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Air Traffic Management Technology Demonstration – 3 (ATD-3) Multi-Agent Air/Ground Integrated Coordination (MAAGIC) Concept of Operations

Version 1.0

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June 2018

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PREFACE

NASA's Airspace Technology Demonstration - 3 (ATD-3) sub-project develops and matures trajectory management tools for en route operations. The Multi-Agent Air/Ground Integrated Coordination (MAAGIC) concept integrates two of these tools: a flight deck-based tool called the Traffic Aware Planner (TAP) and a ground-based tool called the National Airspace System Constraint Evaluation and Notification Tool (NASCENT). The integration of these tools in MAAGIC will assist airspace users, namely flight crews and dispatchers, in more effectively identifying route changes that optimize flights or provide delay reduction from inefficient and stale playbook routes, while increasing air traffic control acceptability of reroute requests.

REVISION HISTORY:

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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1 INTRODUCTION

Delays in the United States national airspace system (NAS) are exacerbated by an air traffic management (ATM) system that is not sufficiently robust and responsive to the unpredictable and dynamic nature of disruptions such as weather. To safely manage these disruptions, flights are assigned conservative routes around the forecasted weather, which are often placed before takeoff and remain in effect despite the evolution and dissipation of the weather system. One of the causes of the sluggish responsiveness is the lack of integration and cooperation among the ATM service providers and flight operators. There is a need for more information sharing, common situation awareness, automation support and communication channels that enable air traffic managers and controllers, pilots, and dispatchers to dynamically and quickly identify and agree on routes.

The advent of advanced technologies in communication, navigation, and surveillance is enabling more integration between the aircraft and the ground systems in managing air traffic operations. Some of these technologies have increased the situation awareness and connectivity of the flight deck. Satellite-based Automatic Dependent Surveillance-Broadcast (ADS-B) provides an aircraft that is equipped with ADS-B In awareness of surrounding aircraft that are equipped with ADS-B Out, whereas traffic information has typically been known only to the ground systems. Data communication (Data Comm) enables more complex clearances to be issued by the air traffic controller to the pilot, such as route changes consisting of multiple waypoints that bring the flight back to its intended path. Internet connectivity allows the aircraft access to information such as wind, weather forecasts, airspace constraints and traffic flow management (TFM) restrictions, which have typically been available only to ground systems. In addition, internet connectivity and advanced information systems such as System Wide Information Management (SWIM) have increased the situation awareness of airline/flight operations centers (AOC/FOC, referred to as AOC henceforth), and of aircraft through Aircraft Access to SWIM (AAtS). This improved awareness includes information on airspace and traffic constraints, in particular flow management restrictions. This information can be used to help the AOCs submit more acceptable strategic (before takeoff) preferred routes as trajectory option sets (TOS) for consideration by the service provider, through the Collaborative Trajectory Options Program (CTOP).

As a result of the increase in available data, automation has evolved to provide the flight crew, flight operators, air traffic controllers, and traffic flow managers with capabilities for information access, visualization, analysis, decision support, and communication that integrate their situation awareness and decision making. NASA has developed a number of these technologies and is pursuing research to investigate and demonstrate their integration under the Airspace Technology Demonstration (ATD) Project, which is part of NASA's Airspace Operations and Safety Program. The ATD-3 subproject focuses on improving en route operations by providing more efficient trajectories through route amendments from initial cruise up to the initial approach at the destination. The goal of ATD-3 is to develop and demonstrate, by 2020, advanced integrated air/ground automation technologies and procedures that enable strategic user-preferred routes and tactical route corrections to be identified and executed. As part of ATD-3, the Multi-Agent

Air/Ground Integrated Coordination (MAAGIC) concept has the goal to demonstrate air/ground coordination of reroutes to support flight operators and service providers in managing dynamic en route trajectory changes to improve flight and system performance in the presence of convective weather and other airspace constraints. The term reroute refers to a change in the currently cleared route, and it includes changes to either the lateral path, the altitude, or both.

The MAAGIC objectives include:

1. Integrate air/ground tools that leverage data exchange between aircraft, dispatch centers, and/or FAA facilities to share trajectory objectives, constraints, reroutes, and other relevant data.
2. Demonstrate MAAGIC tools and procedures in an operationally relevant environment, leveraging partnerships with NAS stakeholders.
3. Quantify benefits of MAAGIC tools and procedures in terms of economic benefit.

The ATD-3 technologies that are integrated by the MAAGIC concept are:

- Traffic Aware Planner (TAP) – flight deck decision support to better achieve an airspace user's business trajectory and enable efficient routing, accounting for wind, known weather, traffic, and special use airspace (SUA) [1].
- National Airspace System Constraint Evaluation and Notification Tool (NASCENT) – decision support to AOC to identify wind-corrected reroutes that provide flight time savings during convective weather activity and accounting for traffic congestion and other airspace constraints, such as SUAs, Traffic Management Initiatives (TMI), and Temporary Flight Restrictions (TFR) [2].

Ultimately, all the stakeholders involved in making decisions about the flight trajectory, including flight crew, dispatcher, air traffic controller, and air traffic manager, will benefit from some degree of integration. NASA is developing a concept for the desired end state of the integration between all these stakeholders, while each one is supported with automation using the ATD-3 technologies [3]. One of the main tenets of this concept is that the flight operators, namely flight crews and dispatchers, should appear to the service provider as a single agent when requesting and negotiating route modification. To this end, this document describes the MAAGIC concept for the integration between the flight crew and the dispatcher to reconcile their objectives, constraints, and reroutes before submitting a route change request to the service provider.

Figure 1 shows the scope of the MAAGIC concept. The flight deck technology (TAP) and the ground-based technology (NASCENT) continuously search for efficient reroutes that may save flight time and/or fuel. MAAGIC integrates these technologies and enables the coordination between the flight crew and the dispatcher resulting in coordinated suggested reroutes. Figure 1 shows one example situation where a playbook route (in blue) was put in place to avoid weather activity. The MAAGIC recommended trajectory resulted in a coordinated reroute (in green) that is more efficient than the playbook route.

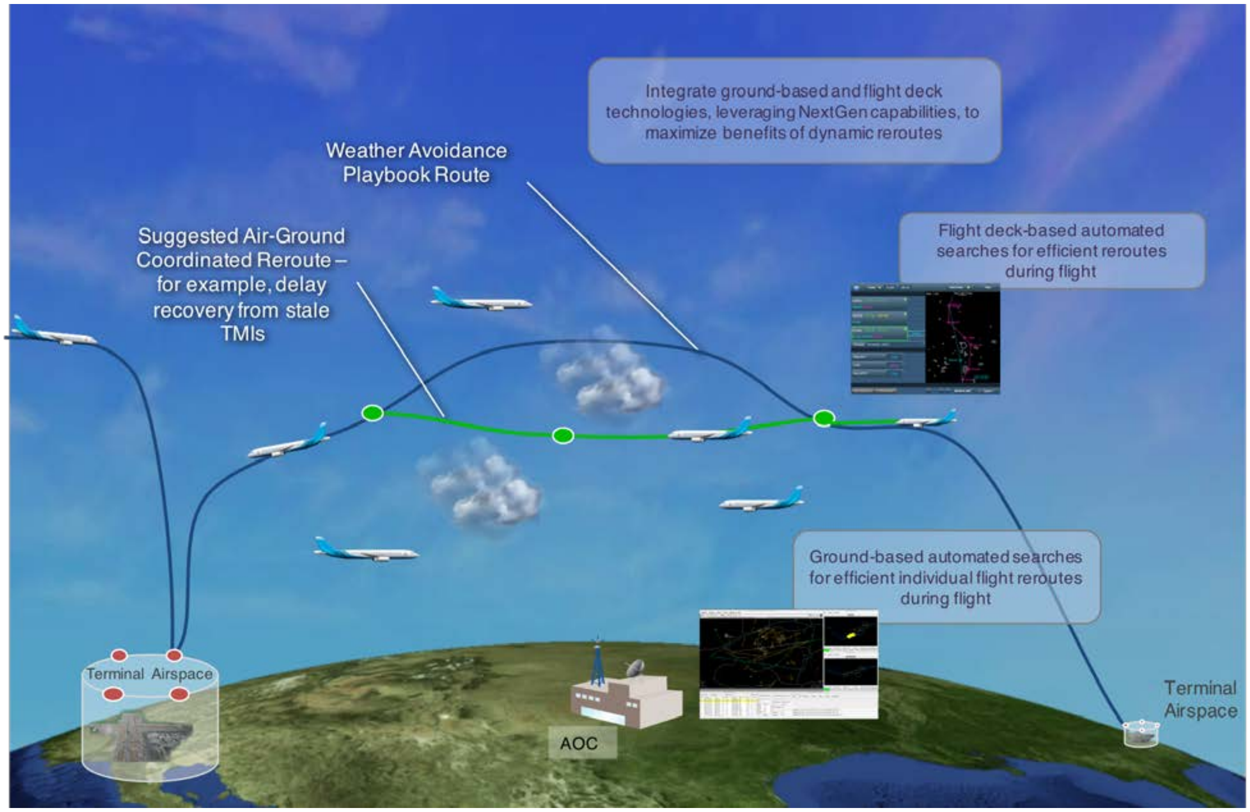

Figure 1. Air-Ground Integration and MAAGIC Scope

The operational environment of the MAAGIC concept is described in Section 2, followed by a discussion of the shortfalls and justification of the changes in Section 3. The MAAGIC solution to the shortfalls is described in Section 4 followed by a number of use cases in Section 5. The technologies that are needed for the concept are described in Section 6, future enhancements in Section 7, ending with a summary in Section 8.

2 Operational Environment

The operational environment for ATD-3 flight trajectories begins in en route airspace upon leaving the departure airspace and extends to the arrival meter fix at the destination airport. In this environment, flights may be traveling on inefficient routes for numerous reasons. For example, flights impacted by convective weather may be placed by the service provider on an inefficient alternate route around the weather, either when it was on the ground or while en route. This is typically done through a coordinated traffic flow management process whereby the service providers impose traffic management initiatives (TMIs).

Overall traffic flow management across the entire US NAS is managed by the Air Traffic Control System Command Center (ATCSCC, or “Command Center”) in Warrenton, VA. The ATCSCC assesses forecast weather and traffic demand throughout the day, and coordinates with the Air Route Traffic Control Centers (ARTCCs, or “Centers”) for en route airspace and Terminal Radar Approach Control (TRACON) facilities for terminal airspace to implement TMIs. TMIs generally involve metering by imposing delays (e.g., miles-in-trail (MIT) restrictions at departure, arrival or en route fixes, Ground Delay Programs (GDPs), and Ground Stops (GS)), as well as rerouting or constraining traffic around hazardous weather or congested airspace (e.g., Severe Weather Avoidance Plan (SWAP) or Playbook routes).

The FAA’s initial traffic predictions are based on weather forecasts and airline schedules. Forecasted weather may not develop as predicted or may fail to materialize altogether, and airline schedules may change due to delays and cancellations. Consequently, strategic TMIs may not be based on the latest demand information and may not manage traffic as intended. Collaborative Decision Making (CDM) is the process used by the FAA and flight operators to coordinate changes to TMIs, routes, flight prioritization, and departure times and sequences.

Once flights have departed, route changes are generally workload intensive, particularly in those instances when coordination is required between the Command Center, multiple en route Centers, or dispatchers to accommodate significant deviations. In addition, the dispatchers and pilots may not have sufficient visibility and awareness about the environment and the service provider constraints to enable them to be proactive in identifying and requesting more efficient route alternatives. As a result, aircraft often remain on inefficient routes culminating in large delays and schedule disruptions. The MAAGIC tools and integrated concept are aimed to improve operations under these conditions.

2.1 Current Practice for Reroutes – Flight Deck

According to interviews conducted with controllers in Atlanta (ZTL) and Jacksonville (ZJX) Centers during TAP flight trial #2, flight crews most typically make requests for short cuts to save time and fuel, for altitude changes to avoid turbulence, and for weather deviations [4]. The flight crew has access to a variety of information that can be used in planning route changes. For example, the flight management system (FMS) provides the flight crew with comparison of actual versus planned fuel at each waypoint, the estimated time of arrival, and the recommended economical altitude accounting for aircraft weight, airspeed, and sensed local atmospheric conditions. The aircraft avionics calculates the wind, but lacks information about the wind and weather forecasts outside the range of these sensors. In some cases, the FMS provides the flight crew with a blend of sensed and forecast wind, but only along the current route. Pilots report turbulence when encountered, which is information that can be used by other pilots in order to avoid it. The cost index of the flight defining the desired balance of flight time and fuel efficiency is set by the company prior to departure and determines the economical speed profile for the aircraft; although the pilot can change the cost index during flight, it is not a typical practice.

Flight crews lack knowledge about air traffic constraints that may be useful when planning route changes. They know from the dispatcher if they were rerouted before takeoff and from the controller if rerouted after takeoff. They may have access to standard operating procedures (SOPs) which dictate certain route constraints, however, they have no access to the letters of agreement (LOA) between ATC facilities. The controller is their source of information about routing restrictions and SUA activity.

According to the operator's procedures, if a pilot-initiated route change involves a large deviation from the current route, the dispatcher needs to concur before the pilot makes the request to the controller. Deviations are considered large if they exceed some threshold, or control authority limit (CAL), which is a company criterion delineating requirement for coordination between the flight crew and the dispatcher. Typical CAL values are 100 nmi lateral deviation, 4000 ft vertical deviation, or 15-minute arrival time deviation (although smaller values may be used, as appropriate). This requirement results in a coordination between the flight crew and the dispatcher which enables cross-checking the route change against the company's flight planning system and other data available to the dispatcher, but also increases the workload needed for making the request.

The coordination of a route change between the flight crew and the dispatcher is manual and not assisted by any automation support. Hence it is workload intensive, which may discourage the dispatcher or the flight crew from taking advantage of beneficial route changes that may save flight time or fuel. It is initiated by the flight crew when required by the company procedures (the route change exceeds CAL) or desired. The Aircraft Communications Addressing and Reporting System (ACARS) is the preferred method of communicating a route change. Voice can be used for the coordination; however, voice is mostly reserved for communicating with the air traffic controller. The dispatcher's main concerns are the impact the route change will have on the fuel reserve of the aircraft, and what impact the new route has downstream of the change (in particular the arrival schedule and its impact to fleet-wide operations). For example, the route change may delay the flight's arrival time significantly resulting in adverse effects on the downstream connections of the passengers, the flight crew, and the aircraft. The dispatcher may also make decisions based on impacts on other flights in the fleet that are competing for the same airspace and airport resources, such as metering time slots and gates.

Pilots make reroute requests to air traffic controllers by voice. In some situations, a pilot may request a more strategic route change from the controller that involves coordinating with multiple facilities. In these cases, the controller workload may lead to a rejection of the request and hence it may have a better chance of being accepted if coordinated first between dispatchers and traffic flow managers (see next section). However, this procedure, while saving workload for the controller, adds workload to pilots, dispatchers, and traffic flow managers.

2.2 Current Practice for Reroutes – Dispatcher

The dispatcher involvement in a flight's route is primarily in pre-departure flight planning and to a lesser degree strategic re-planning during the flight. The flight plan incorporates constraints from SOPs and ATC restrictions. In cases of weather deviations, the dispatcher can file multiple prioritized route options from which the service provider can select the best option. While this capability is operational, it is not frequently used by the airlines and the FAA.

While the flight is en route, the dispatcher monitors the downstream TFM constraints. Some operators have tools to help in estimating the remaining fuel and compare updates from the pilot or the aircraft's automatic reporting system with their estimates. The dispatcher is also concerned about schedule conformance and monitors the flight progress. The dispatcher may instruct the pilot to speed up or to slow down because of gate availability at the destination. The dispatcher monitors the weather, turbulence (from pilot reports (PIREP) and Turbulence Auto PIREP System (TAPS)), and airspace constraints (Special Use Airspace & Air Traffic Control Assigned Airspace (SUA/ATCAA) and TFRs). However, the air traffic controller is usually faster in alerting the pilot to such conditions than the dispatcher.

The dispatcher may, although not frequently, identify opportunities for a flight to save time or fuel. The dispatcher may convey the route to the flight crew through ACARS. The dispatcher typically monitors the Command Center customer hotline (in some cases through the ATC coordinator position) and identifies potential route alternates that other operators are requesting and are being granted by the service provider. In these cases, the dispatcher enters a route change request from the Command Center through the hotline. This request is delivered to the tactical customer advocate position at the Command Center and is then coordinated with the appropriate facilities. If a route change is within the current Center, the dispatcher may coordinate the change with the traffic management unit (TMU) of the Center using phone communication. It is often more effective to convey the route change to the flight crew through ACARS such that the pilot makes the request to the air traffic controller, avoiding TMU coordination.

Another avenue for dispatchers to affect a route change is the participation in the strategic planning telecon held every two hours by the Command Center, with invited participation from FAA facilities and operators. The ATC coordinator advocates for preferred routes when restrictions are discussed on the telecon, typically when they impact several of their flights.

3 SHORTFALL AND JUSTIFICATION OF CHANGE

The ATM system has a number of shortfalls that result in inefficiencies in managing the operational environment described in Section 2. The ATD-3 concept attempts to mitigate these shortfalls by providing integrated automation support to the flight operators and the service providers. MAAGIC is focused on providing mitigation to the shortfalls of the operators while negotiating reroutes with the service provider. In this section, the operator shortfalls that are addressed by MAAGIC and its tools are described.

3.1 IDENTIFYING EFFICIENT REROUTE OPPORTUNITIES

Identifying efficient reroute opportunities requires processing information about the environment such as wind forecasts, aircraft performance, available route and altitude options, and restrictions and constraints that limit these options. The flight crew and the dispatcher have limited access to much of this information, and they are often too busy to search for opportunities to gain efficiency, particularly if it is not safety critical. For example, the dispatcher is often handling multiple flights and is not able to optimize single flight routes.

Operators have difficulty identifying the most beneficial reroutes, given the complexities of wind fields, aircraft performance, weather forecast, and dynamic restrictions. The tools they have now are highly manual (trial and error) and workload intensive. As a result, “rules of thumb” are more often used, such as asking for “directs” and “higher” or avoiding requests altogether.

The MAAGIC tools for the flight crew and dispatcher, TAP and NASCENT respectively, provide automation assistance by conducting continuous and automatic searches for more efficient reroutes, and then issuing alerts for the identified reroute opportunities that can provide efficiency gains.

3.2 SERVICE PROVIDER ACCEPTANCE OF ROUTE CHANGE REQUESTS

While service providers attempt to accommodate pilot requests as often as possible, there are many reasons for rejecting requests, including separation from other traffic, LOA/SOP requirements between facilities, impacts on neighboring sectors, interference with arrival and departure flows, flow restrictions, workload, interference with weather, interference with active SUAs, and whether the controller has already or is about to initiate handoff of the aircraft to another controller [4].

MAAGIC seeks to identify more of the beneficial reroute opportunities that exist and to improve the ATC acceptability of reroute advisories. Given that the use of reroute tools is likely to increase the number of route change requests made to ATC, the need for ATC acceptability of these requests increases even more. However, MAAGIC aims to increase ATC acceptability of reroute requests, regardless of whether their number increases or not. Integration of TAP and NASCENT via MAAGIC attempts to provide reroute recommendations that account for a greater number of factors that increase ATC acceptability. For example, TAP trajectories avoid proximity to known nearby traffic, weather hazards, and active SUAs. NASCENT trajectories also avoid weather hazards and active SUAs, while informing the dispatcher of impacts on sector congestion and TMIs (e.g., playbook reroutes). NASCENT also suggests historically used routes, which accounts for interference with arrival and departure flows and other operational common practices, with which controllers would be familiar. Accounting for the sum of these factors will increase the acceptability of requests and help the flight crew and the dispatcher in gaining situation awareness about the impact on the service provider. Hence the flight crew and dispatcher can make better informed judgments about the likely acceptability of a request and the need to modify it before making it.

3.3 Lack of Integration between Flight Crew and Dispatcher

Route amendments with significant deviations require concurrence between the flight crew and the dispatcher, according to company procedures. A number of factors hinder the coordination between the flight crew and dispatcher:

1. Coordination is time and workload intensive and hence prevents realization of the significant benefits available from reroute opportunities. MAAGIC provides the mechanisms to facilitate coordination and reduce the associated workload. It supports the decision-making needs of dispatchers and flight crews, taking into account their differences in workload, information needs, priorities, and roles. By facilitating the coordination, MAAGIC enables faster agreement on reroutes before the opportunity for their benefits diminishes.

2. Lack of common information between the flight crew and the dispatcher leads to inaccurate and inconsistent advisories that may also take longer to coordinate. For example, the flight crew and TAP have more accurate aircraft weight and airborne weather radar information, whereas the dispatcher and NASCENT have better knowledge of sector-related airspace constraints, schedule conformance, and weather forecasts beyond the range of the onboard weather radar. MAAGIC facilitates sharing some of this information, thus leading each tool to generate more accurate advisories based on the correct information. More accurate advisories tend to be more acceptable and optimal. Sharing information also increases its consistency between the flight crew and the dispatcher (regardless of its correctness), which leads to faster agreement on reroute change requests.

3. Differences in optimization objectives and constraints between the flight crew and the dispatcher leads to inconsistent and suboptimal advisories. The optimization objectives are the stated purpose to be achieved in searching for aircraft reroutes, e.g., minimize fuel burn. Examples of inconsistencies include limited flight crew visibility into fleet-wide concerns and indirect dispatcher access to the aircraft weight and remaining fuel through ACARS updates. Reconciling these differences also delays the coordination. MAAGIC facilitates sharing and reconciling the objectives between dispatcher and flight crew.

4 PROPOSED SOLUTION

In order to address the shortfalls described in the previous section, integration between flight deck-based and ground-based decision support tools is proposed to enable collaboration between the flight crew and the dispatcher on identifying efficient reroute requests while the aircraft is en route. Ultimately, all stakeholders involved in making decisions about flight trajectories, including flight crew, dispatcher, air traffic controller, and air traffic manager benefit from some degree of integration. This section describes the MAAGIC concept for the integration between TAP and NASCENT to enable the flight crew and the dispatcher to reconcile their objectives and constraints before submitting a route change request to the service provider.

First, the dispatcher and flight crew automation tools (NASCENT and TAP respectively) for seeking route efficiencies are described, highlighting their complementary capabilities, while a more detailed description of each tool is provided in Appendix A. Second, the MAAGIC concept of integrating these tools and enabling the collaboration of their operators is described in the following section.

4.1 NASCENT AND TAP CAPABILITIES

NASCENT is a NASA-built decision support tool for flight operators and service providers [2]. In the MAAGIC concept, NASCENT is used as a dispatcher decision support tool for dynamic rerouting that uses SWIM data to build trajectories for all aircraft in the NAS. It continuously monitors airspace conditions and constraints (for example, winds, weather, TMIs, and special use airspace) and identifies opportunities for more efficient routes around those constraints. When the system determines that a flight could save at least a specified amount of time (for example, 2 minutes) by flying a more efficient route and avoid the active constraints, it will suggest a new route segment for that flight.

TAP is a NASA-built cockpit automation system that also monitors airspace constraints and conditions and continuously searches for more efficient routes [1]. Complementary to the ground-based system, it leverages flight management system data and onboard weather, wind, and traffic data to identify wind-optimized routes and altitudes that will save time, fuel, or overall trip cost (combining the costs of time and fuel). In automatic mode, the system continuously scans for three types of trajectory changes: lateral, altitude, and combination lateral/altitude changes. In manual mode, the pilot enters a desired trajectory change into the interface and assesses the resulting time/fuel outcomes and constraint impacts predicted by TAP.

NASCENT and TAP operate independently of each other supporting the dispatcher and the flight crew, respectively, in identifying beneficial reroute opportunities (called advisories henceforth). Figure 2, and the lists below, describe the similarities and complementary capabilities between the two tools in terms of access to external information and internal constraint management capabilities. The current state of coordinating a reroute and implementing a reroute request are also described. The complementary capabilities are leveraged by the MAAGIC concept described in the following section. For more details about the tools and their interfaces see Appendix A.

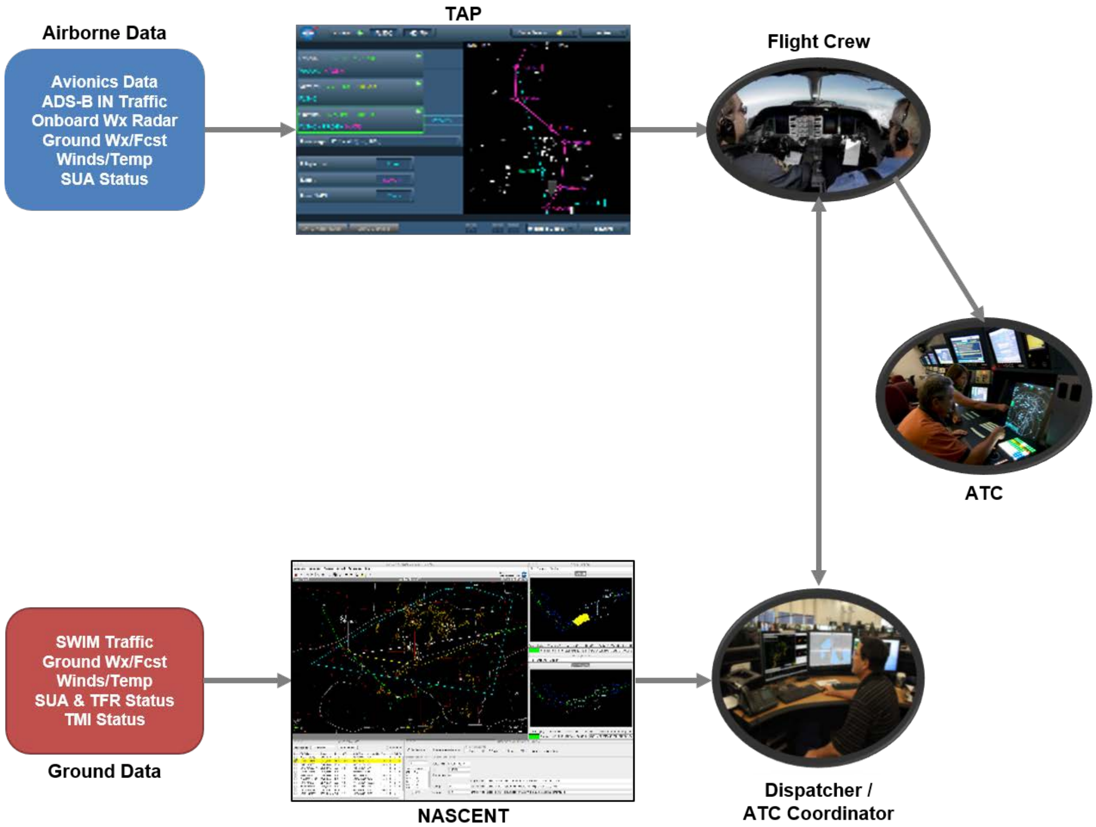

Figure 2. NASCENT and TAP Complementary Capabilities

4.1.1 External Information

As shown in the input boxes (airborne and ground data) in Figure 2, TAP and NASCENT access a number of external information sources that are complementary to each other. In some cases, the differences arise because one tool has access to information that the other tool does not. In both cases, these differences provide opportunities for integrating the tools through information sharing.

Aircraft state and performance information:

By virtue of being a cockpit system, TAP has access to real-time avionics data, such as the aircraft weight and airspeed. TAP also has information about remaining fuel. TAP uses this information in its trajectory computation and aircraft constraint management.

Wind and temperature:

Both TAP and NASCENT have access to the same ground-based wind and temperature information sources. TAP has access to sensed wind information calculated by the aircraft avionics.

Weather information:

TAP has the potential to access weather information from the onboard weather radar. Both TAP and NASCENT have access to weather and weather forecasts from ground sources, such as the

Weather Services International (WSI). Using this information, TAP and NASCENT propose reroutes that avoid known weather hazards.

Traffic information:

On flights equipped with ADS-B In, TAP receives state information from aircraft equipped with ADS-B Out and within reception range of the TAP equipped aircraft. TAP uses this traffic information to generate advisories that enable the recommended trajectories to maintain sufficient distance from the aircraft transmitting the information. NASCENT has access to traffic information from the SWIM traffic flow management data feed, which includes all airborne aircraft that have filed a flight plan. NASCENT uses the known traffic information to assess the impact of an advisory (a tool-computed reroute) on sector congestion.

Airspace and flow constraints:

Both TAP and NASCENT have access to the SUA schedules published by the FAA and use this information to maintain distance from the SUAs. NASCENT has access to information about temporary flight restrictions (TFR) and uses this information to maintain distance from them.

NASCENT also has access to information about TMIs, such as playbook reroutes and traffic management programs like GDP, GS, AFP, etc. It uses this information to maintain dispatcher awareness about the reroute impact on such TMIs.

Fleet objectives and constraints:

While NASCENT does not automatically receive fleet-wide information, it enables the management of fleet constraints by allowing the dispatcher to impose objectives and constraints on a reroute that are geared for accomplishing, for example, network and schedule priorities.

4.1.2 Constraint Management Capabilities

TAP and NASCENT possess a number of complementary capabilities for managing constraints when generating advisories. Figure 2 displays the capabilities of each tool including the overlap between these capabilities, as described below.

TAP capabilities:

TAP uses traffic information for managing traffic proximity constraints, recommending advisories that maintain sufficient separation from known traffic projected along that traffic's path. Currently TAP uses traffic information received through ADS-B In, which includes only aircraft that are equipped with ADS-B Out and are within range.

TAP generates advisories that avoid known weather hazards represented as polygons. Currently TAP use the weather forecast from WSI and has the potential to also avoid weather hazards detected by the airborne weather radar. TAP generates advisories that avoid SUA constraints, based on the SUA schedule published by the FAA.

TAP is also able to account for aircraft constraints such as aircraft performance and remaining fuel in the generated advisories. Some of these constraints may be specified by the flight crew.

NASCENT capabilities:

NASCENT generates advisories that avoid known weather hazards, represented as polygons. Historically, NASCENT has accessed and used several ground-based weather services (see Appendix A for details). These sources provide NASCENT with multiple viewpoints to best utilize the combined information. For the MAAGIC concept described in the next section, NASCENT is assumed to use weather information from WSI.

NASCENT generates advisories that avoid known SUA and TFR constraints, represented as polygons.

NASCENT assesses the congestion impacts of a reroute using SWIM traffic information and sector congestion limits. This assessment is used to maintain dispatcher awareness of the advisory impact on sector congestion and assist the dispatcher in making decisions about modifying the advisory to mitigate these impacts.

NASCENT assesses the TMI impacts of the route and recommend reroute using information about the active playbook reroute and metering restrictions. These assessments are used to maintain dispatcher awareness of the advisory impact on TMIs and assist the dispatcher in making decisions about modifying the advisory to mitigate these impacts.

As mentioned previously, NASCENT allows the dispatcher to impose objectives and constraints on a reroute that are geared for accomplishing fleet-wide concerns, for example, user network and schedule priorities.

4.1.3 Reroute Coordination

Currently TAP and NASCENT work independently of each other as shown in Figure 2. Coordination between the flight crew and the dispatcher, when needed, would be performed manually as in current operations without any assistance from the tools. Therefore, there is an opportunity to use TAP and NASCENT to facilitate the coordination between the flight crew and the dispatcher when needed, reducing the associated workload.

4.1.4 Reroute Implementation

As shown in Figure 2, reroute requests to ATC are made by the pilot to the controller via voice, as in current operations.

4.2 Multi-Agent Air/Ground Integrated Coordination (MAAGIC) System Description

The MAAGIC decision support tools, NASCENT and TAP, assist the dispatcher and flight crew, respectively, by continuously identifying reroute opportunities that save flight time and/or fuel relative to the currently flown trajectory. MAAGIC integrates these tools by:

1. Sharing certain information that one tool has better access to than the other.
2. Cross-checking the proposed reroutes using each tool's particular capabilities and available data sources.
3. Providing an interface to facilitate the coordination of a reroute between the flight crew and the dispatcher.

MAAGIC attempts to leverage the combined information and capabilities of the tools to achieve a more efficient and operationally acceptable advisory, including lateral and/or altitude changes to the current route.

In addition, operator procedures often require coordination between the flight crew and the dispatcher for significant route change, for example, changes with deviations larger than some established threshold (e.g., CAL as was described in Section 2.1). When needed or required by company procedures, the MAAGIC tools provide coordination interfaces for their operators to enable them to coordinate route changes with low workload until they agree on the route change before requesting it from the service provider.

Figure 3 provides a graphical depiction of the MAAGIC operational environment. A flight is shown with an original route (in magenta) that avoids weather and SUA constraints. The route has become inefficient relative to new forecast updates of the weather and SUA constraints. A recommended reroute that is predicted to be de-conflicted from known traffic and avoids the weather and SUA constraints is identified by the MAAGIC tools, as shown in cyan. A probe for sector congestion provides awareness that the sector bordered in yellow is congested and hence should be avoided by the cyan reroute to increase ATC acceptability. The flight crew and airline dispatchers coordinate using MAAGIC tools as interfaces. Dashed lines show the connectivity of the airborne and ground systems to the internet for access to external information about the weather, SUA and other constraints. The pilot can communicate the request to the air traffic controller using either voice or (once available) Data Comm.

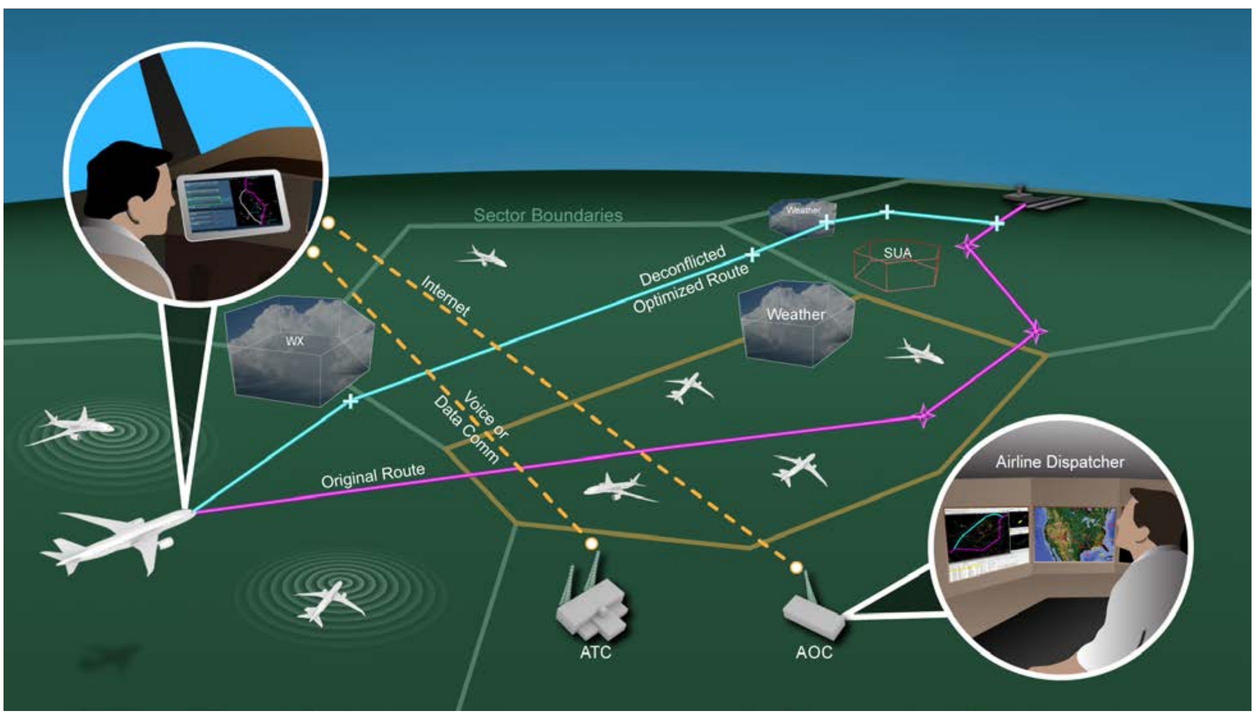

Figure 3. MAAGIC Operational Environment

The initial MAAGIC concept maintains significant human involvement in the air-ground coordination process, i.e. the process is largely controlled by human operators. Though the tools automatically share some of their respectively known information prior to coordination, human operators determine when and how long to coordinate and utilize their respective tools to support their manual coordination process. The initial MAAGIC concept excludes automated coordination in order to minimize complexity, development time, project risk for an operational demonstration, and to explore the need for higher degrees of automation envisioned by the end state concept. In addition, the degree of automated coordination for the operator may be influenced by the desire of the operator, and hence may be different for different flight operators.

The end-state MAAGIC concept envisions a higher degree of automation in the coordination between the air and ground operators [3]. For example, the automation tools supporting the flight crew and dispatcher would attempt to exhaust reconciling their respectively known objectives and constraints before proposing route change advisories to their human operators. Automated negotiation reduces the time needed to agree on route change requests, reduces human workload, and increases the acceptability of the route changes by ATC. MAAGIC takes a step towards this high degree of automation.

4.3 Assumptions

The following assumptions are made to guide the development of the MAAGIC concept:

1. MAAGIC enhances, but does not replace, the individual capabilities of TAP and NASCENT. TAP and NASCENT will continue to be available as independently functioning tools when not operating as an integrated system.
2. MAAGIC leverages the strengths of each tool such that they complement each other, to the extent possible, in the process of developing coordinated route change advisories.
3. MAAGIC procedures are non-mandatory, intended only to supplement existing company procedures for coordination between the flight crew and dispatcher. Dispatchers and flight crews choose when to use MAAGIC for coordinating route changes.
4. While the end-state concept has both dispatcher or pilot submitting recommended MAAGIC reroutes to ATC, during testing conducted to evaluate this concept, the focus is on the requests from the pilot to the controller.
5. Voice communications for making ATC requests will be assumed.

4.3.1 MAAGIC Functional Description

Based on the assumptions described previously and on the tool capabilities described in Section 4.1, the MAAGIC concept was designed to include the following main integration attributes:

1. Information sharing where some complementary information is shared between the air and the ground.
2. Reroute cross-checking where the flight crew or the dispatcher can send one of the advisories displayed by their respective tools (TAP or NASCENT, respectively) to the other tool for feedback on constraint impacts (a predicted effect of executing the reroute, typically an unmet constraint, e.g., predicted weather polygon incursion).
3. Reroute coordination where the flight crew and dispatcher invoke and engage in coordinating a reroute through a series of revisions, supported by TAP and NASCENT, which provide coordination interfaces and reroute evaluation.

4. As in current operations, reroute requests are made by the flight crew to ATC using voice communication.

These attributes are described in the following sections including the roles and interactions of the flight crew, the dispatcher, TAP and NASCENT.

4.3.1.1 Information Sharing

While TAP and NASCENT compute their advisories independently, they both can benefit from sharing information that one operator or tool has that the other does not. Some of the information is shared automatically and regularly between TAP and NASCENT while some information is entered by the operators. Figure 4 depicts the shared information graphically.

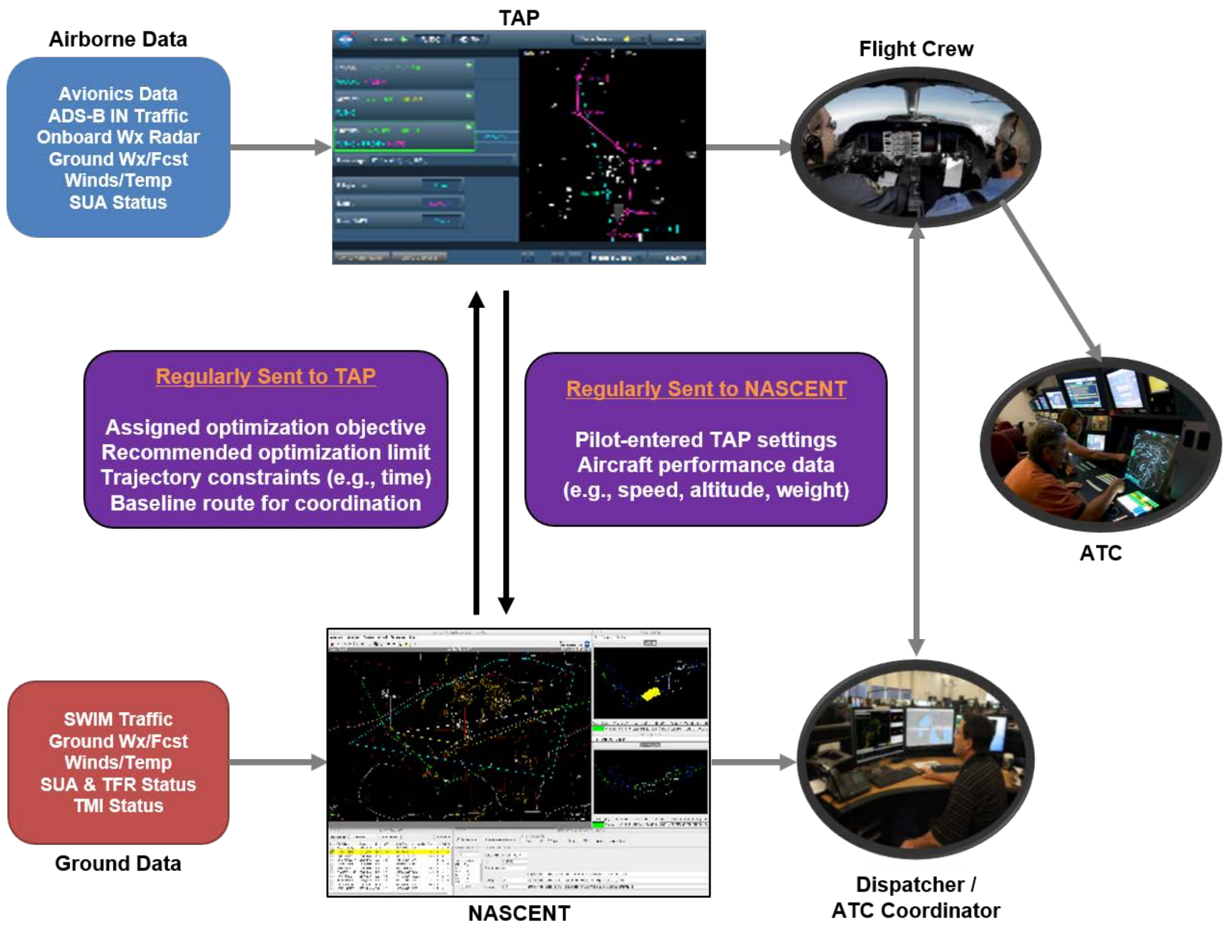

Figure 4. Information Shared between TAP and NASCENT

<u>Ground-to-air information:</u>

The route optimization objectives (for example, to optimize for time vs. fuel) are better known to the dispatcher than the flight crew because they typically are based on fleet considerations such as flight connections and gate availability. Without integration, the dispatcher would convey these objectives to the flight crew, via a cost index in the flight plan, who would enter them into TAP. With MAAGIC, the dispatcher assigns and enters into NASCENT the optimization objective (e.g., time, fuel, or trip cost / cost index) for each flight. NASCENT uplinks the objective to the flight crew via TAP. TAP receives and displays the objective to the flight crew, and uses it in the advisory computation. With MAAGIC, the dispatcher can also update the objective during the flight as circumstances warrant. In addition, TAP regularly updates NASCENT with the current optimization objective(s) to display to the dispatcher. This provides the dispatcher with confirmation of the optimization objective currently being used onboard.

The dispatcher may also enter into NASCENT the trajectory constraints for each flight. For example, the dispatcher may assign time constraints that stem from scheduling and fleet management concerns. NASCENT uplinks these constraints to the flight crew via TAP. TAP receives and displays these constraints to the flight crew, and uses them in the advisory computation.

For reroutes, NASCENT selects a return capture fix (RCF) from waypoints that have been historically acceptable to ATC for reroute clearance into downstream Centers. This information can be used by TAP to improve the acceptability of its advisories. Hence, NASCENT uplinks the RCF to TAP automatically whenever it changes. TAP receives the RCF and uses it in its advisory computation as a default setting for its optimization limit waypoint (farthest RCF that can be considered in TAP).

NASCENT automatically uplinks to TAP a baseline route for CAL computation. TAP computes the deviation of a reroute relative to this baseline route and alerts the flight crew to the need for coordinating the reroute with the dispatcher if the deviation is larger than an established threshold. The baseline route is the filed flight plan or any subsequent route established by the dispatcher.

Air-to-ground information:

Some aircraft performance parameters that are used in advisory computation are better known to the aircraft than to the ground. NASCENT can benefit from using these parameters to compute more accurate and optimal advisories. Some of these parameters are automatically and regularly downlinked from TAP to NASCENT, including but not limited to: weight, airspeed, and climb/descent rate.

The flight crew can set an optimization limit waypoint. To provide the dispatcher awareness, TAP downlinks to NASCENT the TAP optimization limit waypoint automatically whenever it is changed.

4.3.1.2 Reroute Cross-Checking

The flight crew and the dispatcher can cross check advisories between TAP and NASCENT before coordinating with each other. Both NASCENT and TAP periodically compute and display their advisories to their operators, the dispatcher and flight crew, respectively. Nominally, TAP generates and displays three advisories to the flight crew (lateral, vertical, and combination of lateral and vertical maneuvers) and NASCENT generates and displays two advisories (one lateral and one lateral-vertical combination) to the dispatcher. To conserve bandwidth, TAP and NASCENT do not automatically send their advisories to the other tool for cross checking; rather the cross checking is invoked by the flight crew or the dispatcher by selecting an advisory of interest. Therefore, if an advisory has not yet been selected by the operator, the tool displays the advisory and the associated impacts only against the constraints known to the tool.

The cross-checking may be performed differently for the flight crew and the dispatcher because of differences in their responsibilities and their tool capabilities. The cross-checking process is described below for each.

Flight crew initiated cross-checking

Once the flight crew selects a TAP advisory (indicating specific interest in it), TAP sends it to NASCENT for cross checking. NASCENT checks the reroute sent from TAP against its known constraints, such as sector congestion, weather polygons, SUA/TFR, TMI restrictions, and fleet management constraints, and sends the results to TAP. TAP displays the results conveyed by NASCENT to the flight crew. Hence the flight crew always knows the results of NASCENT's check against the constraints known to NASCENT. This allows the flight crew to make decisions based on constraints known to both TAP and NASCENT, rather than just those known to TAP. Based on this additional information, the flight crew may decide to select another of the TAP displayed advisories, which once selected is sent to NASCENT for cross-checking. The flight crew may also decide to either proceed with making the request to ATC despite the constraint impacts (if any) or to make modifications to the advisory to mitigate the constraint impacts. If a coordination with the dispatcher is required (by airline procedures) or desired, the flight crew may invoke a coordination process, which is described in the next subsection.

The cross-checking results sent from NASCENT include supporting data. It includes a description of the constraint impact (e.g., the advisory penetrates a sector above its congestion limit) and a geometric description of the impacted constraint (e.g., the polygon representation of the impacted sector). The geometry description of the impacted constraint allows the flight crew to modify the advisory to avoid the constraint impact. Note that the flight crew modifies the advisory manually in TAP, i.e., TAP will not automatically modify the advisory to mitigate the NASCENT-sent constraint impacts.

Dispatcher initiated cross-checking

Because of dispatcher workload limitations, NASCENT notifies the dispatcher only of reroute opportunities that exceed an established benefit threshold. In the MAAGIC concept the default benefit threshold is set to two minutes. The threshold default is selected to be sufficiently low to identify a significant number of reroute opportunities.

Similar to the flight crew, once the dispatcher selects a NASCENT advisory (indicating specific interest in it), NASCENT sends it to TAP for cross checking. TAP checks the reroute sent from NASCENT against its known constraints such as proximity from ADS-B traffic, SUAs, and weather polygons, and sends the results to NASCENT. NASCENT displays the results conveyed by TAP to the dispatcher. Hence the dispatcher always knows the results of TAP's check against the constraints known to TAP. This allows the dispatcher to make decisions based on all constraints known to both TAP and NASCENT, rather than just those known to NASCENT. Based on this additional information, the dispatcher may decide to select another of the NASCENT displayed advisories, which once selected is sent to TAP for cross-checking. The dispatcher may also decide to make modifications to the advisory to mitigate the constraint impacts.

The cross-checking results sent from TAP include supporting data. The supporting data includes a description of the constraint impact (e.g., the advisory penetrates a weather hazard) and a geometric description of the impacted constraint (e.g., the polygon representation of the impacted weather hazard). Except in the case of violating separation with traffic, where TAP will send to NASCENT information about the impacted traffic (e.g., the state of the traffic) but not the geometry of the conflict. The geometry or traffic description of the impacted constraint allows the dispatcher to modify the advisory to avoid the constraint impact. Similar to TAP, the dispatcher may modify the advisory manually in NASCENT, i.e., NASCENT will not automatically modify the advisory to mitigate the TAP-sent constraint impacts.

4.3.1.3 Reroute Coordination

At any given time, the dispatcher or the flight crew can initiate interaction between each other by sending an advisory, which will be displayed to the other operator. Hence TAP displays to the flight crew up to four advisories (three TAP advisories, i.e., lateral, vertical, and combination of lateral and vertical, plus possibly the NASCENT advisory selected/modified/sent by the dispatcher). NASCENT displays to the dispatcher up to three advisories for each flight (two NASCENT advisories, i.e., lateral and lateral-vertical combination, plus possibly the TAP advisory selected/modified/sent by the flight crew).

Coordination in the MAAGIC concept refers to an interactive process of iterating on a reroute advisory between the flight crew and the dispatcher. Company procedures require coordination for reroute changes that exceed certain criteria (i.e. CAL) relative to a baseline route. If coordination of a reroute is required by airline policy (i.e. due to the proposed reroute deviating from the current route by an amount exceeding CAL) or at any time desired by the flight crew, the flight crew initiates the coordination process. The flight crew has the ability to initiate coordination as desired even when it is not required. When a dispatcher sends an advisory to the flight crew, it initiates interaction but does not imply coordination with the flight crew in the MAAGIC concept. The flight crew can either concur with or modify the advisory sent by the dispatcher and then make the request to ATC, or decide to conduct coordination with the dispatcher. TAP monitors advisories that exceed CAL and alerts the flight crew of the need to coordinate reroutes with the dispatcher.

In MAAGIC, reroute coordination is performed manually by the flight crew and the dispatcher, supported by the messaging and data exchange capabilities of their tools. The flight crew and the dispatcher engage in a coordination process using TAP and NASCENT as interfaces and using MAAGIC functionality within their tools to facilitate their coordination. The flight crew can adjust the reroute and check it in TAP. The dispatcher can adjust the reroute and check it in NASCENT. In each iteration, TAP and NASCENT receive and display the reroute modified by the other operator, via the other tool, along with supporting data. The supporting data include the rationale for the modification and the new constraints that led to the modification. Including the impacted constraints in the supporting data allows the other operator to take them into consideration if they plan to further modify the reroute. As in the cross-checking described in the previous section, except in the case of traffic proximity detected by TAP, the geometry of the impacted constraint is shared as polygon (e.g., polygon of a weather hazard that was penetrated by a reroute or polygon of a sector that exceeded its congestion limit because of the reroute). When TAP detects traffic proximity impacts, it sends information about the impacted traffic (e.g., the state of the traffic). For example, a NASCENT advisory, when evaluated by TAP, may be found to violate separation from local traffic. The flight crew would use TAP to modify the NASCENT-generated advisory to avoid the local traffic and send down to the dispatcher this modified route with a note/icon indicating why it had been modified and the state of the impacted traffic. The supporting data may also include other information relevant to flight crew/dispatcher coordination (e.g., predicted fuel remaining).

The coordination process ends when either the flight crew or the dispatcher concurs with the proposed reroute from the other, or either one terminates coordination. The flight crew or the dispatcher register in their respective tools their concurrence (or termination). TAP and NASCENT exchange and update the concurrence messages.

4.3.1.4 Reroute Implementation

Reroute requests to ATC will be made by the pilot to the controller via voice or by the dispatcher through the air traffic coordination position. TAP displays supporting data to assist the pilot in making the request. After the controller responds, the flight crew enters the ATC response (approved as requested, amended, or denied) into TAP. TAP informs NASCENT that the flight crew made the request and the result from ATC as entered by the flight crew. NASCENT informs the dispatcher that a request was made and the result of the request, as communicated by TAP. If the flight crew informed the dispatcher by voice, the dispatcher can also update NASCENT of the request and its status.

5 MAAGIC USE CASES

MAAGIC is an integrated coordination support system for airline flight crews and dispatchers which enhances the current procedures by which reroutes are implemented in the NAS. MAAGIC continuously evaluates flights from both the flight crew and dispatcher perspectives to identify opportunities for efficient flight reroutes. The following use cases focus on the coordination of advisories. In the first use case, the dispatcher invokes a reroute investigation using a NASCENT generated advisory that involves cross-checking with TAP and potential coordination activities among the operators. In the second use case, the flight crew invokes a reroute investigation using a TAP generated advisory that involves cross-checking with NASCENT and potential coordination activities among the operators.

5.1 MAAGIC USE CASE ONE – DISPATCHER INITIATED REROUTE

In the use case described in this section, the dispatcher selects a NASCENT generated advisory, thereby invoking a series of coordination activities among the operators. The use case is described in Tables 5 and 6, including assumptions, conditions, and process steps. Schematic depictions of the use case are shown in Figures 5 and 6 supporting the descriptions in Tables 1 and 2, respectively.

Table 1. MAAGIC Use Case One: Dispatcher Initiated Reroute

Use Case Name:	Dispatcher Initiated Reroute
Summary:	The dispatcher selects a NASCENT generated advisory that triggers a series of coordination activities between the dispatcher assisted by NASCENT on the ground and the flight crew assisted by TAP in the cockpit
Operational Rules:	Operational rules of the airline regarding airborne reroutes are maintained NASCENT advisories are always reviewed by the dispatcher before sending to TAP for flight crew review TAP displays one NASCENT advisory (if one is present) in addition to the three TAP advisories (total of four advisories)
Assumptions:	All NASCENT advisories selected by the dispatcher are automatically sent to TAP and cross-checked by TAP; NASCENT advisors not selected by the dispatcher are not sent to TAP
Pre-conditions:	NASCENT advisories exist for a TAP-equipped aircraft; time savings are large enough to warrant dispatcher notification (larger than the benefit threshold of two minutes); dispatcher workload is suitable for engagement in this use case; dispatcher selects NASCENT advisory for proposal to flight crew

Table 1. MAAGIC Use Case One: Dispatcher Initiated Reroute (Continued)

Use Case Name:	Dispatcher Initiated Reroute (Continued)
Trigger Events:	Advisory generated by NASCENT is selected by the dispatcher for proposal to the flight crew
Nominal Actions:	See Figure 5: 1. NASCENT regularly computes advisories using ground data and constraints 1.1. NASCENT identifies time-saving lateral and/or lateral-vertical advisories 1.2. NASCENT probes advisories for fleet/ATC impacts 1.3. NASCENT puts advisories with time savings larger than the benefit threshold on list for dispatcher review 2. [When able] [If desired] dispatcher selects advisory of interest 2.1. NASCENT sends selected reroute to TAP for cross-checking 3. TAP checks reroute received from NASCENT against airborne constraints 3.1. TAP probes reroute for airborne constraint impacts (e.g., traffic, weather) 3.2. TAP sends airborne constraint impacts and supporting data (e.g., weather polygon or impacted traffic state) to NASCENT 4. [When able] [If desired] dispatcher reviews and manually modifies NASCENT advisory as desired 4.1. Based on TAP cross-check results displayed by NASCENT 4.2. Dispatcher [via NASCENT interface] sends reroute and supporting data to TAP (e.g., ground constraint impacts such as congestion) 5. TAP displays reroute and constraint-check results to flight crew 6. Flight crew adjusts reroute as desired for all available constraints 6.1. Flight crew inspects display of any TAP-detected impacts (e.g., traffic) and other impacts (e.g., onboard weather) 6.2. Flight crew modifies reroute as desired in TAP (e.g., to resolve impacts) 7. [If modified] [If required] [If desired] Flight crew and dispatcher coordinate on reroute via TAP/NASCENT. See Table 2 and Figure 6 for details

Table 1. MAAGIC Use Case One: Dispatcher Initiated Reroute (Continued)

Use Case Name:	Dispatcher Initiated Reroute (Continued)
Exception Paths:	An advisory times-out if trajectory geometric constraints are exceeded (for example, the initial turn becomes very sharp or the initial trajectory segment becomes too short) or benefits diminish below a preset threshold, during the wait with a frozen route before execution
Post-conditions:	Flight crew/dispatcher agreed-upon reroute request communicated to ATC (Step 8 in Figure 5)
Extension Points:	Both use cases, one and two, are triggered simultaneously. This can be handled as part of the coordination process in Figure 6 as a counter proposal.

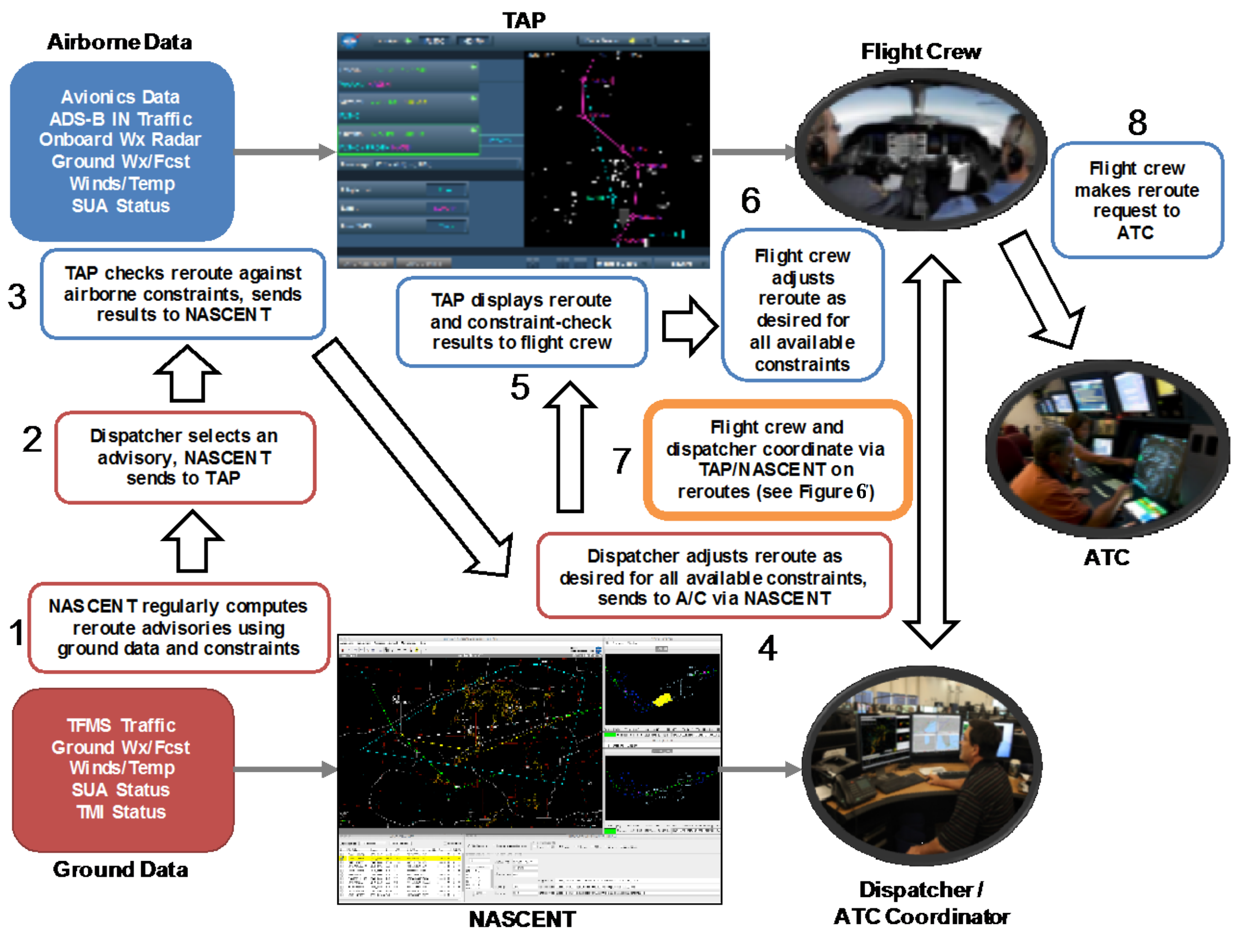

Figure 5. MAAGIC Use Case One: Dispatcher Initiated Reroute

Table 2. Flight Crew – Dispatcher Coordination

Coordination Activities	See Figure 6 1. Flight crew proposes reroute or reroute revision to dispatcher through TAP-NASCENT interface 1.1. TAP sends selected reroute and supporting data (rationale and/or new constraints) to NASCENT 1.2. NASCENT notifies dispatcher of request for coordination 2. [When able] Dispatcher performs constraint checks in NASCENT 3. [When able] [if desired] Dispatcher runs revised flight plan 4. Dispatcher manually modifies reroute in NASCENT as desired or concurs with proposed reroute revision (skip to 9) 5. Dispatcher sends reroute revision to flight crew through the TAP-NASCENT interface, including supporting data (rationale and/or new constraints) 6. TAP displays reroute revision with supporting data (rationale and/or new constraints) to flight crew and notifies flight crew of request for coordination 7. Flight crew checks reroute revision against airborne systems, including the FMS, onboard weather radar (which may be painting convection and/or turbulence) and performing constraint checks in TAP 8. Flight crew manually modifies reroute in TAP as desired (go back to 1) or Flight crew concurs with proposed reroute revision (continue to 9) 9. NASCENT and TAP exchange concurrence and display concurrence messages 10. [When able] [If desired] Flight crew makes reroute request to ATC 11. Flight crew advises dispatcher of ATC response through TAP-NASCENT interface

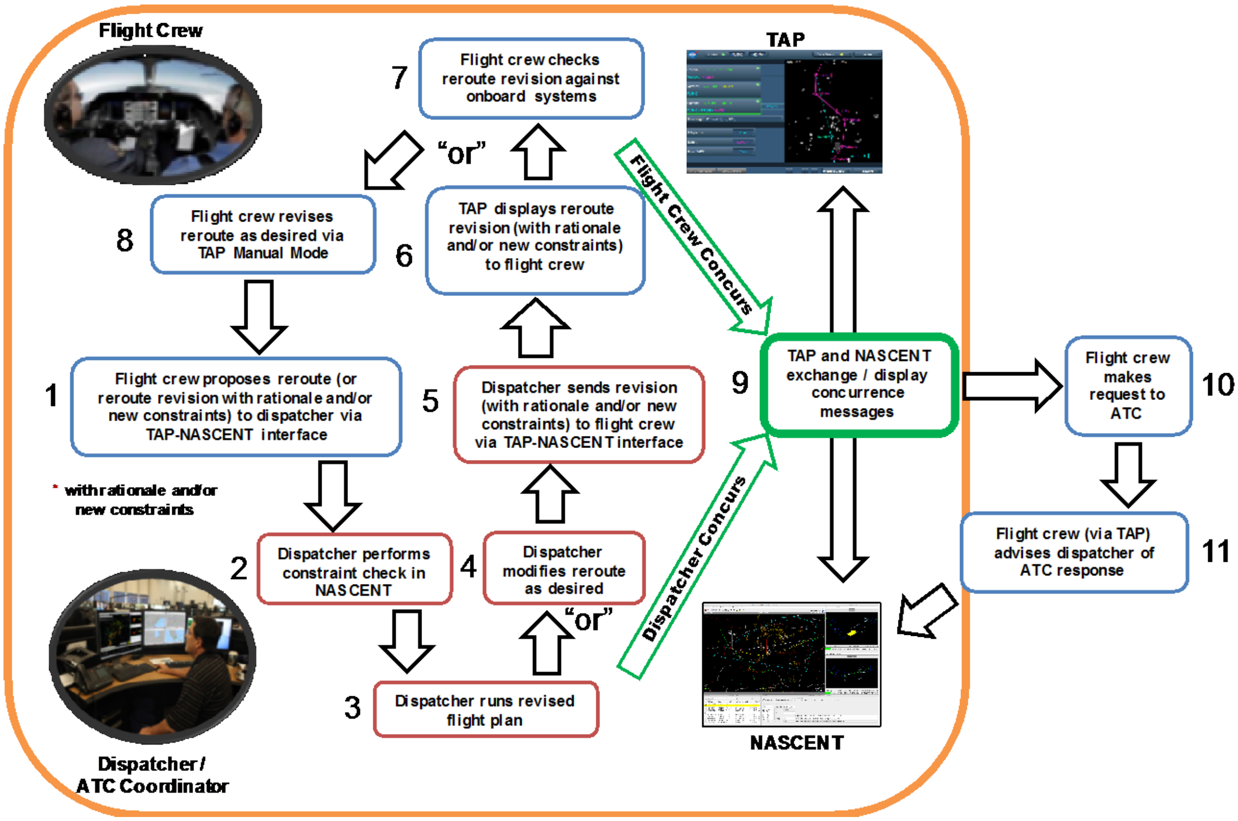

Figure 6. Flight Crew-Dispatcher Coordination (Details of Step 7 in Figure 5, and 6 in Figure 7)

5.2 MAAGIC Use Case Two – Flight Crew Initiated Reroute

In the use case described in this section, the flight crew selects a TAP generated advisory, invoking a series of coordination activities among the operators. Similar to use case one, Table 3 contains a description of the use case. A schematic depiction of the use case is shown in Figure 7.

Table 3. MAAGIC Use Case Two: Flight Crew Initiated Reroute

Use Case Name:	Flight Crew Initiated Reroute
Summary:	The flight crew selects a TAP generates advisory that triggers a series of coordination activities between the dispatcher assisted by NASCENT on the ground and the flight crew assisted by TAP in the cockpit
Operational Rules:	Operational rules of the airline regarding airborne reroutes are maintained NASCENT displays one TAP advisory (if one is present) in addition to the two NASCENT advisories (total of three advisories)
Assumptions:	All TAP advisories selected by the pilot are automatically sent to NASCENT and cross-checked by NASCENT; TAP advisories not selected by the flight crew are not sent to NASCENT

Table 3. MAAGIC Use Case Two: Flight Crew Initiated Reroute (Continued)

Pre-conditions:	TAP advisories exist; flight crew workload is sufficient for engagement in this use case; flight crew selects TAP advisory for potential request to ATC
Trigger Events:	Advisory generated by TAP is selected by the flight crew
Nominal Actions:	See Figure 7: 1. TAP regularly computes advisories using airborne data and constraints 1.1. TAP identifies optimal advisories (lateral, vertical, combo) according to optimization objective 1.2. TAP probes advisories for airborne constraints (e.g., traffic) 1.3. TAP puts constraint-free, highest-benefit advisories on list for flight crew review 2. Flight crew selects an advisory of interest 2.1. TAP sends the selected reroute to NASCENT for cross-checking 3. NASCENT checks selected reroute received from TAP against ground constraints 3.1. NASCENT sends ground constraint impacts and supporting data (e.g., congested sector geometry) to TAP 4. TAP displays reroute and constraint-check results to flight crew 5. Flight crew adjusts reroute as desired for all available constraints 5.1. Flight crew inspects display of any TAP-detected impacts (e.g., traffic) and other impacts (e.g., onboard weather) 5.2. Flight crew modifies reroute as desired in TAP (e.g., to resolve impacts) 6. [If modified] [If required] [If desired] Flight crew and dispatcher coordinate on reroute via TAP/NASCENT. See Table 2 and Figure 6 for details
Exception Paths:	An advisory times-out if geometric constraints are exceeded or benefits diminish below a preset threshold
Post-conditions:	Flight crew/dispatcher agreed-upon reroute request communicated to ATC (Step 7 in Figure 7)
Extension Points:	Both use cases, one and two, are triggered simultaneously. This can be handled as part of the coordination process in Figure 7 as a counter proposal.

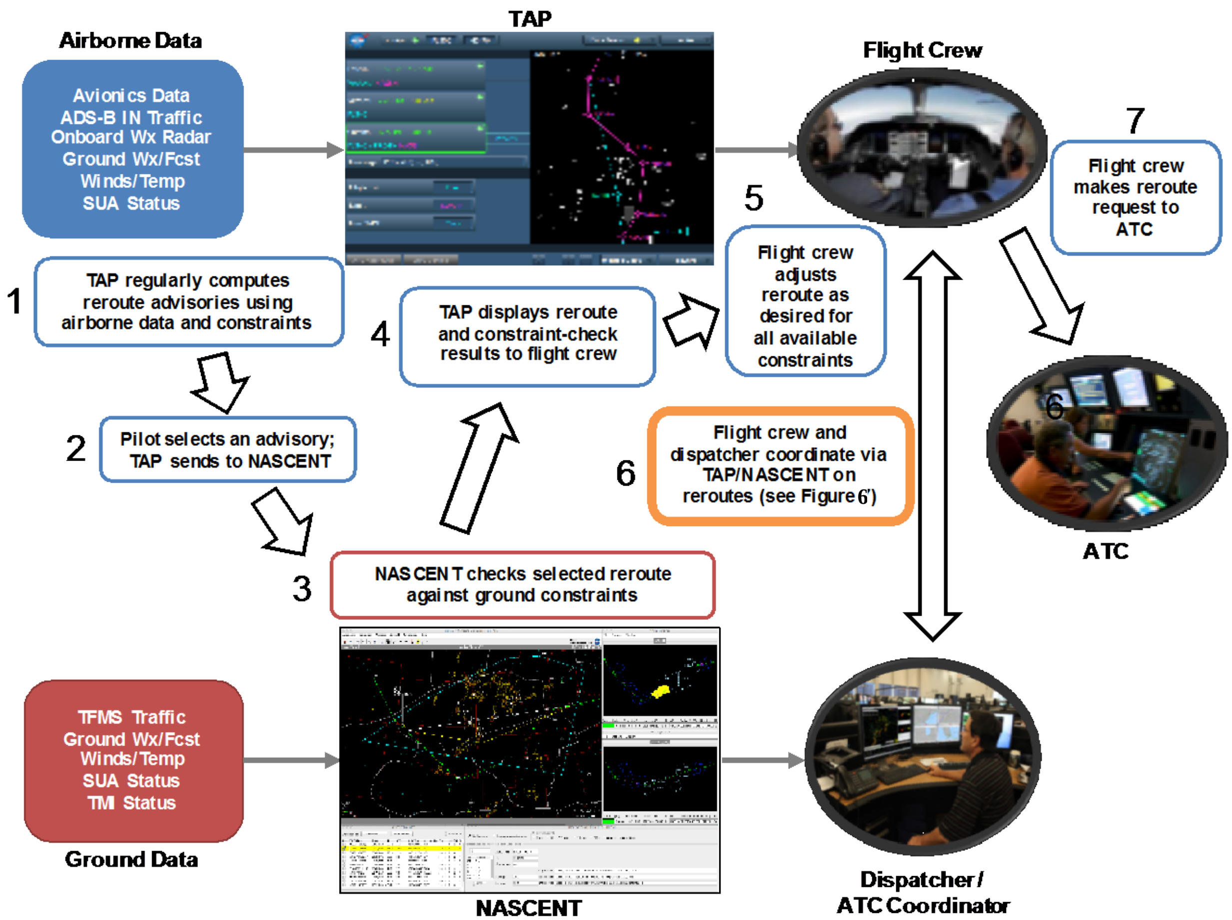

Figure 7. MAAGIC Use Case Two: Flight Crew Initiated Reroute

6 TECHNOLOGIES AND DEPENDENCIES

MAAGIC integrates the functions of two NASA-developed ATM applications to improve reroute operations:

National Airspace System Constraint Evaluation and Notification Tool (NASCENT) – NASCENT is a ground-based automation system that automatically identifies and provides operationally relevant advisories, across all 20 ARTCCs, for wind-adjusted flight-time savings that meet TMIs while avoiding weather and airspace constraints (e.g., SUA/ATCAA and TFRs). NASCENT utilizes the SWIM one-minute traffic flow management update data, state-of-the-art weather products, National Oceanic and Atmospheric Administration (NOAA) wind information, and other airspace constraint information. A detailed description of NASCENT is provided in Appendix A.

Traffic Aware Planner (TAP) - TAP is an onboard automation system to support flight crew reroute requests. Utilizing information available from aircraft flight systems and from ground-based data available through on-board internet connectivity (e.g., weather, special use airspace status), TAP calculates, at one-minute intervals, changes to the current trajectory to better meet user objectives such as saving fuel burn and flight time. Using ADS-B surveillance information, TAP trajectory change advisories are designed to avoid proximity to traffic and thereby achieve a higher probability of approval from air traffic control. A detailed description of TAP is provided in Appendix A.

The following is a list of inputs and dependencies for each tool.

6.1 NASCENT INPUTS AND DEPENDENCIES

NASCENT is a standalone advisory system that does not currently link to the airline dispatcher station. However, the MAAGIC concept depends on the dispatcher interacting with NASCENT using information from the station to enter aircraft route optimization objectives and fleet constraints and to assess impacts of reroutes. The dispatcher may also assess the impact of the route change in the flight planning station.

- Aircraft Communications Addressing and Reporting System (ACARS) – ACARS is a basic data communications system that is interfaced with onboard radio communications units and flight management systems, and can be used to communicate MAAGIC route information between flight crews and dispatchers. The dispatcher uses ACARS to communicate with the aircraft, but MAAGIC provides an alternative conduit for air-ground communication
- Special Use Airspace (SUA) and Temporary Flight Restrictions (TFR) – SUA and TFR activity status information is collected from sua.faa.gov and tfr.faa.gov, respectively.

MAAGIC has no dependence on any FAA automation. Some of the external information used by NASCENT are pulled from FAA systems, in particular from SWIM. This information currently includes:

- Aircraft Tracks (one minute updates) from SWIM.
- Sector congestion – Provides current and forecast sector congestion (Monitor Alert Parameter (MAP)).
- TMI Route Information – Provides active Severe Weather Avoidance Program (SWAP) routes, and Flow Constraint Areas/Flow Evaluation Areas (FCA/FEA).

6.2 TAP Inputs and Dependencies

TAP is a standalone advisory system that does not interfere with the guidance and control of the flight. It connects to the FMS and other avionics though a read-only connection. TAP pulls from the avionics busses data about the aircraft performance such as the current weight and state of the aircraft. In its current form, TAP does not send the FMS any information.

- Flight Management System
  - Trajectory Plan (flight plan) – FMS flight plan is used to identify current trajectory.
  - Aircraft performance parameters and status – Uses onboard and pilot specified performance parameters and preferences to refine recommended reroutes.
  - Wind data from data link feeds (commercial data services or airborne SWIM when available).
- Electronic Flight Bag display – Used as flight crew user interface to interact with TAP. This does not include a moving map depiction.
- Broadband Internet – Flight Information Services
  - Winds and temperature from NOAA.
  - Nexrad weather (current and forecast) from WSI – provides current location, direction and speed of convective cells both in and out of view of on-board weather radar, and is presented in the form of polygon outlines.
  - Regional Winds – Vendor winds aloft forecasts used to augment operator-specific data when needed.
  - SUA Status – FAA SUA status data from FAA's sua.faa.gov used to identify active SUAs.
- ADS-B
  - ADS-B In – TAP uses ADS-B In to determine proximate traffic position to refine proposed reroutes.
- On-board weather radar – provides weather information detected by the on-board weather radar within the radar range. The information is fused with the WSI information for a more accurate weather picture.

7 POTENTIAL FUTURE ENHANCEMENTS

The previous sections described the core capabilities of the MAAGIC concept, which will be demonstrated by the year 2020. This section describes potential future enhancements to MAAGIC envisioned as part of the end-state concept. These additions are desired by NASA and the airline partner who will participate in the demonstration of MAAGIC. The addition of these capabilities will depend on technical feasibility in the project's timeframe.

1. Integration of onboard weather radar: The availability of this data is dependent on technical issues that will need to be resolved by the partner airline.
2. Use of turbulence product: Turbulence data may be included as additional polygons to be included in the reroute search algorithms. Its inclusion is very beneficial as avoiding turbulence has been identified as one of the top reasons for pilot reroute requests (typically altitude changes) in the current environment.
3. Conformance to airline four-dimensional (4D) constraints: The constraints include dispatcher scheduling constraints in the form of flights' being given no later than (NLT) or no earlier than (NET) arrival times at specified waypoints. The inclusion of 4D constraints by the partner airline can facilitate gaining fleet management efficiencies to account for priority among fleet aircraft, connections, gate availability, and to minimize holding.
4. Conformance to TBFM 4D constraints: The constraints include required times of arrival at metering fixes by the FAA Time-Based Flow Management (TBFM) system. The inclusion of 4D constraints can facilitate conformance to FAA arrival scheduling. The role of TAP and NASCENT would be to determine efficient means for arriving close to the specified time, leaving the final conformance to certified systems with Required Time of Arrival (RTA) capability.
5. Integration of NASCENT and TAP advisories with the dispatcher station: The dispatcher handles multiple flights which results in a high workload, limiting the time he or she can devote to evaluating and selecting advisories from the tool. Integrating the advisories into the workstation would eliminate the need to transition between multiple screens, which mitigates some of the workload limitation and facilitates the dispatcher evaluation of candidate reroutes.
6. Output to Data Comm to facilitate ATC request: Integration of Data Comm will allow controllers and flight crews to more easily exchange data (e.g., operator preferences, proposed trajectory changes), review and negotiate reroutes, load proposed reroutes into ground and flight deck automation systems, and improve the situation awareness of both parties. It will enable more complex route changes that include multiple waypoints with increased flexibility and benefits. Data Comm implementation will allow integration of the flight deck and ground systems such that proposed reroutes can be reviewed and

digitally negotiated by the parties involved, regardless of which party initiated the request. This would represent an early implementation of trajectory based operations (TBO).

7. Use of CTOP in flight for communicating route requests with flow management: Using CTOP for airborne flights to digitally deliver complex and strategic route change requests by the dispatcher (or the flight crew) can alleviate workload and increase the success rate of reroute opportunities. Pre-departure CTOP is currently operational but not frequently used by the FAA and the airlines, while CTOP for airborne aircraft is not yet operationally active. MAAGIC would facilitate the use of CTOP and its associated benefits. Also secure internet protocol for authorized users would enable an airline dispatcher and an FAA traffic manager to visualize and coordinate a large route change option that significantly reduces flight time.
8. Airborne Internet: Airborne Internet is a generic term that describes commercial data communications systems between information providers on the ground and aircraft. Airline operators can configure their aircraft systems to utilize some of this data for non-safety critical flight applications which includes ATD-3.
9. Automated NASCENT access to objectives and constraints based on inputs from relevant airline systems (possibly through the dispatcher station): This is the information needed to evaluate the fleet-wide impacts of a reroute is distributed over many airline systems, for example, systems dealing with fleet connectivity, passenger connectivity and aircraft connectivity. Automated access to such information will enable automating some of the evaluation of the fleet-wide impacts of reroutes, which in turn will alleviate some of the dispatcher workload and lead to higher rate of identifying beneficial and feasible reroute requests.

8 SUMMARY

This document presents the MAAGIC Concept of Operations that enables integrated coordination between the flight crew and the dispatcher as they collaboratively plan route changes while the flight is en route. The flight crew is aided by TAP and the dispatcher is aided by NASCENT, two NASA decision support technologies that identify opportunities for more efficient routes and advise and support their respective operators to coordinate these routes if desired or needed (by company procedures) prior to requesting them from the service provider. The operational environment of MAAGIC focuses on flights that are on inefficient routes where some degree of efficiency could be recovered.

Each tool has distinguishable advantages in terms of access to certain information and capabilities to assess route impacts and outcomes. MAAGIC leverages these complementary differences, with three main mechanisms of integration:

1. The tools perform automatic sharing of some information that is initially available to one tool and not the other.
2. At the request of the human operators, each tool sends its candidate route change to the other tool for constraint impact assessment.
3. The tools facilitate flight crew / dispatcher coordination of route changes when either required by the company procedures or desired by the operator.

Each of the tools results in benefits to the operators in terms of fuel and time savings through the identification of more efficient routes and increasing controller acceptability of the route change requests. MAAGIC increases these benefits by facilitating the integration of information and coordination between the flight crew and the dispatcher. With MAAGIC the reroute requests are anticipated to be:

1. More accurate because of sharing information,
2. More optimal and acceptable to the company because of reconciling flight crew and dispatcher objectives and constraints,
3. More expeditious because of sharing impacts and facilitating the coordination, helping the flight crew and dispatcher to agree on advisories faster before the opportunity expires,
4. More acceptable to ATC because of accounting for a greater number of constraints,
5. Less workload intensive for the operators by facilitating their coordination,
6. Less workload intensive to the service provider because of higher acceptability and because of flight crew and dispatcher agreement before making requests.

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APPENDIX A. NASCENT AND TAP DESCRIPTIONS

A.1 NAS CONSTRAINT EVALUATION AND NOTIFICATION TOOL (NASCENT) DESCRIPTION

NASCENT is a NASA decision support tool for flight operators and service providers [2]. In the MAAGIC concept, NASCENT is used as a dispatcher decision support tool for dynamic rerouting. It continuously monitors airspace constraints and identifies opportunities for more efficient routes around those constraints. When the system determines that a flight could save at least a specified amount of time (for example, two minutes) by flying a more efficient route and still avoiding the offending constraints, it will suggest a new route segment for that flight.

The new route segment is defined by up to two additional waypoints, as shown in Figure 8 (which shows reroutes with one extra waypoint). It begins with a Maneuver Start Point (MSP) along the current route, which is a specified time (roughly 5 minutes) ahead of the aircraft's current position. This provides ample time to review and coordinate the route amendment. The end of the route amendment is defined as the Return Capture Fix (RCF) located downstream somewhere on the original flight plan route. RFC distances are limited so as not to exceed downstream fix clearances that are commonly issued today. Graphically connecting this set of commonly cleared downstream fixes creates a "limit polygon" – the cyan box in the display's plan view in Figure 10. RFCs do not extend beyond the transition fix to avoid interfering with approach procedures at the destination airport.

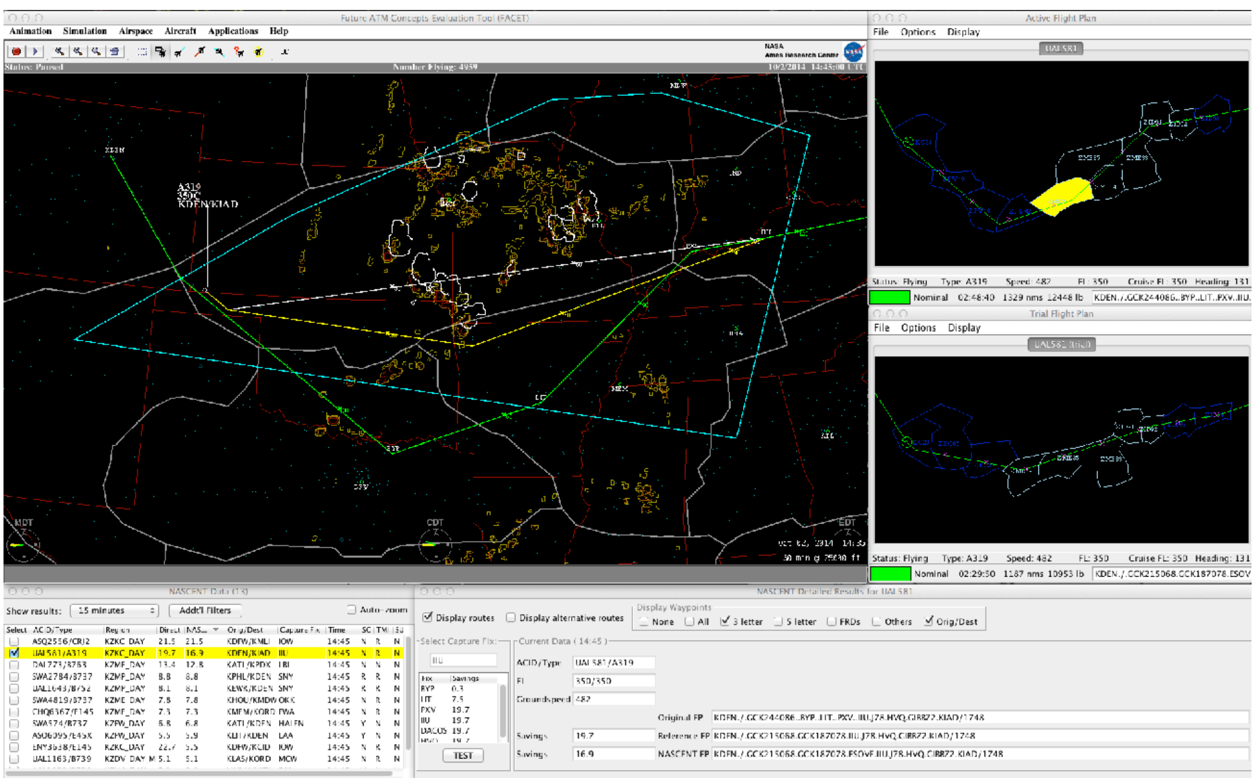

Figure 8. Ground-Based Dynamic Reroute System Display

The system inserts up to two auxiliary waypoints when needed to avoid offending airspace constraints or to issue operationally acceptable clearances. Auxiliary waypoint selection includes an automatic “snap-to” function that will select the nearest named waypoint for ease of use in today’s voice communication environment. Geographic (latitude/longitude) coordinates can also be used for waypoint definition, but are better suited for digital data exchange using Data Comm. Route advisories avoid SUAs/ATCAAs and TFRs, and inform the user when the proposed route is impacted by a FAA TMI or sector congestion. Once a route correction is found that meets the user-defined, time-saving parameter, the flight is posted to a list displayed to the dispatcher showing the estimated time savings based on aircraft speed corrected for winds.

Figure 8 shows a snapshot of the dynamic rerouting display split into 3 main parts. The largest window in the display shows a plan view with the Center boundaries in gray and the current convective weather cells as yellow polygons (from the FAA’s Corridor Integrated Weather System (CIWS)). The white polygons represent the projected convective weather areas that must be avoided and is from the NASA/MIT-LL’s Convective Weather Avoidance Model (CWAM), a product derived from CIWS [5]. The Reference Route is shown in gray, the dynamic reroute in yellow, and the currently active Flight Plan Route in green. Note that the yellow dynamic reroute in the figure uses one additional waypoint to avoid the projected convective weather areas. The limit polygon outlined in cyan represents the boundary within which the downstream return capture fix will be selected by NASCENT.

NASA field trials at American Airlines have shown that dynamic rerouting capabilities can be implemented in airline operation centers (AOCs) to allow ATC coordinators and dispatchers to identify desirable reroutes and coordinate associated trajectory change requests through the flight crew [6]. Coordination with flight crews in this scenario is best done through the airline’s digital communications system (ACARS) due to workload demands on the AOC during active weather days, but can be done via voice communications. In the future, it may be possible for dispatchers to also coordinate reroutes directly with the Center traffic management coordinators (TMCs) via a web interface. In all of these cases, workload constraints in the airline operations center during active weather days may limit the airlines ability to review and coordinate a large number of dynamic reroutes. Therefore, benefits may be higher if both the AOC and Center TMU utilize dynamic reroute capabilities.

A.2 Traffic Aware Planner (TAP) Description

TAP is cockpit automation system that continuously searches for more efficient routes [1]. Complementary to the ground-based system, it leverages flight management systems and onboard weather, wind, and traffic data to identify wind-optimized routes and altitudes that will save time and/or fuel.

TAP is supported by the emergence of three systems: avionics-connected Electronic Flight Bags (EFB), Automatic Dependent Surveillance Broadcast (ADSB)-Out/In, and broadband internet connectivity to the flight deck. The EFB provides a platform for powerful applications to utilize real-time aircraft navigation and performance data, ADS-B traffic data, onboard weather radar and system-wide information from broadband internet connectivity. Airborne internet provides EFB applications with connectivity to an array of external information on operational factors such as airspace constraints, traffic flow restrictions, wind predictions, weather hazards, and Special Use Airspace (SUA) status, thereby giving the applications real-time data on the aircraft's operating environment. As the flight proceeds and conditions evolve, EFB applications can act immediately with the most accurate and up-to-date information. This potentially reduces controller coordination workload for each change since requests will generally be more acceptable and easier to coordinate and should increase the approval rate of reroute requests [1].

TAP allows greater opportunity for optimization and provide immediate benefits for equipped flights. There may be times when airborne weather radar reveals convective activity not detected by ground systems. In such cases, the flight crew would use the flight deck system to identify and request their own reroutes.

The flight deck user interface displays advisories textually and graphically using published fixes to facilitate efficient voice requests to ATC. The display includes no depiction of traffic or own-ship positions, thus minimizing certification costs. The flight deck reroute capability can be operated in automatic (auto) and manual modes. Figure 9 shows an example of the flight deck display in auto mode and Figure 6 in manual mode. Both manual and auto mode displays include a plan view with the flight plan route depicted with a solid magenta line and waypoint, and the proposed reroute is depicted with a dotted cyan line and waypoints. The display provides an indication whether or not data feeds (from airborne internet) are available, and allow the crew to select what data is layered in the plan view window. They also provide winds aloft information. The waypoint button allows the crew to zoom in on each leg of the flight plan and proposed route. The ATC and dispatcher buttons at the bottom of the display are currently used for data collection and analytical purposes, but provide the opportunity for greater automation integration with on-board navigation and digital communication systems in the future.

Figure 9. TAP User Interface in Auto Mode

In auto mode, the system continuously scans for three types of trajectory changes: lateral-only, altitude- only, and combination lateral/altitude changes. The upper left area of the display shows potential fuel and time savings for each. Searching hundreds of candidate trajectory changes with up to two off-route named waypoints, the algorithm converges on the best based on operator preferences. Examples of operator trajectory preferences include the most fuel-efficient, fastest flight time, or minimum trip cost. A typical objective would be to maximize fuel efficiency. The objective (fuel, time, or trip cost) is selected and displayed in using the interface in the lower left of the display.

Candidate advisories are wind-optimized and clear of known traffic and airspace conflicts before the flight crew requests a change from ATC. Advisories for lateral only, vertical only and a combination of vertical and lateral optimization are presented with projected fuel and time savings, and specifics of the lateral and vertical change proposed.

The limit field represents the flight plan waypoint beyond which the system will not search and is set by the flight crew. The flight crew can also set the vertical limit with specific altitudes or to auto, which then uses aircraft performance limits. Like the ground-based system, the maximum number of auxiliary waypoints is two.

Figure 10 shows an example user interface in Manual Mode. In manual mode, the pilot initiates the search for more efficient routes/altitudes in the onboard system when a trajectory change is desired by the crew or airline dispatcher. The pilot enters a desired trajectory change into the interface by identifying or by editing the reroute waypoints on the plan display to the area desired. The line will snap to the nearest published waypoint(s). The system checks the trial trajectory change for weather, traffic and SUA conflicts. The proposed reroute is depicted with a dotted cyan line and waypoints, but will change to yellow if the route conflicts with weather, traffic or SUA. In the case of SUA conflicts, the offending SUA area will be outlined in yellow.

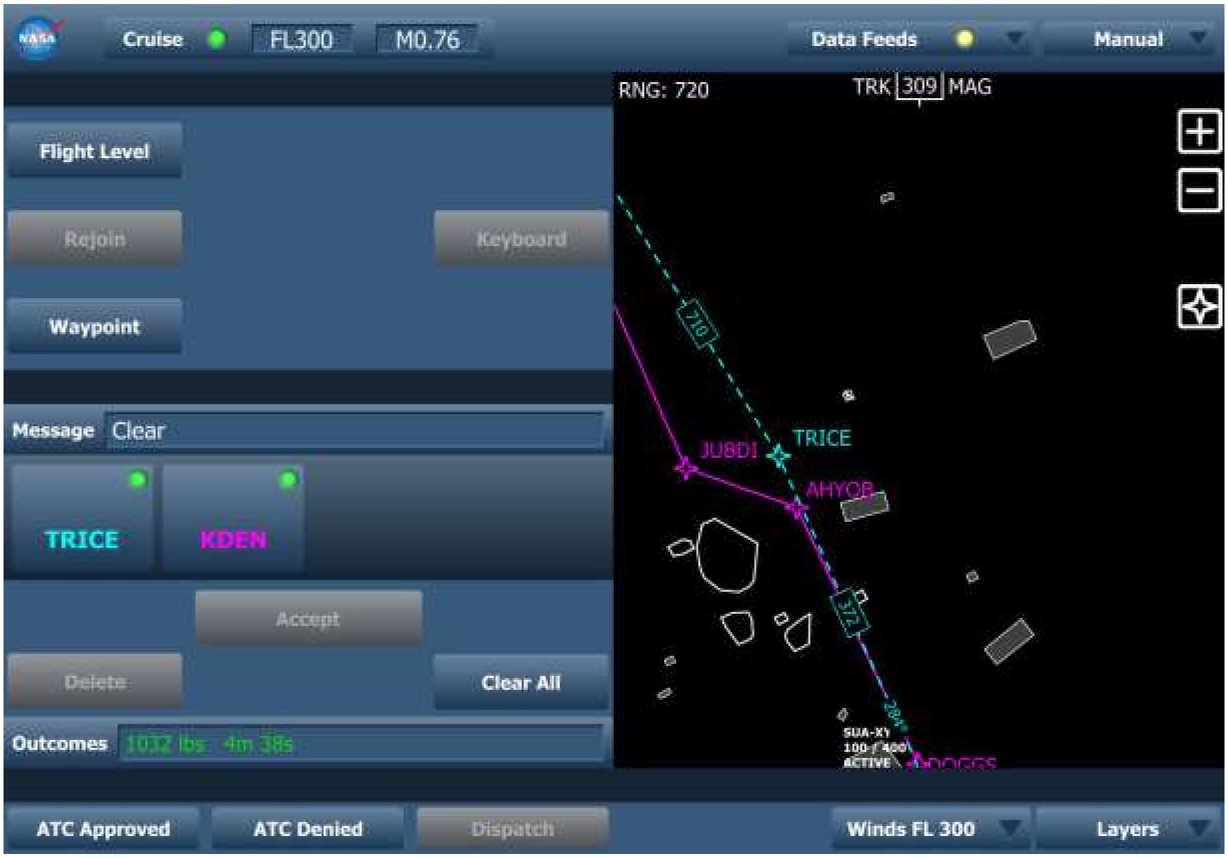

Figure 10. TAP User Interface in Manual Mode

The corresponding estimated fuel and time savings are displayed in the outcomes field. Manual Mode may also be used by the flight crew to evaluate trajectory change proposals initiated by ATC or in response to the crew's request by ATC. In those cases, the crew would manually enter or select the flight level and waypoints if they want to visualize the change prior to entering it in the flight management system. Otherwise, a change to the route in the flight management system would show up on the reroute display as the new flight plan route (dotted cyan line).

The flight deck application is anticipated to save fuel and flight time and provide immediate and on-going benefits to the aircraft operator, as well as improving flight schedule compliance, passenger comfort, and pilot and controller workload.

GLOSSARY

Acronym	Name	Description
4D	Four Dimensional [trajectory]	Planned trajectory defined laterally in two dimensions, plus altitude and time/speed
AAtS	Aircraft Access to SWIM	Concept of aircraft accessing SWIM information feed while in flight
ACARS	Aircraft Communications Addressing and Reporting System	The current technology for digital communication between the cockpit and the AOC
ADS-B	Automatic Dependent Surveillance-Broadcast	Satellite-based surveillance and broadcast system whereby an equipped aircraft senses its position and broadcasts it to it surrounding traffic and the ground. It provides an aircraft that is equipped with ADS-B In awareness of surrounding aircraft that are equipped with ADS-B Out.
AOC	Airline Operations Center	Airline Operations Centers manage the day-to-day flight schedules and operations. This includes coordinating with FAA operations, routing flights, changing or cancelling flights, managing crew and aircraft scheduling, and coordinating changes with flight crews. Some corporate operators use similar resources call Flight Operations Centers (FOC). FOCs have similar capabilities to AOCs, but on a smaller scale.
ARTCC	Air Route Traffic Control Center	Also known as 'center' a facility responsible for controlling aircraft en route in a particular volume of airspace at high altitudes between airport approaches and departures. There are 20 ARTCCs in the contiguous United States.
ATC	Air Traffic Control or Controller	A person or group of people responsible for managing, directing and separating air traffic.
ATCSCC	Air Traffic Control System Command Center	The FAA facility that oversees the system-wide flow of air traffic and coordinates the actions of ARTCCs and TRACONS.
ATD	Airspace Technology Demonstration	NASA's Airspace Operations and Safety Program intended to advance traffic management operations in the NAS. ATD-

		1=Approach, ATD-2=Departure, ATD-3=En route & arrival
ATM	Air Traffic Management	The overall name given to the air traffic processes encompassing air traffic control and traffic flow management
CAL	Control Authority Limit	Company criteria delineating requirement for flight crew / dispatcher coordination
CDM	Collaborative Decision Making	Collaborative Decision Making is used by the FAA and flight operators to coordinate changes to TMIs, routes, flight prioritization, and departure times and sequences
CIWS	Corridor integrated Weather System	3D convective weather forecasts with 0-2 hours predictions of cell development and movement.
CTOP	Collaborative Trajectory Options Program	FAA program that allows operators to file flight plans with multiple routes that will be selected based on the magnitude of departure delay and direction of flight.
CWAM	Convective Weather Avoidance Model	Utilizes CIWS predicted convective cell movement to determine if a candidate reroute will avoid convective cells by a large enough margin to satisfy flight crews.
Data Comm	Data Communications	Generic term used to describe a digital communication system between controllers and pilots to exchange data, issue clearances or instructions, and make requests.
EFB	Electronic Flight Bag	Electronic devices that are external to the cockpit automation and provide the flight crew with certain information.
FCA	Flow Constrained Area	Dynamic airspace area in which some type of traffic flow constraint limits or prevents traffic from being routed through the area and requires implementation of a traffic management initiative.
FEA	Flow Evaluation Area	Airspace that is being monitored to determine if it should become an FCA.
FMS	Flight Management System	A cockpit automation that provides flight control capabilities
FOC	Flight Operations Center	The facility where corporate flight operators coordinate flight plans, aircraft, maintenance, personnel, and related services.

GDP, GS	Ground Delay Program, Ground Stop	TFM programs that imposes delays or stops on flights from several origin airports destined to a constrained airport or a constrained airspace volume
GDS	Ground Data System	An interface built by NASA to connect TAP and NASCENT and access external data sources
LOA	Letters Of Agreements	Letters of agreement between FAA facilities that detail the procedures of their interactions regarding traffic control
MAAGIC	Multi-Agent Air/Ground Integrated Coordination	NASA's concept to demonstrate air/ground coordination of reroutes to support flight operators and service providers in managing dynamic en route trajectory changes to improve flight and system performance in the presence of convective weather and other airspace constraints
MIT	Miles-in-Trail	A traffic management initiative that imposes spacing between successive flights destined to a particular fix or airport for reducing demand
MSP	Maneuver Start Point	The point along a flight planned route at which a DWR reroute begins
NAS	National Airspace System	The National Airspace System is the interaction of commercial aviation, civilian aviation, the FAA, vendors, suppliers, and related parties and agencies.
NASCENT	NAS Constraint Evaluation and Notification Tool	NASA ground-based technology that identifies and advises more efficient routes while in flight.
RCF	Return Capture Fix	The waypoint at which a reroute rejoins the active route.
SOP	Standard Operating Procedures	Descriptions of the procedures that rule the operations of a and FAA facility or an AOC
SUA	Special Use Airspace	Airspace volumes reserved for special activities such as military operations or sport events
SWAP	Severe Weather Avoidance Plan	SWAP is a TMI that utilizes a subset of national predefined routes (Playbook routes) to divert traffic around significant current or predicted constraints, usually convective weather

SWIM	System-Wide Information Management	An FAA centralized information sharing system that enables all stakeholders access to common information
TAP	Traffic Aware Planner	NASA EBF technology that identifies and advises more efficient routes while in flight.
TASAR	Traffic Aware Strategic Aircrew Requests	NASA technology program that enables aircrews to identify and request more efficient routes while in flight.
TFM	Traffic Flow Management	Generic term for personnel, procedures, and decision support tools used to meter and manage traffic demand.
TFMS	Traffic Flow Management System	Traffic flow automation utilized by traffic managers to monitor demand and manage TMIs.
TFR	Temporary Flight Restrictions	Restricted airspace that is imposed temporarily, for example, for maintaining security around a VIP flight
TMC	Traffic Management Coordinator	FAA employee responsible for the flow of aircraft through or within the center's airspace, not for maintaining separation between individual aircraft.
TMI	Traffic Management Initiative	Generic term used to describe various traffic flow management operational tools and procedures to manage and meter traffic demand.
TMU	Traffic Management Unit	Department of ARTCC or TRACON in which TMCs manage traffic using TFM tools.
TOS	trajectory option sets	Set of prioritized trajectories per flight provided by flight operators to the service provider as part of CTOP
TRACON	Terminal Radar Approach Control	Also known as 'terminal' a facility responsible for controlling arriving and departing aircraft inside an airspace volume that surrounds major airports.
ZTL	Atlanta ARTCC	Air route traffic control center (ARTCC) which manages traffic in the region surrounding Atlanta
ZJX	Jacksonville ARTCC	Air route traffic control center (ARTCC) which manages traffic in the region surrounding Jacksonville

Partnership Agreement Maker - PAM *V.2.0*

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

Title of Package:(*edit*)
2017-10-12: ATD-3 MAAGIC Concept of Operations V1.0
Routernumber:33995

Group this package under:
HQAOSP

Routing Package Administrator:Angela Boyle(*edit*)
Comments:(*edit*)

For review and approval. Please expedite

For questions, please contact:
Stephanie Harrison: stephanie.j.harrison@nasa.gov

This Package started routing on:10/12/2017 12:04:20 PM
Time needed to route: 36 days (*edit*)

Who do you want to review this agreement?*(In order of review)*

Routing Sequence Number	Name/Title/Email/Phone/Comments	Concurrence /Approval	P S	A A	X	Options
1	**Husni Idris** **Title:**ATD-3 MAAGIC ConOps Author husni.r.idris@nasa.gov **Phone:**650.604.0737 **Comment From Reviewer:** 10/13/2017 7:16:16 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/13/2017 7:16:16 PM				✉
2	**Karl Bilimoria** **Title:**ATD-3 MAAGIC Ground Lead karl.bilimoria@nasa.gov **Phone:**650.604.1638 **Comment From Reviewer:** 10/13/2017 7:46:51 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/13/2017 7:46:51 PM				✉

2	**David Wing** **Title:**ATD-3 MAAGIC Air Lead david.wing@nasa.gov **Phone:**757.864.3006 **Comment From Reviewer:** 10/14/2017 12:41:31 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/14/2017 12:41:31 PM				✉		
2	**Stephanie Harrison** **Title:**ATD-3 Lead Systems Engineer stephanie.j.harrison@nasa.gov **Phone:**757.864.8812 **Comment From Reviewer:** 10/17/2017 11:16:40 AM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/17/2017 11:16:40 AM				✉		
2	**Kelly Burke** **Title:**ATD-3 MAAGIC Human Factors Lead kelly.a.burke@nasa.gov **Phone:**757.864.5338 **Comment From Reviewer:** 10/16/2017 3:29:03 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/16/2017 3:29:03 PM				✉		
3	**Brian Baxley** **Title:**ATD-3 MAAGIC Lead brian.t.baxley@nasa.gov **Phone:**757.864.7317 **Comment From Reviewer:** Have read the ConOps, no comments or changes, and agree with it as written. 10/17/2017 2:55:13 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/17/2017 2:55:13 PM				✉		
4	**Kapil Sheth** **Title:**ATD-3 Sub-Project Manager kapil.sheth@nasa.gov **Phone:**650.604.5728 **Comment From Reviewer:**	Yes- 10/27/2017				✉		

	10/27/2017 6:17:29 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	6:17:29 PM						
5	**Mike Madson** **Title:**ATD Deputy Project Manager mike.madson@nasa.gov **Phone:**650.604.3621 **Comment From Reviewer:** 10/31/2017 5:19:04 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 10/31/2017 5:19:04 PM						
6	**Leighton Quon** **Title:**ATD Project Manager leighton.quon@nasa.gov **Phone:**650.604.3073 **Comment From Reviewer:** what''s architecture for the TAP/NASCENT interface to send info back and forth? 11/17/2017 1:20:47 PM **Response To Reviewer Comments:** (Add/Edit) Email Sent	Yes- 11/17/2017 1:20:47 PM						
Add Reviewer								
Add to be Template								
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Files Attached to this Package

Name	Description	Add/View Revision	Delete
33995_MAAGIC_ConOps_1.0_20171012-Final_rev1.pdf	ATD-3 MAAGIC ConOps	Add Revison	
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Subject: E-Router Package - 2017-10-12: ATD-3 MAAGIC Concept of Operations V1.0 - Completed
Date: Friday, November 17, 2017 at 10:20:47 AM Pacific Standard Time
From: Angela.M.Boyle@nasa.gov
To: Boyle, Angela M. (ARC-AT)[WYLE LABS]

Angela Boyle
The Routing Package with the title 2017-10-12: ATD-3 MAAGIC Concept of Operations V1.0 has been completed.

Package Number: 33995

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