/capacity constraints take priority over reroutes with greater time savings for efficiency, e.g., MFCR common route will take priority over individual reroute requests.
- Otherwise, reroutes with the greatest savings are given priority as long as they do not negatively impact other flights.
- The number of reroutes requested for a flight are not limited over time when for purposes of safety, e.g., convective cell avoidance.
- The number and rate of reroute requests for all flights within an airspace sector are limited over time to manage controller workload.
- Flights experiencing greatest TFM delay are given higher priority for time-saving reroutes than flights not experiencing delay (see note below).

5.4 CAPABILITY SPECIFIC ENHANCEMENTS

In addition to the capability enhancements mentioned above, there are additional enhancements specific to each of the ATD-3 capabilities that would enhance the capabilities of the mature state vision. A few examples of these capabilities are described in this section.

5.4.1 Vertical Optimization

DWR, MFCR, DRAW, and TASAR optimize routes laterally, but currently only TASAR and DWR are capable of suggesting altitude change. The other capabilities may benefit from some level of vertical optimization in terms of fuel savings or increased opportunities for constraint free reroutes. Like conflict avoidance, this function may require the use of current altitudes and some degree of trajectory intent, especially when flights are changing altitudes. This capability

may be less important to reroutes that use published arrival procedures that include altitude restrictions.

5.4.2 Meter Fix Offloading

Although not part of the ATD-3 program, a demand off-loading enhancement has been explored for DRAW. This capability will detect overloaded arrival meter fixes and off-load some of that demand to alternate arrival meter fixes. This enhancement will allow DRAW to better balance arrival demand, reduce upstream metering delays, and maintain throughput in the presence of convective weather or other arrival airspace constraints [9].

When the demand off-loading capability detects an arrival meter fix overload, a predefined set of arrival routes, filtered based on a flight's geographic location and airport configuration, determines reroute availability for each individual flight. All possible combinations of individual flight reroutes are then prioritized based on trajectory efficiency and overall delay reduction to select a single or multi-flight common reroute solution that provides an acceptable arrival fix demand with minimal flight time or distance impact to airspace users.

Potential arrival fix overloads can be detected as far away as 600 miles or up to two hours in advance of estimated arrival times, leaving ample opportunity for implementing strategic reroutes with reduced impact on flight time and distance. This capability also applies to flights that have not yet departed, but whose departure airports are within the planning horizon. Once the system identifies the optimal distribution of reroutes across active arrival fixes, it displays the suggested multi-flight reroute solution and associated metrics to the TMCs to help determine whether to implement the reroutes as suggested, modify and trial plan changes to the reroute, or not to implement the reroute at all.

6 INTEGRATED ATD-3 CAPABILITIES OPERATIONAL SCENARIOS

The following operational scenarios apply to mature state operations and include the sequence of actions that take place across ATD-3 capabilities for nominal reroute requests, negotiations and implementation.

6.1 SCENARIO 1 – TASAR/DWR INITIATED REROUTE

Some airline and corporate flight departments will take advantage of TASAR equipage in their fleets and/or DWR in their flight operations centers to improve the efficiency of their en route operations during active weather days by actively seeking more efficient weather avoidance routes. They will update flight constraints and preferences prior to each flight's departure based on the current and predicted delay and schedule changes. Flights critical to schedule integrity or cost savings may be assigned preferences to give them higher or lower priority for reroute savings over other company flights. Some or all of these preferences may be shared with the ANSP for the purposes of MFCR and DRAW initiated reroutes. Dispatchers and flight crews will coordinate reroute requests, ANSP negotiations, and concurrence using DWR and TASAR communicating via digital links. Traditional company voice radio communications may be used when digital communications are not available but may impose greater workload.

Common situations in which DWR and TASAR would be used include “short-cutting” stale playbook routes or taking advantage of gaps in lines of convective weather wide enough to permit a flight to safely take a shorter route, saving time and fuel. TASAR/DWR will continuously search for and identify more efficient routes accounting for the weather (Figure 9). DWR will present a list of candidate reroutes to the airline's ATC coordinator and/or dispatcher for review and coordination with flight crews. In both cases, candidate reroutes are checked against known ANSP and airspace user constraints and preferences. Constraints, in this case, include en route airspace constraints known in the NAS to the dispatcher, the constraints known to the flight crew, and flow restrictions for sites where TBFM metering operations are in effect.

These candidate reroutes are auto negotiated via cross-checking and coordinating between the dispatcher and the flight crew. The DWR and TASAR interfaces, combined with digital communication links, will be leveraged to streamline and potentially automate the coordination process. Once an acceptable, auto-negotiated candidate is determined, the initiator of the negotiation conveys the single candidate reroute to the ANSP depending on airspace user's equipage and policy/procedures. DWR presents the candidate reroute via terrestrial communication link (e.g., SWIM) and TASAR sends the candidate reroute via the cockpit-based communication link (e.g., DataComm). If the flight's reroute end point is outside the TBFM/DRAW planning horizon, the request would go to MFCR; if inside the planning horizon, to DRAW via DWR.

MFCR/DRAW confirms that the requested reroute complies with all known ANSP constraints, that the flight's new route and ETA are compatible with arrival flow constraints, and that MFCR/DRAW is not preparing to request a group reroute involving that flight. Assuming the requested reroute complies, MFCR/DRAW (depending on location with respect to the TBFM planning horizon) will present it to the TMC for approval. If the reroute is out of compliance,

MFCR/DRAW will highlight the offending constraint for TMC review, modification and/or disposition. The TMC may also choose to accept the reroute even if the new ETA falls within a congested time period knowing the flight can be fitted into the metering stream once it is closer to the meter fix.

If the TMC determines the initial reroute request to be unacceptable, they can offer a modification or deny the request all together. Any concurrence, modification, or denial is sent back to the airspace user for review and disposition. The AOC/FOC and flight crew may coordinate any reroute negotiation before responding. If the airspace user rejects a modification, DWR begins to search for a new time-saving route and the process begins again.

Once all parties concur, the reroute is forwarded to the controller handling the flight. The controller reviews the reroute to ensure no traffic conflicts exist in the near-term and issues a clearance relaying the reroute to the flight crew via a digital communication capability or voice to accept the clearance. The flight crew reviews the clearance, confirms it safely avoids hazardous weather, coordinates with the dispatcher if needed, and accepts the reroute clearance.

Scenario:
TASAR or DWR Initiated
Reroute - Nominal

—→ = Terrestrial communications
 - - -→ = Datacomm
 - . . .→ = Commercial Data Link

1. Airspace user AOC/FOC - Flight Crew coordination
2. Airspace user submits candidate route to MFCR/DRAW using TASAR or DWR via terrestrial network
3. MFCR/DRAW confirms candidate reroute complies with ANSP constraints and arrival flow constraints as appropriate, presents to TM/TMC
4. TM/TMC reviews and concurs, and forwards reroute request to Controller managing the flight.
5. Controller handling flight is notified of proposed reroute, confirms no traffic conflicts, and sends reroute "as requested" to flight crew via data or voice communications.
6. Flight crew reviews reroute on TASAR if equipped, to confirm reroute is still acceptable, and accepts via Datacomm, FMS is updated.
7. Flight's trajectory is updated in automation system and available to ATD-3 capabilities.

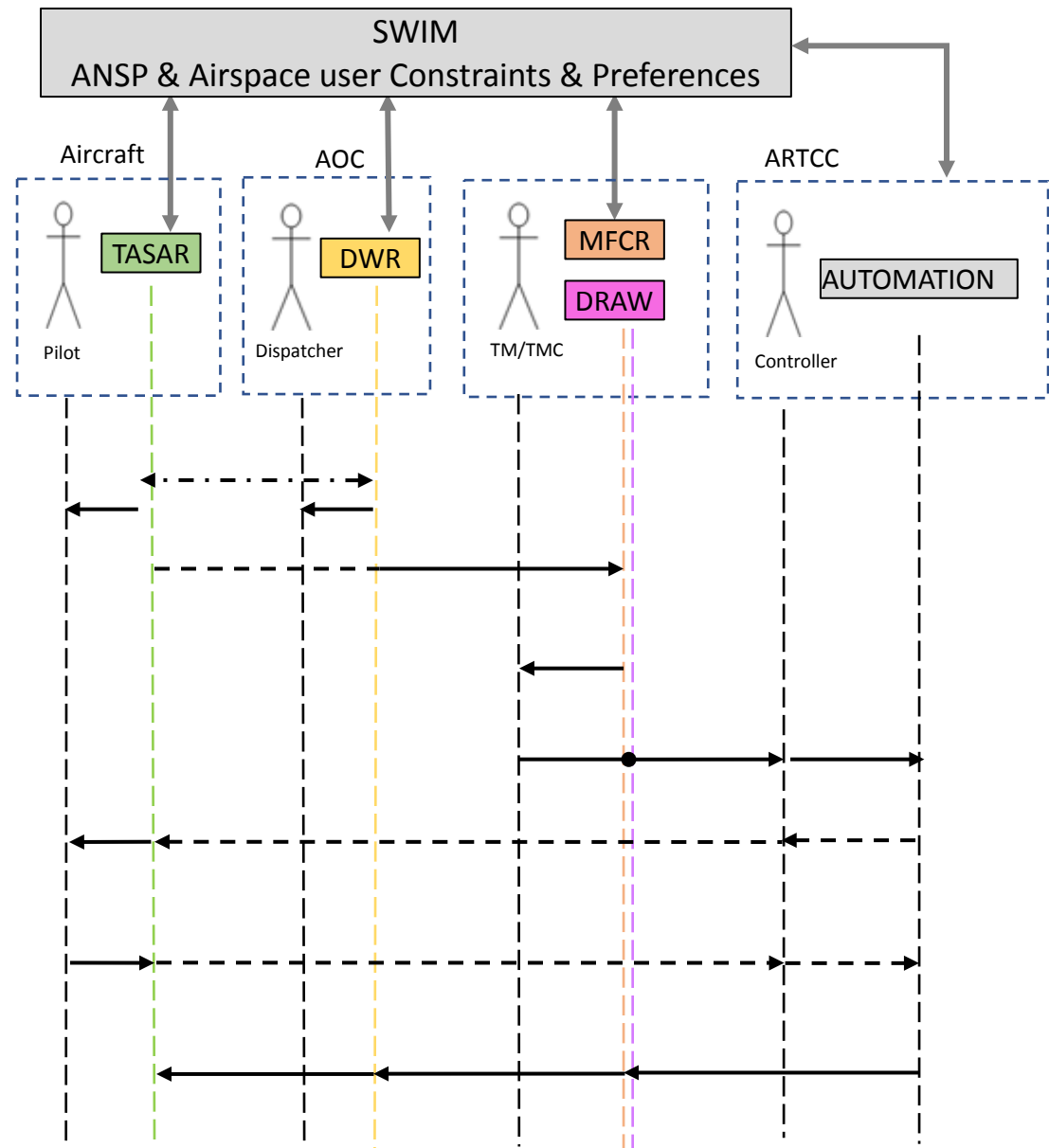


Figure 9: TASAR/DWR Initial Reroute Use Case

6.2 SCENARIO 2 – MFCR INITIATED REROUTE

When severe weather avoidance routes are implemented, many aircraft traveling to and from similar regions within the NAS are affected. While MFCR is capable of identifying individual reroutes for each aircraft, there may be times when reroutes may be very similar based on time savings or airspace constraints, such as a limited number of gaps in weather through which all the traffic in the area must be funneled or flights affected by the same stale route TMI. Grouping flights on a common reroute using MFCR provides the most efficient use of airspace capacity, the best compromise in time-savings across the group and reduces TM/TMC effort. By leveraging the FAA's ABRR digital communication system, TM/TMCs can initiate a common reroute for multiple flights with a single reroute request.

MFCR identifies flights that would benefit from a common reroute that is more efficient given available airspace and human resources.

MFCR first determines if a flight's destination is subject to metering constraints and ignores a candidate reroutes of flights ending inside the TBFM/DRAW planning horizon given DRAW will handle any reroutes for those flights (Figure 10). MFCR then checks candidate routes against all known ANSP and airspace user constraints and preferences, and identifies the options with the greatest overall time savings. MFCR also checks downstream arrival flow constraints to ensure rerouted flights will not create excessive arrival demand through sector congestion or fix loading and associated downstream delays. If MFCR determines that some flights included in the candidate group reroute will create excessive demand at their destinations, they can be removed from the group when developing the candidate reroute and presenting it to the TMC.

Once the TMC concurs with the candidate reroute, the reroute request also goes to the AOC via terrestrial communication links. Once received by the airspace users, the flight crews and dispatchers may review the reroute on their DWR and TASAR interfaces and accept or decline the reroute. If accepted by the airspace user, it is forwarded to the controller(s) for review and clearance issuance. The reroute approval status of each flight is updated throughout ATD-3 capabilities and SWIM infrastructure. Each flight's new trajectory is updated throughout the associated automation systems and is available throughout the ANSP and airspace user systems. If it is not accepted or is modified by the airspace user, the flight is removed from the group. The airspace user can request a modification, in which case MFCR will treat the request as an individual route request.

Scenario:

MFCR Initiated Reroute –
Nominal Case (could originate
 from any Center or ATCSCC)

—▶ = Terrestrial communications

- - -▶ = Datacomm

- . . .▶ = Commercial Data Link

1. MFCR identifies candidate group reroute for multiple flights located outside TBFM/DRAW planning horizon that complies with all ANSP and airspace user constraints, and presents to TM/TMC.

2. TMC reviews, concurs and forwards to Controller(s) and to AOC

3. Controller(s) handling flight(s) are notified of proposed reroutes, confirm no traffic conflicts, and send reroutes to flight crew(s) via Datacomm.

4. Flight Crew(s) and AOCs/FOCs coordinate as needed

5. Flight Crew(s) accept reroute(s) clearance via Datacomm

6. Flight's trajectory is updated in automation system and available to ATD-3 capabilities.

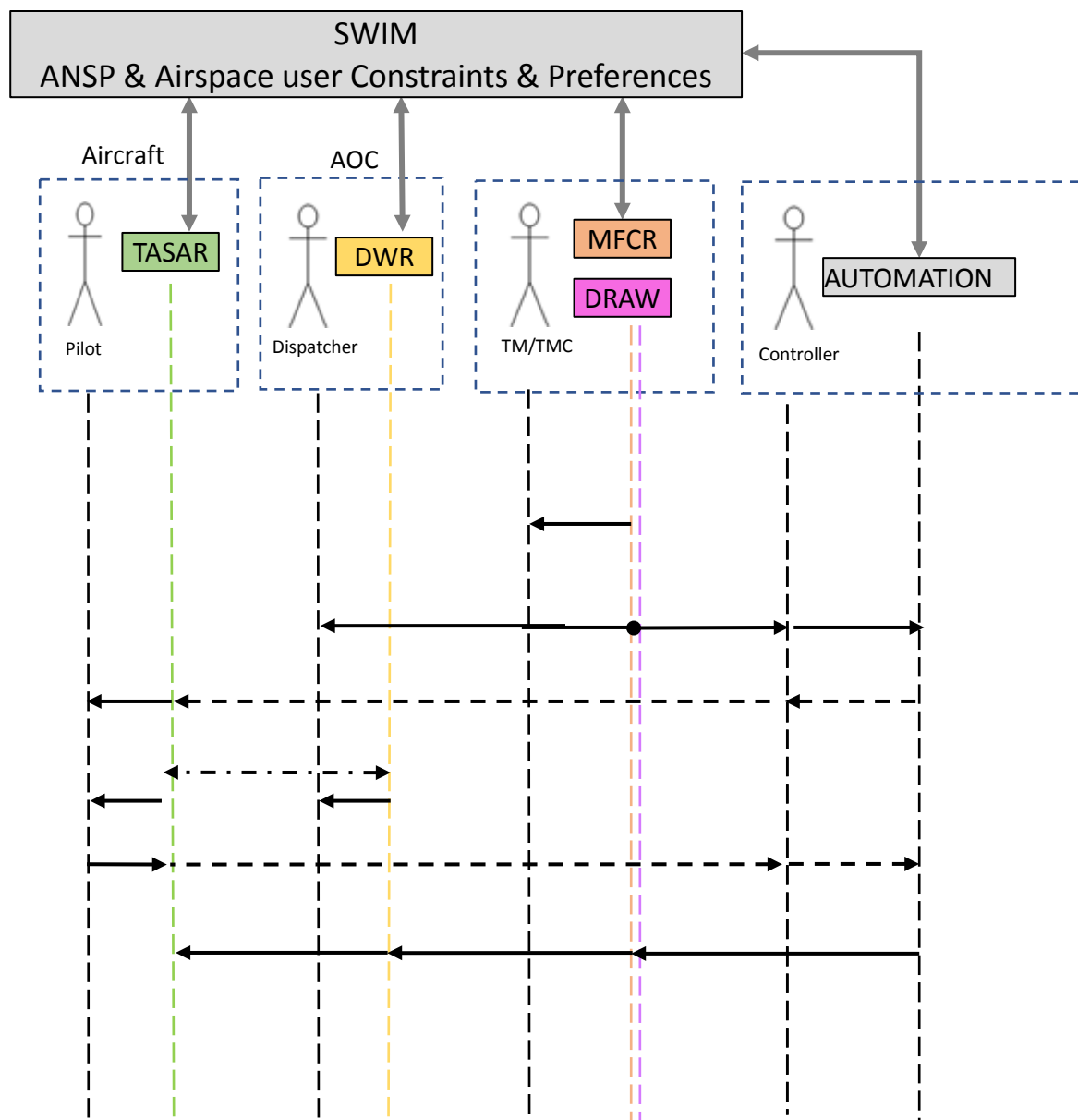


Figure 10: MFCR Initial Reroute Use Case

6.3 SCENARIO 3 – DRAW INITIATED REROUTE

When adverse weather or other constraints interfere with arrivals, controllers vector aircraft around convective cells, and apply airborne holding to meter demand. Consequently, TBFM arrival metering times are no longer accurate and arrival metering is suspended.

DRAW addresses these scenarios by continually searching for and identifying more efficient routes and meter fix assignments to alleviate imbalances. DRAW provides a trial planning capability to the Traffic Managers which allow them to assess the impact of modified routes on the STAs in the timeline. This capability is described further in reference 6. Given DRAW reroutes provide the trajectory definition and intent information needed for TBFM to accurately predict ETAs at meter fixes and assign STAs, TBFM metering operations can be sustained longer in the presence of convective weather.

DRAW continuously analyzes all arrival flights within its planning horizon, but outside the meter fix freeze horizon, to identify flights that could be routed around weather more efficiently than their current route assignments, or traditional weather avoidance mitigations (Figure 11). The demand off-loading function in mature-state DRAW will also divert excess demand from an overloaded arrival meter fix to other available arrival routes and meter fixes in the most efficient manner possible (e.g., minimizing overall delay cost) to reduce overall arrival delays for that terminal area. When DRAW identifies a flight or flights that could be routed more efficiently around constraints, it evaluates the candidate reroutes against downstream flow constraints and airspace user constraints and preferences. It then presents the candidate reroute(s) to the TMC for review and concurrence. The TMC selects and modifies the candidate reroute if necessary using the trial planning function and receives immediate feedback if the revision violates any constraints or preferences. Once the TMC is satisfied with the candidate reroute, it is forwarded to the controller handling the flight as a reroute request and to the dispatcher at AOC through the terrestrial communication link. The controller reviews the reroute, modifies it if necessary, and issues it to the flight crew via a digital communication mechanism or voice. The flight crew reviews the request, coordinates with their AOC if needed, and accepts or declines the reroute request. If equipped with TASAR, the flight crew may use it to review and modify the proposed reroute before responding. TASAR provides immediate feedback on constraint conflicts with each trial modification. Similarly, if sent to the dispatcher, DWR provides feedback on the acceptability of the suggested reroute and provides feedback as needed. If the flight crew requests a modification to the route, the controller can approve it, forward it to the TMC for review/concurrence, or deny the request. DRAW is automatically updated on the flight's new trajectory once the controller updates the automation system with the revised route.

Scenario:

**DRAW Initiated Reroute –
Nominal Case**

—→ = Terrestrial communications

- - -→ = Datacomm

- . . .→ = Commercial Data Link

1. DRAW identifies candidate reroute for multiple flights, that complies with all ANSP and airspace user constraints, presents to TMC.

2. TMC reviews, concurs, and forwards to Controller

3. Controller(s) handling flight(s) are notified of proposed reroutes, confirm no traffic conflicts, and send reroutes to flight crew(s) via Datacomm.

4. Flight Crew(s) and AOCs/FOCs coordinate as needed

5. Flight Crew(s) and accept reroute(s) clearance via Datacomm

6. Flight's trajectory is updated in automation system and available to ATD-3 capabilities.

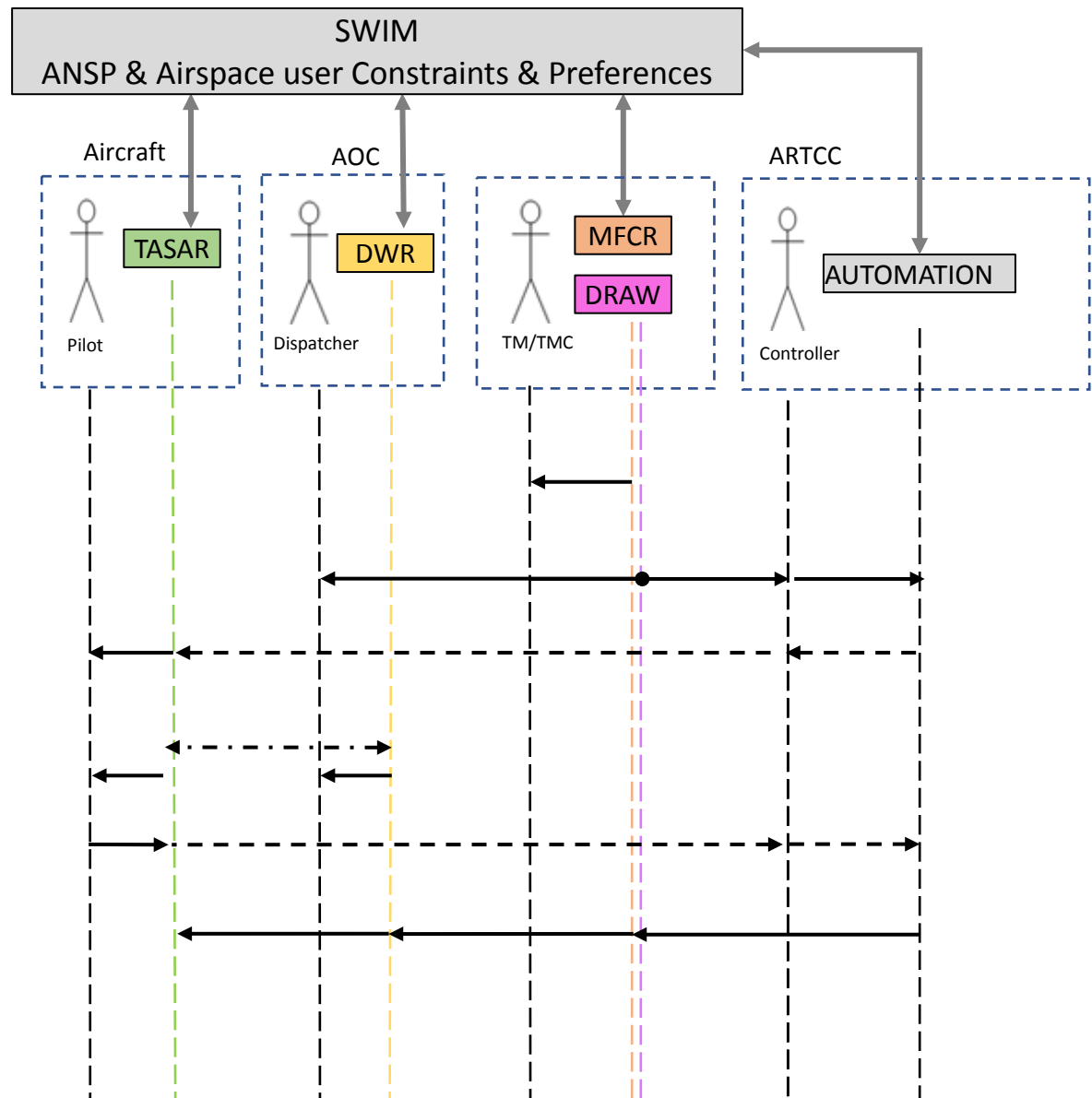


Figure 11: DRAW Initiated Reroute Use Case

7 SUMMARY OF IMPACTS

This section presents a summary of impacts to the users involved in the utilization of the ATD-3 technologies. These users are the TMCs at TMUs or TMs at the ATCSCC, the air traffic controller in en route or terminal airspace, the ATC Coordinator or dispatcher at an AOC/FOC, and the flight crew. Table 2 presents the impacts of using ATD-3 technologies as opposed to current operational practices. The ANSP users are impacted mainly through the use of MFCR and DRAW, while the AOC/FOC users are impacted mainly through the use of DWR and TASAR.

Table 2: Description of Impacts of Using ATD-3 Capabilities

User	Current Operational Use	Enhanced Use with ATD-3 ConOps
Traffic Management Coordinators (TMC)	<p>Use weather and TFMS data to manually identify and coordinate individual reroutes and overall traffic flows.</p> <p>Use TBFM to establish the sequence and schedule for aircraft arriving at high-density airports but fall back to manual sequencing and spacing during convective weather or similar airspace constraints.</p>	<p>Use MFCR and DRAW to: Identify, modify and select time-saving reroutes that comply with automated downstream metering constraints checks</p> <p>Reduce need for coordination of reroutes with downstream ARTCCs</p> <p>Off-load excess arrival demand to alternate arrival meter fixes.</p> <p>Negotiate reroutes with airspace users.</p>
En route Controller (ARTCC)	<p>Use radar vectors to route aircraft around convective cells and coordinate with other sectors and facilities to reroute aircraft around areas of adverse weather as time permits.</p> <p>Comply with facility procedures for delivering aircraft to meet TBFM sequence and STAs. Apply tactical mitigations to meter traffic and route traffic around adverse weather when weather halts TBFM metering and/or divert demand to open arrival routes, i.e. MIT, holding, radar vectors.</p>	<p>Review pre-coordinated, time/fuel-saving reroutes around weather and other airspace constraints from TMC/MFCR/DRAW/TASAR.</p> <p>Apply any tactical reroute modifications for traffic avoidance, and issue reroute clearance to flight crews via DataComm if available, otherwise by voice comm.</p> <p>Continue metering operations during convective weather or meter fix overload enabled by DRAW reroutes.</p>
AOC/FOC with DWR	N/A	<p>Use DWR to: Identify time-saving reroutes for company flights.</p> <p>Coordinate with flight crew.</p> <p>Negotiate with TMC/MFCR/DRAW.</p>

User	Current Operational Use	Enhanced Use with ATD-3 ConOps
		Respond to service provider reroute requests.
AOC/FOC without DWR	Find and coordinate reroutes with ATCSCC and ARTCC TFM when needed.	Respond to flight crews equipped with TASAR to coordinate candidate reroutes
Flight crew of non-TASAR equipped aircraft	<p>Use on-board weather radar and out-the-window view to avoid hazardous weather.</p> <p>Rely on TMCs, controllers and AOC/FOC to find and coordinate reroutes that comply with airspace constraints and flow restrictions.</p>	Respond to AOC/FOC equipped with DWR to coordinate candidate reroutes.
Flight crew of TASAR equipped aircraft	N/A	Use TASAR to identify time/fuel-saving reroutes, coordinate with dispatcher, negotiate with DWR, make digital requests to service provider, and respond to service provider reroute clearances.

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APPENDICES

9 APPENDIX A: GLOSSARY AND DEFINITIONS

Table 3: Glossary and Definition of Terms

Acronym	Term	Definition
4DT	Four-dimensional trajectory	The centerline of a path formed by segments that link consecutive trajectory change points; each point defined by a longitude, latitude, altitude, however not every point will have a time. NOTE: some waypoints may have time, altitude, and/or speed constraints, and can be equality or inequality constraints.
AAR	Airport Arrival Rate	Rate at which an airport is able to accept aircraft arrivals in an hour.
AAtS	Aircraft Access to SWIM	System through which the FAA provides SWIM data access to aircraft.
ABRR	AirBorne ReRoute	A means, via SWIM, for traffic managers to share and coordinate proposed reroutes with sector controllers.
ADS-B	Automatic Dependent Surveillance - Broadcast	ADS-B is a technology where aircraft avionics (or ground equipment) autonomously broadcasts the aircraft's (or ground vehicle's) position, altitude, velocity, and other parameters. "ADS-B Out" refers to the broadcast of ADS-B transmissions from an aircraft or vehicle, and "ADS-B In" refers to reception of ADS-B transmissions from other aircraft or vehicles.
ACARS	Aircraft Communications Addressing and Reporting System	A digital datalink system for transmission of short messages between aircraft and ground stations via air band radio or satellite.
AFP	Airspace Flow Program	A traffic management initiative that identifies constraints in the en route domain and develops a real-time list of flights that are filed into the constrained area, distributing departure clearance times to meter the demand through the area.
ANSP	Air Navigation Service Provider	Government or private organizations that manage flight traffic on behalf of a company, region, or country.
AOC	Airline Operations Center	Responsible for decision-making and operational control of an airline's daily schedules and facilitating disruption recovery. Similar to Flight Operations Center (FOC). Typically referred to in this document together (AOC/FOC).

Acronym	Term	Definition
AOSP	Airspace Operations and Safety Program	NASA Program under which ATD-3 is supported.
ARTCC	Air Route Traffic Control Center	A facility providing air traffic control service to aircraft operating on IFR flight plans within controlled airspace, principally during the en route phase of flight.
ATC	Air Traffic Control	Used in this ConOps to mean traffic management by front line/sector controllers responsible for directing and separating traffic, and enforcing traffic management initiatives.
ATCAA	Air Traffic Control Assigned Airspace	A form of dynamic special activity airspace (SAA) in the high-altitude structure supporting military and other special operations.
ATD-1	Airspace Technology Demonstration-1	The first of a series of NASA NextGen Airspace Operations and Safety Program technology demonstrations. This demonstration integrates three research efforts to achieve high throughput fuel-efficient arrival operations using precision time-based schedules, aircraft speed control, and controller display technologies.
ATD-2	Airspace Technology Demonstration-2	The second of a series of NASA NextGen Airspace Operations and Safety Program technology demonstrations. This demonstration integrates research efforts for gate pushback and taxi scheduling with departure scheduling to achieve a smooth transition to en route traffic flow using precision time-based schedules and controller, traffic management and airline ramp control display technologies.
ATD-3	Airspace Technology Demonstration-3	The third of a series of NASA NextGen Airspace Operations and Safety Program technology demonstrations. This demonstration integrates research efforts for airspace user and service provider technologies to search for and recommend efficient, weather avoiding en route trajectories coordinated with terminal arrival metering using precision time-based schedules, federated systems architecture communications protocol, flight deck, airline operations/dispatcher, controller and traffic management display technologies.
ATSCC	Air Traffic Control Systems Command Center	National service provider facility that plans and regulates the flow of air traffic to minimize delays and congestion while maximizing the overall operation of the National Airspace System (NAS). When significant events impact an airport or portion of airspace, the Traffic Management Specialists adjust traffic demands to meet system throughput.

Acronym	Term	Definition
ATCSCC	Air Traffic Control Systems Command Center	FAA facility that manages air traffic for the entire NAS, is responsible for issuance of Traffic Management Initiatives, and coordination across FAA facilities.
CCFP	Collaborative Convective Forecast Planning	A tool that predicts where and when severe weather is most likely to develop. The CCFP is a forecast of intense convective activity predicted for two-, four- and six-hour periods for defined geographic areas. It describes maximum cloud tops, growth and decay tendencies, predicted movement (direction and speed), and level of confidence in the forecast.
CDM	Collaborative Decision Making	An operating paradigm where air traffic flow management decisions are based on a shared, common view of the NAS and an awareness of the consequences these decisions may have on the system and its stakeholders.
CDR	Coded Departure Routes	Predetermined routes described by a code for ease of use and flexibility to select an alternate departure for specific airport when airspace constraints exist.
CIWS	Corridor Integration Weather System	Three dimensional (3D) 0-2 hour predicted weather depiction of precipitation (vertically integrated liquid) and Echo Tops [MIT Lincoln Labs].
ConOps	Concept of Operations	Document describing a proposed operation that utilizes new technologies or procedures.
CTOP	Collaborative Trajectory Options Program	A traffic management initiative (TMI) that automatically assigns delay and/or reroutes around one of more flow control area (FCA) airspace constraints in order to balance demand with available capacity.
CWAM	Convective Weather Avoidance Model	Depiction of probabilistic weather avoidance fields that pilots are likely to avoid due to the presence of convective weather. The model uses CWIS and national lightning detection network data to predict aircraft deviations and penetrations [MIT Lincoln Labs, NASA Ames Research Center].
DataComm	Controller-Pilot Data Communications	Data communications services between pilots and air traffic controller via digital link between ground automation and flight deck avionics for safety-of-flight air traffic control clearances, instructions, traffic flow management, flight crew requests and reports.
DRAW	Dynamic Routes for Arrivals in Weather	Decision support for adjusting traffic flows into terminal areas based on overloading of meter fixes and/or dynamic weather events. Functionality integrated into Time Based Flow Management (TBFM).

Acronym	Term	Definition
DST	Decision Support Tool	Technologies providing support to traffic managers and airspace users for traffic management decision-making.
DWR	Dynamic Weather Routes	Decision support for airline/flight operations centers (AOC/FOC) to identify and/or approve flight deck proposed reroutes for weather avoidance and efficiency.
EFB	Electronic Flight Bag	An electronic information management device that helps flight crews perform tasks more easily/efficiently with less paper. An EFB may have computational functions that aid the flight crew in operating the aircraft.
ERAM	En route Automation Modernization	Fully implemented in 2015, it enables air traffic controllers to utilize NextGen capabilities in en route Centers to manage and control air traffic.
ETA	Estimated Time of Arrival	The current estimate of the aircraft's time-of-arrival at a point along its flight path based on forecasted winds, aircraft performance and defined arrival procedures, but not adjusted to compensate for traffic separation or metering delays. The ETA is re-calculated on events and radar updates.
FCA	Flow Control Area	An area of airspace that is reaching saturation and is monitored by traffic managers for possible ways of metering traffic through it to ensure that it does not exceed what air traffic control can handle safely.
FIM	Flight deck Interval Management	Flight crew makes use of specialized avionics that provides speed commands for interval management.
FMS	Flight Management System	An FMS is a computerized avionics component found on most commercial and business aircraft to assist pilots in navigation, flight planning, and aircraft control functions. It is composed of: FMC (Flight Management Computer), AFS (Auto Flight System), Navigation System including IRS (Inertial Reference System) and GPS, and EFIS (Electronic Flight Instrument System).
FOC	Flight Operations Center	Responsible for decision-making and operational control of an airline's daily schedules and facilitating disruption recovery. Similar to Airline Operations Center (AOC). Typically referred to in this document together (AOC/FOC).
---	Freeze Horizon	After an aircraft crosses the Freeze Horizon for an En route Flow Management Point (ERFMP) or Arrival Flow Management Point (AFMP), the Scheduled Time-of-Arrival (STA) for that aircraft to that waypoint is "frozen" (no longer updated).

Acronym	Term	Definition
FSM	Flight Schedule Monitor	The primary tool for the traffic manager at the ATCSCC to monitor, model and implement ground delay program (GDP) operations.
GDP	Ground Delay Program	A traffic management procedure where aircraft are delayed at their departure airport in order to reconcile demand/capacity imbalances at their destination airport.
IADS	Integrated Arrival Departure Surface	A concept encompassed by ATD-2 in which scheduling and decision support for arrivals, departures and airport surface are harmonized to advise efficient operations in all three domains.
ICAO	International Civil Aviation Organization	United Nations agency that codifies international air navigation standards and practices.
IRL	Integration Readiness Level	Method of estimating readiness of critical technology elements for implementation in their intended operational environment.
LoA	Letter of Agreement	Documents that clarify the methods and procedures to be used at adjacent air traffic control facilities.
MAP	Monitor Alert Parameter	Nominal number of aircraft that can be handled by controllers in a particular sector, at or above which a sector is considered congested.
MFCR	Multi Flight Common Routes	Decision support for traffic flow management to identify opportunities for efficient routing of individual and multiple aircraft around weather or to more dynamically respond to Traffic. Functionality integrated into Traffic Flow Management System (TFMS).
MIT	Miles in Trail	An air traffic control operational procedure to separate aircraft that in trail by a specified number of miles (typically 10 NM, 20 NM, etc....).
MSP	Maneuver Start Point	A point along the current route and ahead of the aircraft's current position by at least a user-set time period (e.g., 20 minutes) at which an ATD-3 advised reroute begins.
NAS	National Airspace System	Airspace, navigation facilities, and airports of the United States along with their associated information, services, rules, regulations, policies, procedures, personnel, and equipment.
NCR	NAS Common Reference	An enterprise level NAS SWIM service available to both NAS and non-NAS systems. Provides consistent spatially and temporally correlated NAS information relevant to any route of flight or geometry. Integrates cross-domain dynamic NAS status and constraint data.

Acronym	Term	Definition
NGIP	NextGen Implementation Plan	FAA document describing the phased implementation of NextGen capabilities.
NOTAMs	Notices to Airmen	A notice filed with an aviation authority to alert aircraft pilots of potential hazards along a flight route or at a location that could affect the safety of flight.
OI	Operational Improvement	Integrated effort of NextGen in which initiatives implemented through a series of capabilities or improvements that provide individual benefits.
ORC	Optimized Route Capability	Decision support within DRAW functionality that balances arrival meter fix loading during heavy arrival periods that will overload one or more of the arrival meter fixes.
PBN	Performance Based Navigation	Area navigation based on performance requirements for aircraft on a route, approach procedure, or designated airspace. Navigation performance requirements are expressed in terms of accuracy, integrity, continuity, availability, and functionality needed for the proposed operation.
R&D	Research and Development	Work directed toward the innovation, introduction, and improvement of products and processes
RCF	Return Capture Fix	A point that returns a flight from a reroute located downstream along the original flight plan route. The RCF does not extend beyond the arrival meter fix. To avoid interfering arrival metering and approach operations at the destination airport, the RCF is subject to additional limits on distance or time from arrival meter fixes, based on Center or TRACON constraints.
RMT	Route Management Tool	National routes database updated on a 56-day chart cycle that facilitates the timely dissemination and implementation of reroutes.
RNAV	Area Navigation	Area navigation based on performance requirements for aircraft on a route, approach procedure, or designated airspace. Navigation performance requirements are expressed in terms of accuracy, integrity, continuity, availability, and functionality needed for the proposed operation.
RNP	Required Navigation Performance	The navigation performance necessary for operation within defined airspace. (May be used but not an ATD-1 requirement.)
RTA	Required Time of Arrival	A specified time that a flight is scheduled/expected to arrive at a designated point in space (e.g. meter fix).

Acronym	Term	Definition
---	Separation	<p>The spacing of aircraft to achieve their safe and orderly movement in flight and while landing and taking off. (FAA Pilot/Controller Glossary)</p> <ul style="list-style-type: none"> 1) Applicable separation minima remain unchanged by any ATD-3 operation. 2) During ATD-3 operations, the controller remains responsible for providing separation between aircraft. 3) Flight crew conducting FIM operations are responsible for achieving the assigned spacing from a designated (Target) aircraft as stipulated by the controller.
SOP	Standard Operating Procedures	Procedural agreements within FAA facilities for handling of aircraft.
STA	Scheduled Time of Arrival	Calculated by the ground scheduling software to meet all of the scheduling and sequence constraints, set at 'Freeze Horizon', and normally not changed. Changing a frozen STA is a 'reschedule', and is triggered manually by the Traffic Manager in response to a significant event (weather, runway change, etc.).
SUA	Special Use Airspace	Various airspace constraints imposed by the FAA (e.g., Military Operation Areas, Restricted Areas) for aircraft to avoid when active.
SWAP	Severe Weather Avoidance Plan	During significant convective activity, FAA traffic managers use Severe Weather Avoidance Plans (SWAP), or Playbook routes, to safely divert traffic around weather-impacted regions.
SWIM	System Wide Information Management	Provides the digital data-sharing backbone of NextGen. The information-sharing platform provides increased common situational awareness throughout the National Airspace System (NAS).
TASAR	Traffic Aware Strategic Aircrew Requests	Decision support for flight deck to better achieve an airspace user's business trajectory and enable efficient routing in the presence of traffic, weather, and airspace restrictions.
TBFM	Time Based Flow Management	An operational FAA system/concept using time to more efficiently utilize available airport capacity without decreasing safety or increasing workload.
TBO	Trajectory Based Operations	An operational concept that utilizes shared, accurate trajectory predictions to schedule and harmonize traffic flow across an airspace domain.

Acronym	Term	Definition
TCF	TFM Convective Forecast	TCF provided improved prediction of where and when severe weather is most likely to develop. Formerly known as the CCFP, the TCF is a forecast of intense convective activity predicted for two-, four- and six-hour periods for defined geographic areas.
TFDM	Terminal Flight Data Manager	An operational FAA system/concept using real-time information to more efficiently manage airport surface movements/operations without decreasing safety or increasing workload.
TFMS	Traffic Flow Management System	An operational FAA system/concept that serves as the primary system for planning and implementing traffic management initiatives (TMIs).
TMC	Traffic Management Coordinator	An air traffic management position that coordinates the traffic flow in a given facility to balance demand with throughput utilizing various automation tools including TBFM.
TMI	Traffic Management Initiative	Techniques or tools used to manage excess demand in en route airspace or lowered acceptance rates at airports.
TMU	Traffic Management Unit	Non-control, coordination positions in the ARTCC and the TRACON, connected to the central flow control function and responsible for dissemination of flow control information at the local level.
TRACON	Terminal Radar Approach Control	Radar control facility associated with an airport or metroplex.
TRL	Technology Readiness Level	Method of estimating technology maturity of critical technology elements to help management in making decisions concerning the development and transitioning of technology.
TSAS	Terminal Sequencing and Spacing	FAA technology that helps terminal airspace controller predictably and efficiently guide aircraft from the arrival meter fix to the runway.
URET	User Request Evaluation Tool	Decision support tool for en route controllers that provides automated conflict probe for up to 20 minutes and trial planning for potential conflicts

10 APPENDIX B: ATD-3 RESEARCH NEEDS

10.1 ATD-3 ACTIVITIES

Under ATD-3, NASA is developing and testing prototypes of the ATD-3 capabilities for today's operations with current-day data sharing and automation infrastructure limitations in mind. Each capability supports different users and addresses the challenges they face in today's system in different ways.

The DWR prototype was tested and evaluated in an operational environment by American Airlines and was transferred to the FAA in September 2016. Since the technology transfer, the prototype has been available for commercial licensing. The MFCR prototype was evaluated during a Subject Matter Expert (SME) Evaluation and Human-in-the-loop simulation before being transferred to the FAA in December 2017. The DRAW prototype is being tested in human-in-the-loop simulations as well as fast time simulations. The prototype DRAW capabilities and supporting documentation will be transferred to the FAA in 2019. The TASAR prototype, has been tested in human-in-the-loop simulations, flight tests, and operational evaluations. The TASAR prototype is available for commercial licensing from NASA.

In addition to testing and demonstrating the prototypes of the ATD-3 capabilities individually, a concept for the integration of the DWR and TASAR prototypes for reroute requests is being developed and tested through operational evaluations with the airline partner. This air/ground integration activity will serve as a foundational building block for future integration in working towards the mature state concept described in this document.

10.2 FUTURE RESEARCH NEEDS

Due to time and resources, ATD-3 will not be able to develop, test, and evaluate all capabilities required to support the fully integrated system as envisioned for the mature state concept. Further research and development will be required to refine and validate the fully integrated concept. Section 5 outlines mature state capability enhancements. The following describes additional research needed to accomplish assumed capabilities in Section 5.

10.2.1 Automated Modes

ATD-3 capabilities automatically identify reroute opportunities in an automated mode, providing the potential to greatly reduce human workload, accelerate reroute approvals, and maximize operational benefits. Additional research will be required in order for successful development and integration of automation logic, user interfaces, information sharing, and digital communications between the ATD-3 capabilities.

There are three key tasks that could be automated: reroute requests, reroute negotiations, and reroute concurrence. Each of these tasks pose similar but slightly different research questions. Additional research will be needed to understand how the ATD-3 user interfaces will need to allow users to control when and how to apply automated modes, monitor and intervene when necessary, and adjust parameters to achieve desired results. The ATD-3 capabilities are envisioned to be embedded within future FAA technologies. It is assumed that the additional coordination required by ATD-3 capabilities will be handled by these FAA investments.

For automated request, research areas include the parameters for desired control, triggers for requests, controls on frequency of requests, and methods for providing adequate user oversight. For automated negotiation, research areas include the number of negotiation iterations allowed for system stability and request time-out, avoiding infinite loops, ability of systems to combine or change reroute requests and still comply with constraints and preferences, and criteria for requiring user input or intervention. For automated concurrence, it is assumed that reroutes will always be reviewed by controllers and flight crews prior to being implemented; however, automated concurrence by the ATD-3 capabilities prior to submission to the controller or flight crew would require research. This research includes defining automated approval criteria, user acceptance, and adequate oversight to avoid undesirable outcomes.

10.2.2 Constraints & Preferences

The integrated concept relies heavily on NAS constraint and airspace user preference data to identify desirable reroutes, minimize user workload and avoid causing downstream issues. Consequently, research is needed to identify the scope, definition and timeliness of constraints and preferences to enable automated modes and minimize workload in manual modes.

A fundamental question in this research scope is determining whether or not all the pertinent constraints and preferences needed to support automated modes can be collected and shared. This includes identifying when the necessary constraints and preferences are not available to enable one or more of the automated modes, and the ability to adequately inform ATD-3 capabilities and users.

Constraint definition is another significant area of research to enable the integrated concept. Constraints and preferences will need to include enough information to identify viable reroutes that are acceptable to the service provider and airspace users without further coordination the vast majority of the time. Because reroutes can potentially extend hours into the flight, planned and pending constraint changes need to be shared and factored into reroute logic. Ongoing research related to information sharing should be leveraged to support and enhance the integrated concept.

10.2.3 Digital Communication Link Requirements

In the integrated concept, data sharing, reroute negotiations, and ATC clearances, between both the users and the ATD-3 capabilities, rely on digital communications. DataComm requirements to communicate clearances between controllers and flight crews are already being developed. Additional requirements will need to be defined and incorporated as needed to support the integrated concept. In addition to DataComm, digital communication conduits will need to be deployed between the ATD-3 capabilities to enable data sharing and communication between these capabilities. Potential safety assurance, security, and performance requirements must be defined for each element of shared data to determine communication requirements. The acceptability of various conduits can then be determined and pursued.

10.2.4 Balance of Workload and Automation

As with any automation, human oversight, control, and workload must be balanced with automation functions. Particular concern in ATD-3 operations should be given to user workload.

If too many reroutes are implemented for flights being managed by a sector, the sector

controller's workload could become excessive. Because controllers are not directly involved in reroute generation and negotiation, adequate feedback loops are needed to manage controller workload. Likewise, frequent reroute requests on flight decks could create excessive workload and distractions for flight crews particularly during the arrival phase of flight. User-defined savings threshold settings in each ATD-3 capability provide some control in this respect, but additional limitations may be needed to ensure the frequency of reroute requests remains manageable.

11 APPENDIX C: TECHNOLOGY/AUTOMATION DEPENDENCIES AND INTEGRATION

The ATD-3 Integrated Concept integrates the functions of several NASA-developed Air Traffic Management (ATM) capabilities with FAA automation to improve reroute coordination. The sections below outline current FAA systems that could support the integrated system.

11.1 SYSTEM WIDE INFORMATION MANAGEMENT (SWIM)

SWIM provides access to the necessary airspace information and constraints required by the ATD-3 capabilities for optimization of reroutes. Data available via SWIM includes aircraft track data, current and forecast sector congestion, TMI route information, Special Use Airspace (SUA) and Temporary Flight Restrictions (TFR) [10]. SWIM is also being developed to provide access to different weather sources and other airspace information that would enhance the knowledge and functionality of the ATD-3 capabilities.

11.2 TRAFFIC FLOW MANAGEMENT SYSTEM (TFMS)

MFCR interface with TFMS to enable complete and timely data exchange with respect to TFM constraints affecting both systems. TFMS provides timely traffic management data such as sector congestion, TMIs, or non-weather constraints. Within TFMS, Airborne Reroutes (ABRR) functionality enhances communication capabilities between the Traffic Manager and the sector controller in communicating reroute opportunities to the sector controller. [11]

11.3 TIME-BASED FLOW MANAGEMENT (TBFM)

DRAW builds on TBFM to identify metering delays and arrival fix imbalances, and utilizes the TBFM plan and timeline-view interfaces to display and manipulate proposed trajectory changes, as well as show trial impacts of those proposed changes. Integrating DRAW into TBFM ensures scheduling impact of proposed reroutes can be accurately assessed by the TMC before they are implemented. This is a result of DRAW's utilization of TBFM's trajectory modeling at the core of its arrival-specific rerouting algorithm and integrated route-schedule trial planner. Reroutes for metered flights originating from TBFM-based tools can be evaluated for scheduling constraints with DRAW's integrated route and schedule trial planner. Additional information about TBFM and its capabilities is available from reference 11.

11.4 DIGITAL DATA COMMUNICATION

DataComm is expected to significantly reduce controller and flight crew workload, reduce radio frequency congestion, and greatly improve air/ground system integration and acceptability. Integration of DataComm will allow controllers and flight crews more easily exchange data, review and negotiate reroutes, load proposed reroutes into ground and flight deck automation systems, and improve situational awareness of both parties.

11.5 ADS-B IN

ADS-B is a technology where aircraft avionics (or ground equipment) autonomously broadcasts the aircraft's (or ground vehicle's) position, altitude, velocity, and other parameters. "ADS-B In" refers to reception of ADS-B transmissions from other aircraft or vehicles. TASAR uses ADS-B IN to determine approximate aircraft position and identify potential conflicts to refine proposed reroutes.

12 APPENDIX D: INTEGRATION WITH ATD-1 AND ATD-2 FUNCTIONS

The goal of the ATD Project is to accelerate the maturation of concepts and technologies to higher levels of maturity for transition to stakeholders. The Project is primarily responsible for facilitating the Research and Development (R&D) maturation of individual concepts to higher Technology Readiness Levels (TRLs), and integrated concepts to higher Integration Readiness Levels (IRLs), through evaluation in relevant environments, enabling the transition of NASA technologies to stakeholders that are on a path to implementation in the system. The project focuses on delivering tangible benefits, by 2020, to NAS stakeholders and users. ATD collaborates and partners with the FAA and industry to further the development of NextGen technologies towards implementation.

ATD-1: Advanced Arrival Management: Completed in FY17, ATD-1 directly addressed terminal area congestion. ATD-1 evaluated the benefits of advanced arrival management technologies across a range of aircraft equipage levels during moderate to high levels of traffic demand. The integrated ATD-1 flight-deck and ground-based technologies allow pilots to achieve precise aircraft intervals and controllers to manage variability between flights and to respond to disturbances to the schedule. This integrated set of capabilities will enable increased fuel efficiency, while maintaining runway throughput to high-density airports. The ground-based tools comprise the Terminal Sequencing and Spacing (TSAS) software and operational concept, and were transferred to the FAA in 2015. The flight-deck tool for aircrew use for spacing (Flight-deck Interval Management or FIM) was transferred to the FAA in 2017 for further development at the William J. Hughes Technical Center, and to industry [12].

ATD-2: Integrated Arrival/Departure/Surface (IADS): The goal of ATD-2 is to improve predictability and operational efficiency in complex terminal environments, while maintaining or improving throughput. Working with the FAA and industry, NASA has developed the ATD-2 IADS system to demonstrate these benefits in the field. The ATD-2 IADS system improves the efficiency of surface operations at the nation's busiest airports through time-based metering of departures and improved sharing of flight operations information amongst the various stakeholders. The ATD-2 IADS system also couples a trajectory-based surface decision support tool (similar to TFDM) with the overhead stream insertion capabilities of the TBFM en route metering decision support system. The result is more precise scheduling of surface departures into constrained overhead flows, better communication between the en route and tower controllers, and significant improvement in compliance with target takeoff times. The ATD-2 Field Demonstration is being conducted in three, year-long phases. The first baseline IADS phase commenced on September 29, 2017 and demonstrates tactical surface departure metering at the American Airlines ramp tower and FAA's Air Traffic Control Tower at Charlotte-Douglas International Airport, as well as overhead stream insertion at Washington Air Route Traffic Control Center [13].

ATD-3 develops the en route rerouting tools and extended arrival metering capability, including maintaining metering in the presence of weather and other constraints, that completes the gate-to-gate "connection" of the ATD technologies. Collectively they provide a framework for a gate-to-gate TBO concept if their functionalities are implemented in the NAS. This would also increase the level of integration across the FAA TBFM, TFMS and Terminal Flight Data

Manager (TFDM) systems. An evolving TBO-Services concept is under consideration within NASA and the FAA, and an architecture with the ATD capabilities fits within that construct.

ATD-1 provides in-trail arrival sequencing and spacing using Performance Based Navigation (PBN) procedures through TBFM, integrated with FIM capabilities on the aircraft [12]. ATD-3 capabilities integrate with ATD-1 operations by building an extended metering capability to provide more accurate and predictable arrival metering information and spacing for ATD-1. ATD-3 weather avoidance routes upstream of arrival operations would improve arrival demand predictability by enabling the continuation of arrival metering operations, and reducing ETA uncertainty associated with traditional vector-based avoidance maneuvers.

ATD-2 provides collaborative departure scheduling capability from gate pushback to en route traffic stream insertion. The added accuracy and predictability of departure scheduling provided by ATD-2, supports ATD-3 capabilities by improving demand predictions for en route airspace and the accuracy of related airspace constraint information. More accurate departure scheduling information also improves TBFM, and the DRAW functionality within it, by improving arrival demand predictions and related demand constraints.

Gate-to-gate traffic management will benefit greatly from the added accuracy and predictability of demand, constraint and departure scheduling information provided by ATD and associated data sharing capabilities. These improvements come from several elements of ATD operations. First, better 4D trajectory information provide greater predictability of traffic demand and enable more efficient scheduling of airspace, airport and controller resources. Second, improved constraint definition needed by ATD-3 capabilities, will provide more clarity and insight into NAS constraints and potential mitigations. Third, data sharing provided by and for ATD capabilities will enhance coordination and collaboration across both service provider and airspace users. Finally, a fully integrated ATD system would provide a level of responsiveness to changes in the NAS that would reduce the level conservatism needed in strategic TFM, and improve the flexibility, predictability, and efficiency of the whole ATM system.

13 APPENDIX E: FAA SUPPORT AND COLLABORATION

In order to prepare the NAS for the traffic volume increases predicted for 2025 and to improve the efficiency of the air transportation system, the Congress enacted the Vision 100 – Century of Aviation Reauthorization Act in 2003 and created the Joint Planning and Development Office (JPDO) for the Next Generation Air Transportation System. The JPDO – composed of representatives from the FAA; NASA; the aviation industry; the Departments of Transportation, Defense, Homeland Security, and Commerce; and the White House Office of Science and Technology Policy – was tasked to develop a vision of the NAS for the year 2025 that promotes scalability of air traffic operations.

The JPDO published a Concept of Operations for NextGen describing a high-level vision for the air transportation system for the year 2025 including a description of the roles for the various operating elements within the air transportation system 1. The FAA has continually updated concept elements and its implementation plans since that time [15] [16] [17] The ATD-3 ConOps is consistent with the goals and vision for this evolving concept. It aligns with the FAA NextGen Segment Implementation Plan Lite 2017 and the FAA NextGen Future of the National Airspace System (NAS) June 2016, and it is consistent with the expected FAA NAS Enterprise Architecture Operational Improvements (OIs) [15] [16]

ATD-3 capabilities also align with the FAA NextGen Mid-term Implementation Plan (NGIP) by leveraging Performance-Based Navigation, Automatic Dependent Surveillance–Broadcast (ADS-B), and controller-pilot Data Communications (DataComm) to provide measurable operational benefits in the form of improved trajectory efficiency and reduced direct operating costs. Additionally, ATD-3 capabilities complement ATD-1 Interval Management – Spacing (IM-S) capabilities and ATD-2 Departure Scheduling capabilities by fulfilling the gate-to-gate vision of NASA’s IADS concept. ATD-3 capabilities also respond to and extends RTCA’s Recommendations for Implementing TBO in the Mid-Term (September 2011) by robustly extending high- and medium-priority capabilities for TMI reroutes, point-in-space metering, integration of weather into NAS decision making, and on-demand NAS information for collaborative decision making with AOC/FOCs [17]. The ATD-3 Integrated Capabilities ConOps also aligns closely with the International Civil Aviation Organization (ICAO) Global Air Traffic Management (ATM) Operational Concept (ICAO Doc. 9854) and the ICAO draft Global Concept for Trajectory Based Operations.

The following FAA NextGen Operational Improvements (OI) and their increments (grouped by Portfolio) and the capabilities that enable them are addressed by ATD-3 capabilities1 [14] [15]

- Performance Based Navigation
 - **OI 104123:** Time-Based Metering Using RNAV and RNP (Required navigation Performance) Route Assignments [2014-2016]
 - Optimized Route Capability (104123-24) [2023-2025]
- Time Based Flow Management
 - **OI 104120:** Point-in-Space Metering [2014-2025]
 - Metering During Reroute Operations (104120-21) [2021-2025]
 - Meet Time Based Flow Management (TBFM) Constraints Using Required Time of Arrival (RTA) Capability (104120-22) [2021-2025]
 - FOC Preferences Incorporated into Metering (104120-28) [2021-2025]

- Collaborative Air Traffic Management
 - **OI 101103:** Provide Interactive Flight Planning from Anywhere [2018-2025]
 - Flight Planning from Anywhere (101103-21) [2018-2020]
 - **OI 105207:** Full Collaborative Decision Making [2020-2030]
 - Airborne Trajectory Negotiation (105207-28) [2021-2025]
 - **OI 105208:** Traffic Management Initiatives with Flight-Specific Trajectories [2012-2025]
 - Airborne Rerouting (105208-21) [2016-2017]
 - Advanced Flight Specific Trajectories (105208-25) [2021-2025]

The following FAA NextGen OI (grouped by Portfolio) and the increments that support functionalities in ATD-3 8 [15]

- NAS Infrastructure
 - **OI 103119:** Initial Integration of Weather Information into National Airspace System (NAS) Automation and Decision Making [2012-2022]
 - Enhanced Satellite-Based Observation (103119-21) [2017-2022]
 - Enhanced NAS-Wide Access of 0-2 Hours Convective Weather on Traffic Forecast for NextGen Decision Making (103119-11) [2020-2022]
 - Enhanced Weather Radar Information for ATC Decision-Making (103119-14) [2020-2022]
 - Extended Convective Weather on Traffic Forecast for NextGen Decision-Making (103119-15) [2020-2022]
 - Convective Weather Avoidance Model (CWAM) for Arrival/Departure Operations (103119-16) [2018-2022]
 - 4-D Tailored Volumetric Retrievals of Aviation Weather Information (103119-17) [2018-2022]
 - **OI 103123: Full Integration of Weather Information into NAS Automation and Decision Making [2021-2027]**
 - Generation of Enhanced NextGen Weather Information (103123-05) [2021-2026]
- On-Demand NAS Information
 - **OI 103306:** Tailored Delivery of On-Demand NAS Information [2019-2025]
 - Static Airspace Constraints (103306-01) [2022-2025]
 - Tailored NAS Status via Digital NOTAMS for ANSP (10306-02) [2018-2022]

Partnership Agreement Maker - PAM v.2.0

PAM Menu > E-Router Group List > Packages in Routing

Title of Package:([edit](#))**ATD-3 Integrated Operational Concept**

Routernumber:38492

Group this package under:

HQAOSPRouting Package Administrator:Angela Boyle([edit](#))Comments:([edit](#))

Please expedite approval.

Any questions, please contact:

Stephanie Harrison at 757-864-8812 or Stephanie.j.harrison@nasa.gov

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Routing Sequence Number	Name/Title/Email/Phone/Comments	Concurrence /Approval	P S	A A	X	Options
1	Stephanie Harrison Title: ATD-3 Lead Systems Engineer stephanie.j.harrison@nasa.gov Phone: 757.864.8812 Comment From Reviewer: 6/19/2018 10:13:54 AM Response To Reviewer Comments: (Add/Edit)	Yes- 6/19/2018 10:13:54 AM				✉
2	Kapil Sheth Title: ATD-3 Sub-Project Manager kapil.sheth@nasa.gov Phone: 650.604.5728 Comment From Reviewer: This looks good for me now. Thank you Mike and Stephanie, and all the other contributors. 6/19/2018 12:59:13 PM Response To Reviewer Comments:	Yes- 6/19/2018 12:59:13 PM				✉

		(Add/Edit)							
		Email Sent							
3		Mike Madson Title: ATFM RTT Co-Lead mike.madson@nasa.gov Phone: 650.604.3621 Comment From Reviewer: 6/19/2018 3:08:13 PM Response To Reviewer Comments: (Add/Edit)	Email Sent	Yes- 6/19/2018 3:08:13 PM				<input type="checkbox"/>	
4		Shawn Engelland Title: ATD Project Manager, Acting shawn.engelland@nasa.gov Phone: 817.858.7634 Comment From Reviewer: Concur/Approve subject to document review comments provided to the authors. 6/21/2018 12:30:44 PM Response To Reviewer Comments: (Add/Edit)	Email Sent	Yes- 6/21/2018 12:30:44 PM				<input type="checkbox"/>	
	CC-P	Easter Wang Title: Program Planning And Control Manager easter.wang@nasa.gov Phone: 650.604.3923 Comment From Reviewer: Response To Reviewer Comments: (Edit)	Email Sent	CC Reviewer-				<input type="checkbox"/>	
	CC-P	Kevin Witzberger Title: ATD Deputy Project Manager, Acting kevin.e.witzberger@nasa.gov Phone: 650.604.2035	Email Sent	CC Reviewer-				<input type="checkbox"/>	
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