Federal Aviation Administration

Integrated Required Time of Arrival (RTA) and Interval Management (IM) Concept of Operations

Approved:

DANIEL S. HICOK Digitally signed by DANIEL S. HICOK
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Dan Hicok
Director, Mission Support Strategy Directorate, AJV-S

Federal Aviation Administration
800 Independence Avenue
Washington, D.C. 20591

Version History

Version	Date	Notes
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Coordination Draft (v0.2)	June 16, 2022	Addressed comments from AJV-S's second review.
Coordination Draft for FAA Review (v0.3)	July 8, 2022	Updates based on feedback from FAA reviewers during review kick-off briefing. Addressed editorial comments identified by team.
Coordination Draft for FAA Review (v0.4)	August 16, 2022	Address comments from ANG and AJM-4 reviewers.
Coordination Draft for FAA Review (v0.5)	November 15, 2022	Incorporate feedback from AJT, NATCA, AIR, and AFS reviewers.
Coordination Draft for FAA Review (v0.6)	December 5, 2022	Incorporate written feedback from NATCA, AJT, and AFS.
Final Version (v1.0)	December 16, 2022	Final version of the ConOps delivered to industry stakeholders.

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Terminology

The terminology used in this document is defined here. In some cases, terms have been changed from other documents to provide clarity and consistency between the Required Time of Arrival (RTA) and Interval Management (IM) operations and their respective flight-deck capabilities.

RTA and Time of Arrival Control (TOAC)-related Terms

- **Required Time of Arrival (RTA)** describes the operation using the TOAC capability on the flight deck to meet an Air Traffic Control (ATC)-provided clock time (also called the RTA) at a defined point. RTA operations involve the use of ground-based automation systems to identify RTA-capable aircraft and the RTA clearance information.
- **Time of Arrival Control (TOAC)** refers to the flight-deck capability (i.e., the avionics) used for RTA operations.
- **TOAC speed guidance** refers to the speed guidance calculated by the TOAC capability to meet the RTA at the point where it applies.
- **RTA-capable aircraft** refers to a flight that is equipped with the TOAC capability and the flight crew has been trained to perform RTA operations.
- **RTA Aircraft** refers to an aircraft that is implementing TOAC speed guidance to meet an ATC-issued RTA clearance.
- **Absolute spacing** describes the use of fixed (clock) times at points in the airspace to meet Time-Based Management (TBM) objectives. An RTA operation is an absolute spacing operation.

IM and Flight-deck IM (FIM)-related Terms

- **Interval Management (IM)** describes the operation using the FIM capability on the flight deck to meet an ATC-provided Assigned Spacing Goal (ASG) relative to a Lead Aircraft. IM operations involve the use of ground-based automation systems to identify IM-capable aircraft and the IM clearance information.
- **Flight-deck Interval Management (FIM)** refers to the flight-deck capability (i.e., the avionics) used in IM operations.
- **Assigned Spacing Goal (ASG)** is the ATC-provided spacing goal that the FIM capability is attempting to achieve or maintain. The ASG is provided in time (seconds) or distance (Nautical Miles [NM]). This document only describes the use of time-based ASGs as time is the relevant parameter for TBM operations.
- **IM clearance type** refers to the desired IM spacing behavior. Two different IM clearance types are described in this document: Cross and Maintain.
- **Cross clearance type** describes the use of the FIM capability to achieve the ASG at the Crossing Point (CP) and then maintain the ASG until the Planned Cancellation Point (PCP) or until terminated by ATC.
- **Maintain clearance type** describes the use of the FIM capability to quickly achieve the ASG and then maintain the ASG until the PCP or until terminated by ATC.
- **FIM speed guidance** refers to the speed guidance calculated by the avionics to achieve and/or maintain the ASG relative to the Lead Aircraft.
- **IM Aircraft** refers to a flight that is implementing FIM speed guidance to meet an ATC-issued IM clearance.
- **Lead Aircraft** refers to a flight that an IM Aircraft is spacing relative to.
- **Intended Flight Path Information (IFPI)** describes the information provided in the IM clearance to describe the Lead Aircraft's cleared navigation route. This information is used by the FIM

capability to predict the Lead Aircraft's trajectory and is used as part of the FIM speed calculation.

- **IM-capable aircraft** refers to a flight that is equipped with the FIM capability and the flight crew has been trained to perform IM operations.
- **RTA+IM-capable aircraft** refers to a flight that is equipped with both the FIM and TOAC capabilities and the flight crew has been trained to use both.
- **Relative spacing** describes the use of a spacing interval relative to another aircraft to meet TBM objectives. An IM operation is a relative spacing operation.

General Terms

- **Data link communications** describes a flight-deck capability to receive and send messages digitally. This document will not imply specific data communications links described in the baseline operation.
- **Ground-based automation** is generally used to refer to automation systems used by Federal Aviation Administration (FAA) air traffic personnel to manage and separate aircraft.
- **Leading aircraft** is used to refer to the sequence of flights (i.e., an aircraft preceding the trailing aircraft).
- **Trailing aircraft** is used to refer to sequence of flights (i.e., an aircraft following the leading aircraft).

1. Introduction

The purpose of this concept of operations (ConOps) document is to describe the operational and functional characteristics of Required Time of Arrival (RTA) and Interval Management (IM) operations when used together in a Trajectory-Based Operations (TBO) environment.

This integrated RTA and IM ConOps document was developed by the Federal Aviation Administration (FAA) in response to a NextGen Advisory Committee (NAC) recommendation requesting the FAA clarify and document how these concepts could be used together in a TBO environment. To date, the avionics capabilities needed to conduct RTA and IM operations have been developed independently. This document provides input to committees developing standards for the avionics capabilities needed to conduct RTA and IM operations, avionics manufacturers developing those capabilities, and to airlines considering future flight-deck capabilities for their fleets. Without this ConOps, the avionics capabilities will continue to be developed independently, potentially limiting benefits to the National Airspace System (NAS) and airlines.

1.1 Background

To enable a more efficient and predictable NAS with reduced flight delays, the FAA has been deploying capabilities and procedures to introduce TBO into the NAS. The FAA defined TBO as "an Air Traffic Management (ATM) method for strategically planning, managing, and optimizing flights throughout the operation by using Time-Based Management (TBM), information exchange between air and ground systems, and the aircraft's ability to fly precise paths in time and space" [1]. TBM capabilities provide the underlying ATM Decision Support Tools (DSTs) that enable controllers and traffic managers to efficiently manage flights in high-density traffic conditions. TBM tools enable the transition from tactical, distance-based traffic management techniques to more strategic TBM techniques. TBM also involves strategic management and optimization of trajectories throughout an operation by leveraging Performance Based Navigation (PBN) procedures and aircraft abilities to fly precise paths in time and space.

The first phase of TBO (termed initial TBO), completing in 2025, will leverage significant FAA investments already made in PBN procedures, surveillance infrastructure, and upgrades to TBM DSTs and flight data management systems. The TBM systems that enable TBO (shown in Figure 1-1) are the Traffic Flow Management System (TFMS), the Time-Based Flow Management (TBFM) system, and the Terminal Flight Data Management (TFDM) system. With respect to the environment shown in Figure 1-1, the purpose of each system is:

- TBFM: schedules airborne and departure flights to points in en route and terminal airspace and provides air traffic controllers with DSTs to manage flights to their schedule times.
- TFMS: helps plan and implement Traffic Flow Management (TFM) strategies, including Traffic Management Initiatives (TMIs), use of TBM operations, and airborne and pre-departure re-routes to mitigate demand and capacity imbalances in en route and terminal airspace. TFMS also supports Collaborative Decision Making (CDM) processes by providing a common view of the NAS and helping quantify the impacts of ATM decisions on various stakeholders.
- TFDM: integrates surface operations into TBM and provides air traffic controllers with flight data management tools to increase surface and terminal area traffic management efficiencies.

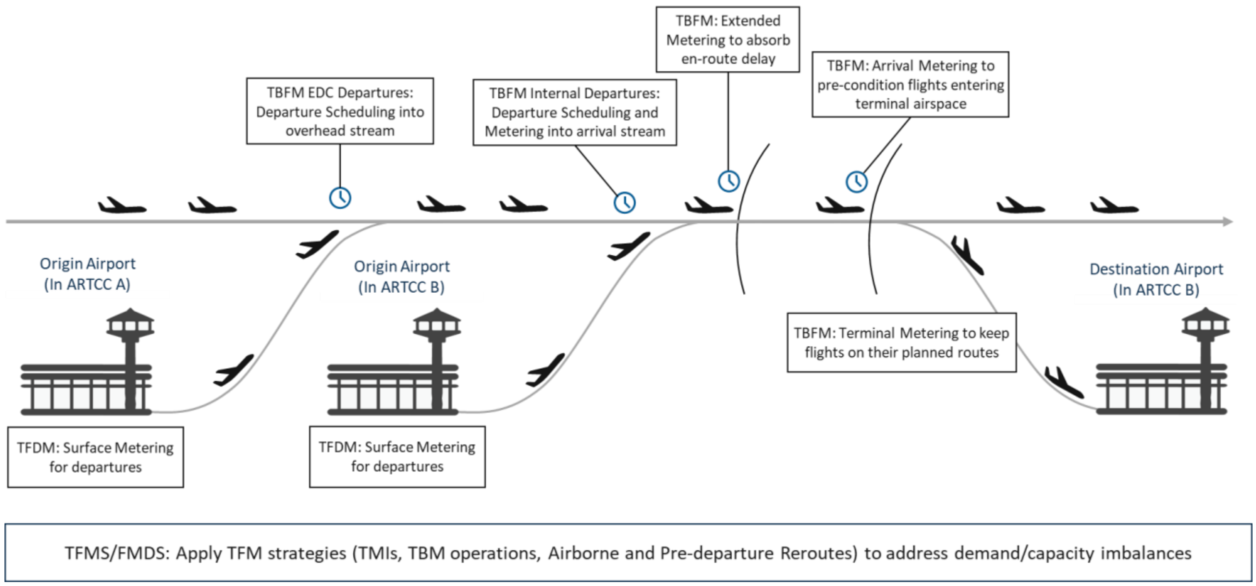

Figure 1-1. Initial TBO: Realizing Performance Based Navigation and Time-Based Management.

Following initial TBO, the FAA will continue to enhance and expand TBM automation and flight-deck capabilities toward full and dynamic TBO [2].[1] Full and dynamic TBO phases include integrated automation capabilities for advanced trajectory management, such as improved strategic flow management and flight planning, airborne flight negotiation, and departure planning. It also includes individual aircraft solutions enabled by Automatic Dependent Surveillance-Broadcast (ADS-B) In applications and mobile applications. The capabilities included in full and dynamic TBO phases highlight an increased use of flight-deck capabilities, including information exchange between air and ground systems and PBN capabilities on the aircraft.

The FAA recently published a document describing operations in an information-centric NAS (referred to as the "Info-centric NAS") [3]. That vision document highlights the need to scale NAS operations to accommodate diverse users (i.e., greater numbers of traditional NAS users, commercial space operations, as well as new entrants like Urban Air Mobility). To support this future vision, the foundation provided by TBO, including capabilities supporting air/ground information exchange, ground-based automation enhancements, and aircraft systems, must be in place.

For the past two decades, the FAA and other stakeholder organizations have been researching and developing flight-deck capabilities intended to increase NAS throughput and reduce delays. These include the Time of Arrival Control (TOAC) capability, used for RTA operations, and ADS-B In applications, such as the Flight-deck Interval Management (FIM) capability used for IM operations. While the FAA has studied the use of TOAC and FIM capabilities in the TBO environment to enable throughput and efficiency benefits, the concepts and avionics standards have been largely studied and developed independently. This integrated ConOps has been developed to describe how RTA and IM operations may be used in a common environment. As a result of this effort, changes to TOAC and FIM avionics standards may be identified to ensure consistency in avionics performance, promoting ATC and flight crew acceptability.

[1] See slide 6 in reference [2] for details on full and dynamic TBO phases.

1.2 Concept Overview

This section provides a high-level summary of the TBM, RTA, and IM concepts. Further details on the RTA and IM concepts and their avionics capabilities are provided in Section 4.

1.2.1 Time-Based Management

TBM operations are one TFM method to efficiently balance traffic demand with available airspace and airport capacity. TBM uses time as a common planning variable to define a sequence and appropriate flight crossing times at constraint points in the airspace. Implementation of TBM is achieved through the integration and application of TFMS (or its future replacement system, Flow Management and Data Services [FMDS]), TBFM, and TFDM to schedule and manage flights over their entire operation.

Figure 1-2 depicts TBM operations in en route and terminal airspace. In this environment, TBM operations are primarily enabled using the TBFM system, which was originally developed for the arrival metering operation to effectively manage flows into terminal airspace by scheduling flights at Meter Fixes (MFs), on the boundary between en route and terminal airspace, and at the runway [4]. The core functions of the TBFM system include the trajectory generation, scheduling, and meet-time advisory generation functions [4, 5]. As part of the original TBFM implementation, flights were only managed to their Scheduled Times of Arrival (STA) at the MFs, which helped to pre-condition traffic as it entered the terminal. The extended metering operation, depicted in Figure 1-2, was later added to TBFM to extend metering operations further into the en-route environment. This allows scheduled delays, which are needed to deconflict flights at the MFs and runways, to be absorbed over longer distances using speed changes instead of less-efficient, path-lengthening maneuvers. En route meter arcs upstream of the MF are used to segment metering operations into smaller distances, which allows scheduled times to be frozen as flights progress thereby allowing schedule flexibility as flights are subject to uncertainties in the operational environment [6].

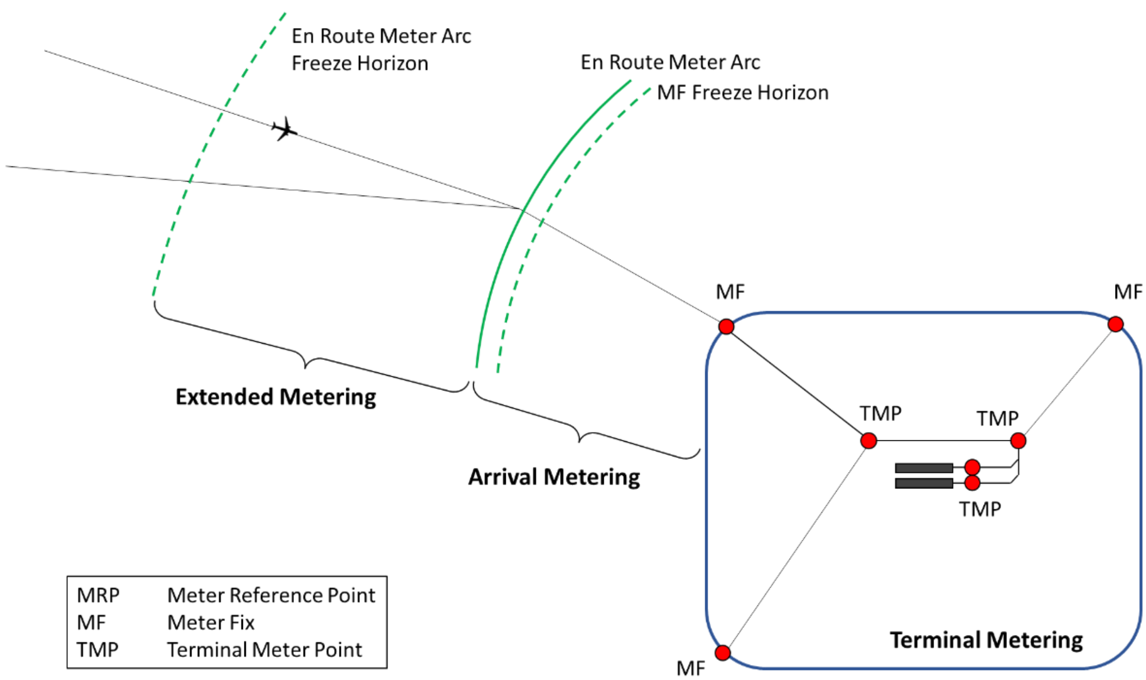

Figure 1-2. Depiction of TBM Operations including Extended, Arrival, and Terminal Metering Operations.

As a flight crosses the en route meter arc freeze horizon[2], its STA at the en route meter arc is frozen, and ATC begins managing the flight to meet its STA. As depicted in Figure 1-2, when the flight crosses the en route meter arc freeze horizon, only the STA at the en route meter arc is frozen. This keeps the TBM operation flexible and responsive to how actual flights are traversing the airspace. The STAs at the MF and the runway are frozen when the flight crosses the MF freeze horizon.

When terminal metering operations, which extend the TBM operation into terminal airspace, are in use, TBFM will also calculate STAs at Terminal Meter Points (TMPs). The STAs at TMPs are frozen when the aircraft crosses the MF freeze horizon. The necessary DSTs will be provided on the Standard Terminal Automation Replacement System (STARS) display to help Terminal Radar Approach Control Facility (TRACON) ATC manage flights to their STAs [7].

TBFM Departure Scheduling is also used to schedule departures to busy arrival airports. TBFM may schedule departures directly to the arrival timeline (i.e., to an en route meter arc or the MF). These operations are referred to as internal departures.

While TFMS and TFDM are components of TBM operations, as noted in Section 1.1, RTA and IM operations will primarily interact with TBFM. Therefore, further details on TFMS and TFDM will be limited in this document.

1.2.2 Required Time of Arrival

1.2.2.1 High-Level Description

The objective of an RTA operation is for an aircraft to cross a defined point in space at a specified clock time; this time is also referred to as the RTA. Various operational concept documents have described how RTA operations may be used in the context of air traffic operations. Reference [8] describes a Single European Sky ATM Research (SESAR) concept that relies on flight crews to communicate the range of feasible RTAs from which a sequence and schedule of arrival flights may be determined. RTA operations are then used to precisely meet the assigned RTAs. Separately, a U.S.-based operational concept was developed to use the TBFM schedule as the basis for RTA operations. References [9] and [10] describe how RTA operations may be used in TBM operations with TBFM providing the underlying schedule to inform the RTA clearance provided to the flight crew. The most recent FAA-developed concept, referred to as TBM-RTA and described in [11], reflects the FAA's TBO vision including more details on TBFM enhancements, the use of PBN procedures, and specifies the use of the Flight Management System (FMS) TOAC capability to conduct RTA operations.

The TOAC capability, as defined in avionics standards described in Section 1.2.2.2, accepts an RTA as a time constraint and calculates speeds that are implemented automatically by the flight guidance system to precisely meet the RTA. Examples of the TOAC flight-deck interfaces are shown in Figure 1-3. The aircraft's navigation route is graphically depicted on the navigation display, as shown on the left, with the Estimated Time of Arrival (ETA) at the next waypoint, BUKKO, shown in the top right. The RTA operation status is shown on the RTA progress page on the Control Display Unit (CDU) on the right. The

[2] The freeze horizon specifies when a flight's schedule should be "frozen." Prior to the freeze horizon, the flight's "unfrozen" STA is updated each scheduling cycle (on average, every 12 seconds). The unfrozen STA can change each time it is calculated as the flight's ETA changes and as the STAs of other flights may also be changing. Once the flight crosses the freeze horizon, its STA becomes frozen, meaning it will remain a constant value until the flight crosses the downstream meter arc or MF. The frozen STA provides ATC with a fixed time for managing the flight.

RTA point, SLIDR, and RTA are shown in the top row. The distance to SLIDR and ETA at SLIDR are also provided on the progress page.

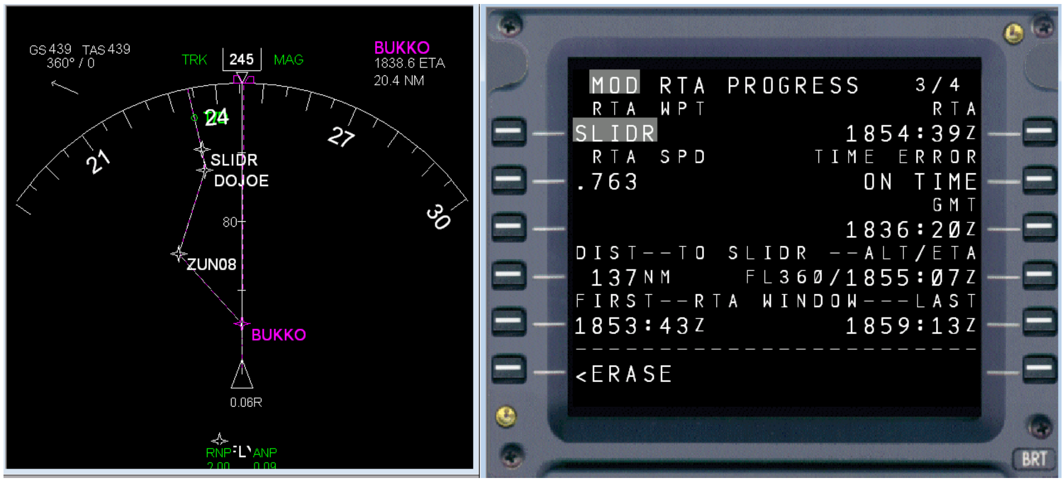

Figure 1-3: Pilot Configures FMS TOAC Function with RTA.

1.2.2.2 State of Avionics Standards

Current avionics standards for TOAC are defined in the Minimum Aviation System Performance Standards (MASPS): Required Navigation Performance for Area Navigation (RTCA DO-236C, Change 1) [12]. This standard provides performance requirements for TOAC and specifies two meet-time accuracies:

- Tolerance for points located in the cruise phase of flight: 30 seconds (95%)[3]
- Tolerance for points located in the descent phase of flight: 10 seconds (95%)

Detailed performance and display requirements are provided in the Minimum Operational Performance Standards (MOPS) for Required Navigation Performance (RNP) for Area Navigation (RNAV) (DO-283B) [13], which includes additional information such as system-level test procedures for the TOAC capability. Currently, the TOAC capability is not referenced in Technical Standard Order (TSO)-C115d [14] for *RNP Equipment using Multi-Sensor Inputs*, which references DO-283B. In Advisory Circular (AC) 20-138D for *Airworthiness Approval of Positioning and Navigation Systems* [15], TOAC is classified as an advanced RNP function intended for "longer-term implementation and remains optional for all equipment due to uncertain equipment requirements and airspace implementation." Furthermore, the paragraph on TOAC in AC 20-138D states the TOAC function is "not well defined for either equipment requirements or airspace implementation." Implementers are directed to DO-283B for guidance.

The requirements for RTA operations in level flight only were specified in the first version of the RNP for RNAV MASPS (DO-236) [12]. As a result, a cruise-only RTA capability exists in a significant portion of the airline fleet and is based on manufacturer-derived lower-level requirements. While much of the fleet currently supports RTA cruise operations and some portion also supports RTA operations during descent (see Appendix B for legacy RTA/TOAC capability in the current fleet), the ATC acceptability of RTA operations using the legacy flight-deck capability, developed based on earlier standards, remains an open question and requires further study. Research has suggested that RTA performance variability during level flight is likely to be minimal [16]. Today, use of the legacy RTA/TOAC capability is largely

[3] This notation means that 95% of operations should meet the RTA within $\pm$30 seconds.

limited to oceanic operations. Some flight crews may also use the capability in domestic operations today; these are pilot-initiated uses of the legacy RTA/TOAC capability as opposed to ATC-initiated clearances. In pilot-initiated uses of the capability, speed changes deviating from an ATC-issued speed instruction by more 10 knots (kt) must be coordinated with ATC prior to flight crew implementation.

In 2020, RTCA Special Committee 227 (SC-227) resumed efforts to update the RNP for RNAV MASPS and MOPS. As part of the effort, the committee considered changes to the TOAC requirements to standardize TOAC behavior during cruise and descent operations, thereby addressing potential variability in implementations that have been identified as a risk to ATC acceptability. Updates to requirements on limits to speed changes to bound TOAC speeds on segments of PBN procedures without speed restrictions, while also allowing bounded speed changes on segments of PBN procedures with speed restrictions, were proposed. However, the proposed changes were not ultimately implemented with the lack of a well-defined operational concept cited as the reason.[4] SC-227 has acknowledged that this ConOps document may provide the operational concept description needed to justify updates to the latest versions of DO-236 and DO-283.

1.2.2.3 State of FAA Investments

The TBM-RTA ConOps, developed in 2017, describes the use of RTA operations with TBM operations in en route airspace [17]. That ConOps covered two scenarios: RTA operations in an extended metering environment, crossing multiple en-route sectors during level flight, and RTA operations in an arrival metering environment during initial descent to the MF.

In 2018, the FAA planned to pursue ground-based automation enhancements as part of the TBFM Enhancement 2 investment to enable RTA operations, but only during level flight. This would have allowed legacy RTA capabilities to also be used, as current implementation variations are expected to be negligible during level flight. TBFM requirements in support of RTA operations were later removed from the TBFM Enhancement 2 investment scope based on an assessment of the maturity of the avionics standards.[5] Except for SC-227 activities and this ConOps document, there are no current FAA activities focused on deploying RTA operations in the NAS.

1.2.3 Interval Management

1.2.3.1 High-Level Description

The IM operational concept comprises a set of operational applications in which the flight crew of a trailing aircraft follows FIM capability-generated speeds (or FIM speeds) to achieve or maintain a spacing goal relative to an ATC-specified Lead Aircraft. The use of IM operations will yield precise, inter-aircraft spacing and improved spacing consistency by enabling more frequent speed adjustments than possible with a ground system alone. Precise and consistent spacing translates into increased arrival throughput when aircraft can be spaced closer to separation minimums without increasing the need for controller interventions. IM combines ground-based and flight-deck capabilities to provide air traffic controllers another tool to manage traffic flows:

- Ground-based automation assists ATC in identifying and issuing IM clearances to merge and space aircraft safely and efficiently and in monitoring the progress of those IM operations; and

[4] As noted in Section 1.2.2.1, several operational concept documents have been developed with some key differences between the SESAR concept document and more recent FAA-sponsored concepts.

[5] As noted in Section 1.2.2.2, the TOAC capability is listed as an optional function in DO-283B, and FAA regulatory documents do not yet include certification guidance for TOAC.

- Flight-deck capabilities[6] allow the pilot to conform to the IM clearance by providing FIM speeds to achieve and maintain a spacing goal relative to another aircraft.

Examples of a retrofit[7] FIM traffic display (left) and speed guidance display (right) are shown in Figure 1-4. In this example, speeds are displayed to the flight crew in the forward field of view and implemented manually. In forward-fit flight deck implementations, the speed-implementation functionality may be incorporated into the FMS and flight crews may monitor the operation and speed compliance via installed displays.

Sample Cockpit Display of Traffic Information (CDTI) Traffic Display

Sample ADS-B Guidance Display (AGD)

Figure 1-4. Sample Implementation of the FIM Capability.

The Assigned Spacing Goal (ASG) is provided by the controller and may be given in time or distance. The value of the ASG will align with the controller's goal of establishing an efficient and safe traffic flow. In a

[6] While we use the term "flight-deck capabilities" in this ConOps, the TOAC and FIM capabilities are used in combination with the flight guidance system to implement the TOAC or FIM speed guidance, respectively. As such, TOAC and FIM could be considered "aircraft capabilities." Furthermore, the ability to meet the RTA or Assigned Spacing Goal (ASG) within tolerance at a downstream point can only be measured in a closed-loop manner where the speed guidance is implemented and the aircraft responds during flight to the RTA point or Crossing Point (CP), respectively.

[7] The FIM capability is not required to be implemented in the FMS. Retrofit installations could implement the required functionality across new and existing flight-deck systems. In forward-fit installations, the functionality will likely be implemented in existing flight-deck systems, such as the FMS.

TBM operation, the ASG will be based on the automation-generated schedule at a Meter Reference Point (MRP)[8], such as a meter arc, MF, or TMP. In TBM operations, ATC DSTs will be used to help ATC manage aircraft instructed to cross a desired location at a particular time (i.e., metered aircraft) and aircraft managing spacing relative to other aircraft (i.e., IM) within the same overall flow. IM can be used in the cruise, arrival, and approach phases of flight, but not on departure.

The FIM capability has two distinct stages of spacing behavior: the achieve stage and the maintain stage. During the achieve stage, the FIM speeds are calculated to achieve the ASG no later than the ATC-specified Crossing Point (CP). During the maintain stage, the FIM speeds are calculated to maintain the ASG until crossing the Planned Cancellation Point (PCP). Different IM clearance types map to these stages and are intended to support different operational objectives.

1.2.3.2 State of Avionics Standards

The ADS-B In concepts are briefly summarized in reference [18]. The lower-level flight-deck capability requirements are defined in the Aircraft Surveillance Applications (ASA) MOPS, DO-317C [19]. The IM operational concept and performance and safety analyses are provided in the FIM Safety, Performance, and Interoperability Requirements document, DO-328B [20], which was most recently updated in 2020. The FIM MOPS, DO-361A [24], was also updated in 2020. The FIM standards provide performance requirements for the FIM capability:

- During the achieve stage: the ASG must be met within 10 seconds (95%)[9] at the CP.
- During the maintain stage: the ASG must be met within 10 seconds for 95% of the time in the Maintain Stage.

The achieve and maintain stages can be used in cruise, arrival, or approach phases of flight.

At the time of publication of this ConOps, the TSO for ADS-B ASAs [21] was being updated to TSO-C195c. This revision of the TSO includes the FIM capability and references the most recent version of the FIM MOPS [22]. TSO-C195c also references the most recent version of the ASA MOPS [19]. Airbus, Boeing, and various avionics companies offer products that support one or more ASAs, and several ADS-B In IM flight trials have already been conducted with retrofit avionics. These include a UPS Field Test in 2010, the National Aeronautics and Space Administration (NASA) ATM Technology Demonstration-1 (ATD-1) flight test in 2017, and a Paired Approach flight test conducted with United Airlines and Alaska Airlines aircraft at San Francisco and Tucson International Airports in 2019. These flight test results generally validate the achievability of the DO-361A [22] performance requirement with acceptable tolerances under real-world conditions.

1.2.3.3 State of FAA Investments

In parallel with the standards work, the FAA released an IM ConOps document in 2017 describing a comprehensive set of IM operations enabled by the FIM MOPS [23].[10] These included the use of IM to manage the spacing between aircraft arriving to the same runway or to dependent runways (both parallel and crossing or converging configurations). Due to expected cost and risk of deploying the full set of automation enhancements needed to enable the end-state IM operations, the FAA's Surveillance and Broadcast Services (SBS) program defined a phased investment strategy for ADS-B In applications.

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[8] In this ConOps, we use MRP to refer generally to a meter element (e.g., a meter arc, MF, or TMP) where an STA applies.

[9] This performance requirement specifies that 95% of flights must meet the 10-second tolerance at the CP.

[10] This ConOps is not currently publicly available, but a summary of the operations is available in [53].

The initial phase would support simpler operations relying on fewer automation changes. This phased investment and operational deployment approach would allow lessons learned from early operations to be incorporated into later operations.

In support of the first investment and deployment phase, an initial set of IM operations was defined to support en route extended metering and arrival operations, en route Miles-In-Trail (MIT), and approaches when the IM Aircraft and Lead Aircraft are landing on the same or parallel runways. A ConOps document describing these operations was drafted in 2020 [24].

Additionally, the FAA, American Airlines, Aviation Communication & Surveillance Systems (ACSS), and the National Air Traffic Controllers Association (NATCA) have partnered in an activity called the ADS-B In Retrofit Spacing (AIRS) Evaluation. The AIRS Evaluation will quantify operational benefits and provide feedback on conducting ADS-B In operations in an actual operational environment to support the FAA's ADS-B In investment analysis. At time of development of this ConOps, American Airlines was in the process of equipping over 300 Airbus A321 aircraft with FAA-certified ACSS SafeRoute+® avionics that are capable of several ASAs, including a sub-set of the IM capabilities defined in DO-361A [22] termed Initial IM (I-IM).[11] The AIRS Evaluation of I-IM operations began in late 2022 and will continue for one year. The final report is expected in early 2024.

As the American Airlines A321 fleet may be the only aircraft equipped with a set of FIM capabilities when IM operations are deployed in the NAS, the first phase of IM operations following the AIRS evaluation will likely leverage the ACSS SafeRoute+ avionics capabilities as well as any aircraft equipped with TSO-C195c-compliant avionics.

1.3 Statement of Purpose

While the RTA and IM operational concepts and flight-deck system requirements have been developed independently to date, the concepts are similar in their provision of speeds on the flight-deck to precisely achieve a spacing objective. In 2020, the FAA's Mission Support-Strategy organization (AJV-S) tasked The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) with evaluating how flight deck-enabled operations, including RTA and IM, could be implemented in a TBO environment. That effort produced documents covering operational concepts and benefits, key actions needed for implementation in the NAS, and an implementation roadmap [25, 26, 27].

Since that time, avionics standards and other industry efforts have highlighted a need for consensus on an operational concept that considers how the TOAC and FIM capabilities may be used in concert[12] during TBM operations in the NAS. Avionics manufacturers have asked the FAA for help in understanding how TOAC and FIM capabilities may be implemented on the same flight deck, allowing aircraft equipped with both TOAC and FIM capabilities to conduct either RTA or IM operations, respectively, as directed by ATC. For aircraft equipped with both capabilities, pilots must understand the differences in the operations and flight-deck systems. When possible, flight-deck interfaces and performance should be made consistent to improve pilot acceptance, reduce errors, and reduce pilot training needs.

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[11] I-IM operations will be conducted in Albuquerque Air Route Traffic Control Center (ARTCC) (ZAB) airspace for flights destined to Phoenix Sky Harbor International Airport (PHX) and overflights passing through ZAB airspace and destined to other airports.

[12] This refers to the use of RTA operations for some aircraft and IM operations for other aircraft in the same airspace and even in the same flows. It should not be interpreted to mean using TOAC and FIM capabilities on the same aircraft at the same time.

A recent NAC ADS-B In Task Group therefore included the following recommendation in their final report to the FAA [28]:

> *Formalize an FAA approved concept of operations for the use of Flight-deck Interval Management applications with Time-Based Management procedures such as Time of Arrival Control (TOAC) and communicate it to Operators, [Original Equipment Manufacturers] OEMs, pilots, and air traffic controller associations, and standards developing organizations as changes occur.*

The NAC further noted that while MITRE has analyzed how RTA and IM operations could be implemented in a TBO environment in the NAS[13], an authoritative, FAA-approved ConOps is needed.

In response, this document defines an integrated operational concept and identifies key avionics functionality that enables these concepts to be used in a mutually beneficial manner. Furthermore, this document aims to identify ways to ensure consistent aircraft behaviors from an ATC perspective as well as to flight crews that may use TOAC and FIM capabilities on the same aircraft. As such, this document will help the FAA, its partners, and industry stakeholders standardize TOAC and FIM capabilities and form a basis for regulators to approve the flight-deck capabilities for use in air traffic operations.

This document also aims to help FAA stakeholders understand how RTA and IM operations may be used in a TBO environment such that FAA resources may be coordinated to deploy ground-based automation enhancements and certify flight-deck capabilities in an efficient and cost-effective way. For example:

- The FAA Mission Support-Strategy Organization (AJV-S) could promote an operationally acceptable, feasible, and beneficial integrated concept aligned with TBO and Info-centric NAS objectives.
- The FAA Program Management Organization (AJM) could understand how an integrated operational concept impacts TBM automation requirements and how automation enhancements should be deployed in an efficient way.
- The FAA Aircraft Certification Service (AIR) could understand how TOAC and FIM capabilities should be implemented on a flight deck to ensure their performance and speed behavior are consistent with ATC expectations and ground system assumptions.
- The FAA Flight Standards Service (AFS) could understand the operations that certified TOAC and FIM capabilities can support in the NAS.

1.4 Document Overview

The remainder of the document is organized as follows:

- **Section 2** describes the baseline operation that does not include the use of TOAC or FIM capabilities.
- **Section 3** describes the benefits from using the TOAC and FIM capabilities.
- **Section 4** describes the use of the TOAC and FIM capabilities in TBM operations in detail.
- **Section 5** presents an operational scenario illustrating the use of RTA and IM operations in level flight and during arrival operations.
- **Section 6** summarizes the impact on NAS operations and airlines based on this ConOps.

[13] This refers to the AJV-S-sponsored research described previously.

2. Assumed Baseline Operation

This section describes the baseline operation that has the potential to be in place prior to the inclusion of RTA and IM operations. The timeframe for the baseline operation follows the completion of initial TBO in 2025 and before the initial implementation of the Info-centric NAS. While some of the capabilities and procedures described have already been implemented in the NAS, enhancements and/or further proliferation of capabilities and procedures will be needed.

In the assumed baseline operation, the FAA will be in the process of modernizing TFM strategies as described in the TBO Vision [1] and in preparation for the Info-centric NAS [3]. The application of TFM strategies will be data-driven and continuously evaluated using FMDS to ensure demand/capacity imbalances are efficiently addressed. Integrated TFM strategies will consider the use of TBM operations (using TBFM) in combination with TMIs, such as Ground Delay Programs (GDPs) or Airspace Flow Programs (AFPs). TFDM will also be deployed to several sites enabling more efficient surface metering and improved compliance with FMDS- and TBFM-generated departure times. In addition, some aircraft are assumed to be equipped with advanced flight-deck capabilities, like select ADS-B In applications and data link communications, and those capabilities are assumed to be in use.

As RTA and IM operations will primarily be impacted by TBFM, PBN, and other flight-deck capabilities, this section describes the expected use of the TBFM system in the baseline operation and advanced flight-deck capabilities that are likely to be available in the same timeframe.

2.1 Use of the Time-Based Flow Management System

TBFM is assumed to be used in all Air Route Traffic Control Centers (ARTCCs) in the NAS in the baseline environment, though its specific use will vary as described here.

At some busy arrival airports, TBFM will be adapted for arrival metering operations (see Figure 1-2) to pre-condition flights to terminal airspace. These TBM operations will end at the MF on the en route/terminal airspace boundary with MF STAs helping to pre-condition flows to terminal airspace. This preconditioning improves lateral conformance to the en-route portions of the Standard Terminal Arrival Routes (STARs) as well as reduces the need for path-lengthening maneuvers inside terminal airspace. PBN procedures have been designed and implemented to support effective arrival metering operations, meaning STARs have altitude and speed restrictions to support flow control through consistent flight times and to provide input to TBFM for better trajectory predictions and improved ETA accuracy [29]. TBFM DSTs, like the Delay Countdown Timer (DCT), which is the difference in a flight's ETA and STA at the MF, and TBFM-calculated speed advisories may be used to manage flights to their STAs at the MFs. In the baseline environment, TBFM may be used throughout the day and across all demand levels.[14]

Where appropriate, TBFM may also be adapted to use Extended Metering/Coupled Scheduling [6] and Adjacent Center Metering functionality [30] to allow TBM operations to begin earlier in en route airspace (i.e., extended metering in Figure 1-2). This enables schedule delay, which is needed to deconflict flights at downstream meter arcs and MFs, to be absorbed over longer distances using speed changes instead of less-efficient, path-lengthening maneuvers. In these cases, TBFM-generated speed advisories and DCT values will be presented to ATC to assist them in managing flights to meet their STAs

[14] Today, TBO objectives include more regular use of TBFM across demand periods. As later described, the RTA and IM concepts rely on the TBFM schedule to inform the flight-deck clearances. Therefore, regular use of TBFM is important for maximizing the use of the flight-deck capabilities.

at downstream meter arcs and MFs. When schedule delay cannot be absorbed with speed changes alone, ground-based automation will propose path stretch solutions to meet STAs [31]. A path stretch solution combines a new navigation route, defined as a two-leg route extension (i.e., turn-out and rejoin legs), with a speed along the path. Compared to an ATC-issued vector to absorb delay, the path stretch capability improves the accuracy of DSTs used to assist ATC in delivering aircraft to their STAs since the ground-based automation knows the aircraft's new navigation route. In the baseline operation, path stretch is assumed to be limited to level flight segments prior to Top of Descent (TOD).[15]

In the assumed baseline operation, some terminal operations will use terminal metering DSTs to continue managing flights to STAs inside terminal airspace (see terminal metering in Figure 1-2).[16] Terminal metering functions provide a higher-fidelity representation of RNAV and RNP procedures in the terminal, including modeling RNP Radius to Fix (RF) approaches and assigning those flights that are equipped to fly them to those approaches. TMPs placed at merge points, or other scheduling constraint points in the terminal, identify points where STAs should be deconflicted. Terminal metering operations provide additional efficiency benefits by scheduling flights to the procedures for which they are best equipped and pre-conditioning flights such that ATC can manage flights in the terminal along their planned routes using speed changes alone. In the assumed baseline operation, all PBN procedures at airports conducting terminal metering operations have been updated to connect STARs to Instrument Approach Procedures (IAPs), providing a fully defined path and clearance to the runway[17] [29, 32]. In arrival airports not using terminal metering DSTs, other ATC tools like the Converging Runway Display Aid (CRDA) may be used to assist controllers in managing mixed PBN-equipage flights (i.e., some flights are capable of flying the RNP RF approach procedures and others are not equipped) [33, 34].

TBFM Departure Scheduling is also used to schedule departures to busy arrival airports. TBFM may schedule departures directly to the arrival timeline (i.e., to the MF). These operations are referred to as internal departures. Improvements to departure scheduling operations through use of the Integrated Departure/Arrival Capability (IDAC) [35], which automates coordination between the ARTCC Traffic Management Unit (TMU) and the departure airport tower, are in place across the NAS in the baseline operation.[18] In airports that have TFDM, surface metering can be used to comply with the TBFM-calculated departure times. When TMIs are in effect, departure times calculated by FMDS and TBFM are appropriately coordinated to reduce ground-based delays.

[15] TBFM and ERAM enhancements to enable path stretch were previously included in the TBFM Enhancement 2 investment but were removed when that investment was rescoped. Path stretch is expected to improve the use of TBFM over ATC-determined vectors for delay absorption as the path stretch route is known to the automation, thereby improving ETA accuracy at a downstream point. In comparison, when ATC vectors an aircraft off its route, TBFM applies route rejoin logic to calculate the flight's route and ETA. The TBFM-assumed route is often inconsistent with the aircraft's actual route, degrading the ETA accuracy and TBFM DSTs.

[16] Terminal metering operations were enabled by the Terminal Sequencing and Spacing (TSAS) enhancements to TBFM. Operational implementation of these enhancements has been indefinitely delayed.

[17] At a minimum, STARs should be connected to IAPs to provide an unambiguous two-dimensional (2D) path (i.e., resulting in no discontinuity in the FMS route) to the runway. Altitude restrictions may be used to improve the predictability of the three-dimensional (3D) trajectory. Lastly, speed restrictions on the STAR and IAP further improve the predictability and consistency of flight times on those route segments via a fully defined 4D trajectory.

[18] TBFM Departure Scheduling and IDAC are in regular use at several ARTCCs today with plans to deploy IDAC at additional sites.

2.2 Use of Flight-deck Capabilities

In the baseline operation, several flight-deck capabilities are also assumed to be available and in use.

The ADS-B In Cockpit Display of Traffic (CDTI)-Assisted Visual Separation (CAVS) capability is used to conduct CDTI-Assisted Separation (CAS) operations. CAS operations extend the use of pilot-applied visual-like separation into weather conditions previously excluded [36]. In the baseline operation, CAS is assumed to be used on final approach to yield visual-like throughput when conditions prevent continual flight crew visual tracking of the leading aircraft going to the same runway. CAS operations are expected to yield improved airport throughput in weather conditions when pilot-applied visual separation would normally be discontinued.

Data link communications technologies are assumed to be in use for more complex ATC clearances like path stretch, which may use ground-based automation-calculated points (e.g., defined by latitude/longitude or place-bearing-distance formats).[19] Otherwise, ATC and pilot communications are conducted primarily via voice, and voice communications always exist as a backup to data link communications in this environment.

In the baseline operation, improved data connectivity on the flight deck has also led to increased use of advanced Electronic Flight Bag applications to improve airline operations.[20] These include the use of improved weather forecast information (i.e., wind and temperatures) in trajectory prediction in the FMS and other flight-deck avionics.

[19] Some aircraft are equipped with Future Air Navigation System (FANS) 1/A systems today, which allows flight crews to receive and send messages defined in RTCA DO-305A. Path stretch clearances can be sent using the FANS 1/A message set.

[20] As described in Section 3.4.3 of reference [25], several airlines are already using mobile applications to improve access to weather information as well as to improve the efficiency of flight operations.

3. Justification of Changes

Figure 3-1 shows a general depiction of enabling technologies that support ATC PBN procedure conformance as airport demand increases based on the research in [37]. At lower airport demand levels (e.g., less than 40% of its maximum capacity), ATC can pre-condition flights such that most flights may remain on their planned routes, as defined by their RNAV STARS, without ATC-issued off-path maneuvers (i.e., vectors). At medium airport demand levels (e.g., between 40% and 70% of its maximum capacity), ground-based TBM automation (i.e., scheduling automation and DSTs) is needed to keep flights on their planned routes without vectoring. Reference [37] posits a 30-second (95%) MF delivery accuracy supports keeping flights on their planned routes and conflict-free crossing times at the MF when demand is between 40% and 70% of maximum capacity. The 30-second delivery accuracy has been proposed as the operational goal for TBM operations in the initial TBO timeframe. At higher airport demand levels (e.g., exceeding 70% of maximum capacity), additional precision is needed to keep aircraft on their planned routes without vectoring and to prevent conflicting crossing times at the MF. Without this increased precision at the MF, controllers will need to vector aircraft more frequently to prevent conflicts, reducing flight efficiencies during the initial descent to the MF. As such, flight-deck capabilities like TOAC and FIM are proposed to enable improvements in delivery accuracies beyond 30 seconds (95%).

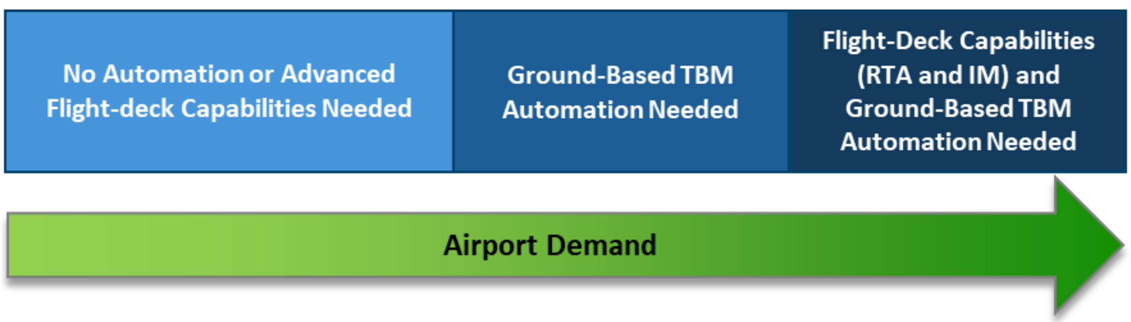

Figure 3-1. Enabling Technologies to Support ATC PBN Procedure Conformance.

The 30-second (95%) MF delivery accuracy has also been shown via modeling, fast-time simulation, and Human-in-the-Loop studies to support terminal metering operations. Flights must be accurately delivered to their MF STAs to ensure flights can remain on their planned routes in the terminal using speed changes alone [38, 39, 40]. However, greater precision may be required for some TRACONs when the distance between the MF and runway is relatively short (e.g., Los Angeles International Airport [LAX] arrivals from the east require less than 30-second (95%) delivery accuracies to achieve terminal path conformance rates of 95%) [41].

RTA and IM operations enable additional precision beyond what can be achieved using ground-based TBM capabilities alone. Performance requirements in DO-361A Change 1 specify that IM Aircraft must achieve their spacing goal by the CP in 95% of operations and, when in the maintain stage, must stay within 10 seconds of their ASG for 95% of the operation. Similarly, RTA Aircraft must cross the RTA point within 10 seconds of the RTA for descent fixes and 30 seconds for en-route fixes in 95% of operations. When STAs are met more precisely, fewer aircraft need to be vectored off their intended arrival routes to avoid conflicts, as shown in [37], and terminal metering operations are more likely to be successful.

The benefits of improved delivery accuracy are illustrated in Figure 3-2 using a model, based on the work in [37], to relate delivery accuracy to the rate of controller interventions needed to prevent conflicts between successive arrivals at the MF. STAs at the MF are assumed to be uniformly spaced based on the demand rate (i.e., aircraft are closer together for higher demand). For each demand rate, the frequency with which successive arrivals would be within 5 Nautical Miles (NM) at the MF is calculated assuming different delivery accuracies at the MF. As controllers monitor separation during these operations, this rate is related to the controller intervention rate. The horizontal axis shows the assumed delivery accuracy for 95% of operations.[21] The vertical axis shows the number of operations that would require ATC intervention because of poor delivery accuracy at the MF. Each of the lines represents different demand rates, in aircraft/hour (ac/hr), over a MF.

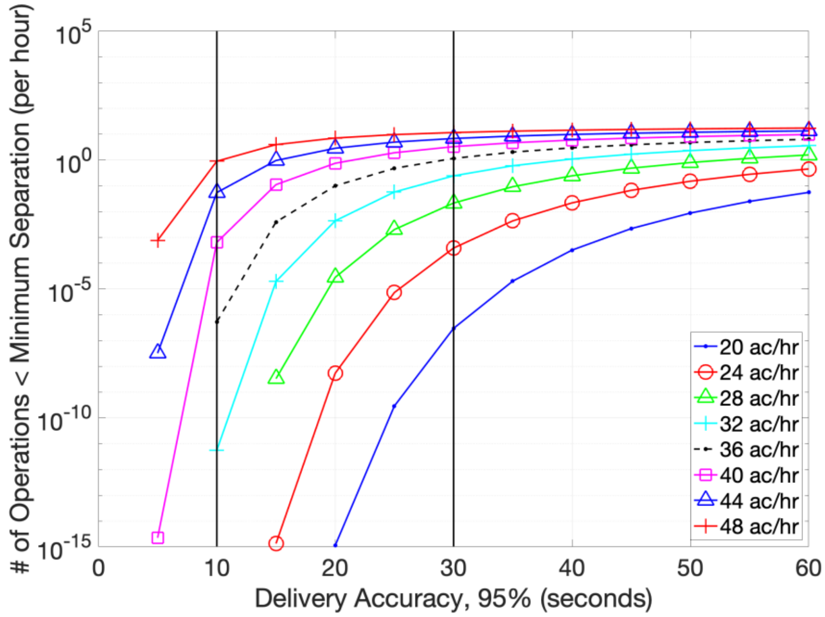

Figure 3-2. Rate of Intervention for Different Delivery Accuracies.

As the MF demand increases, the frequency of ATC intervention also increases. As the delivery accuracy improves (moving toward the left on the horizontal axis), the frequency of ATC intervention decreases. For example, on a STAR with a demand of 40 ac/hr, a 30-second (95%) delivery accuracy would result in a controller intervention once every 18 minutes on average. In contrast, a 10-second (95%) delivery accuracy would result in a controller intervention fewer than once in every 1,500 hours on average.[22] Decreased vectoring results in more fuel-efficient arrivals [37] and can also, in some cases, decrease controller workload.

In addition to the flight efficiency benefits resulting from improved delivery to the MF, runway throughput improvements are also expected when IM operations continue into the terminal domain. Reduced delays resulting from increased runway arrival throughput have been quantified as part of FAA ADS-B In benefits assessments and are described in [18, 42].

[21] The 95% delivery accuracy value is used in the modeling for consistency with how the avionics performance is defined (see Sections 1.2.2.2 and 1.2.3.2). The modeling approach extends easily to allow other confidence intervals (e.g., a 99.9% bound on the delivery accuracy).

[22] For a delivery accuracy of 30 seconds (95%) and a 40 ac/hr flow rate, the number of operations with less than minimum separation at the MF (without controller intervention) is 3.32/hr or one intervention every 0.30 hours (or 18 minutes). For a delivery accuracy of 10 seconds (95%) and the same flow rate, the number of operations with less than minimum separation at the MF is 6.43×10^{-4}/hr, or one intervention every 1,556 hours.

4. Use of Flight-deck Capabilities in TBM Operations

4.1 Assumptions

Table 4-1 lists the assumptions associated with this ConOps.

Table 4-1. Assumptions for the Integrated RTA and IM ConOps.

ASSUMPTION	RATIONALE
TBM operations using the TBFM system are in regular use	The use of RTA and IM operations in a TBO environment relies on the TBFM-generated schedule to determine RTAs and ASGs, respectively. To achieve the flight-deck-enabled benefits, facilities must be using TBM operations regularly.
PBN procedures have been designed for successful TBM operations	Consistent with TBO objectives, the flight-deck capabilities must support speed changes along the cleared navigation procedures to achieve spacing objectives. PBN procedures must be designed to balance trajectory predictability (i.e., procedures include altitude and speed restrictions from which TBFM and the FMS produce consistent trajectories) with an ability for the aircraft to adjust its speed along its path.
RTA operations are only used in en route airspace	Previous RTA research studying the use of RTA operations during busy arrival operations was limited to en route airspace (for level flight and initial descent to the MF) due to TOAC implementation variability and integration with path stretch. There has been no research evaluating the use of RTA operations during terminal metering operations and in mixed-equipage environments during high-demand periods. As such, the use of RTA operations is limited to en-route operations in this document.
The frequency of rescheduling events after the schedule has been frozen (and the sequence at each runway has been established) is low.	For IM to deliver the full range of intended operational benefits, the frequency with which the IM operation must be cancelled early due to rescheduling events causing changes in the lead aircraft is low.
In this ConOps, RTA and IM operations are only used when directed by ATC through provision of a clearance	Successful use of RTA and IM operations in a TBO environment rely on using RTAs and ASGs, respectively, that are consistent with the TBFM-generated schedule. Therefore, the RTA and IM operations are only initiated and executed when ATC provides a clearance to do so.

ASSUMPTION	RATIONALE
The TOAC and FIM speed guidance is equivalent to an ATC speed instruction	The TOAC and FIM speeds are designed to achieve the operational objectives specified by the ATC-issued RTA and IM clearances, respectively. As such, flight crews comply with the ATC-issued clearance when implementing the TOAC and FIM speeds unless otherwise directed by ATC. Avionics standards, air traffic orders (e.g., JO7110.65), and the FAA Aeronautical Information Manual (AIM) [43] would need to be aligned before these operations may be deployed in the NAS.
The TOAC and FIM capabilities described in this document are informed by their published avionics standards, respectively, but changes may be warranted to harmonize RTA and IM operations from ATC and flight crew perspectives.	The use of RTA and IM operations should be consistent from an ATC perspective meaning TOAC and FIM speed changes are similar in magnitude as an RTA or IM operation progresses. From a flight crew perspective, the implementation of an RTA or IM clearance should be consistent in terms of entering the clearance information, executing the speed guidance, and monitoring the operation. As such, changes to avionics standards may be needed to harmonize the performance of TOAC and FIM capabilities.
The data communications messages defined in the Aeronautical Telecommunications Network (ATN) Baseline 2 (B2) standards are available to provide RTA and IM clearances to appropriately equipped aircraft	In the baseline operation, some aircraft may be equipped with data communications technologies (a discussion of the specific links is outside the scope of this document). The ATN B2 messages, including RTA clearances with RTAs defined to 1-second precision and IM clearances, are assumed.

4.2 Constraints

Table 4-2 lists the constraints associated with this ConOps.

Table 4-2. Constraints for the Integrated RTA and IM ConOps.

CONSTRAINT	RATIONALE
ADS-B In reception range is 70 NM in areas with high spectrum congestion (e.g., the Northeast Corridor) and 90 NM elsewhere	ADS-B In reception range is based on expected spectrum congestion. Analysis suggests ADS-B In range is expected to be at least 70 NM in areas with high spectrum congestion like the Northeast Corridor. In less congested areas, the ADS-B In range is expected to be at least 90 NM [44].

CONSTRAINT	RATIONALE
For RTA+IM-capable aircraft without data link communications capability, operations are limited to clearances that can be communicated via voice	Past IM research found 8 to 10 elements was the maximum number of IM clearance elements over voice communications in the en route environment. Four to 7 elements may be a more reasonable number of elements based on past IM research and given that the Lead Aircraft Intended Flight Path Information (IFPI) is one of most challenging elements in the clearance [45]. In the absence of data link communications capabilities, strategies have been identified to reduce the complexity of voice communications. These include the use of named waypoints rather than latitude/longitude, and including clearance information in defined procedures (e.g., the PCP can be included on the navigation chart).
TBM operations including RTA and IM operation must accommodate mixed flight-deck equipage	This ConOps will consider RTA-capable, IM-capable, RTA+IM-capable flights in addition to flights with no flight-deck spacing capability. ATC will use DSTs, as described in the baseline operation, to manage unequipped flights.

4.3 Concept of Operations

This ConOps describes the envisioned operation using flight-deck capabilities when fully integrated with TBM automation and TBO. The ground-based automation functionality, described in the following sections and needed to enable the RTA and IM operations in the NAS, is not currently deployed, and the FAA does not currently have funding allocated for such enhancements.

4.3.1 Roles and Responsibilities

The RTA and IM operations described in this document are similar in several ways. The RTA and IM operations are only conducted when cleared by ATC. ATC provides the flight crew with a clearance comprising the necessary information to achieve ATC's operational objective. The flight crew enters the clearance information in the TOAC or FIM capability, which then provides speeds to achieve the clearance. The flight crew is responsible for executing the TOAC or FIM speeds in a timely manner.[23] The flight crew monitors the progress of the operation and notifies ATC if they cannot implement the TOAC or FIM speeds for any reason (e.g., turbulence limiting the available speed envelope).

For both operations, the controller is always responsible for the separation of aircraft executing RTA or IM operations. The controller is not responsible for ensuring the RTA or ASG are met within the expected operational performance tolerances as described in Sections 1.2.2.1 and 1.2.3.1, respectively.

[23] The TOAC capability is integrated in the FMS and the speed guidance is automatically implemented by the flight guidance system. Therefore, the flight crew is responsible for monitoring progress of the operation and ensuring the desired speed is achieved (e.g., adding drag when needed). The FIM capability has requirements for notifying the flight crew via an aural advisory when the aircraft's selected speed is not conforming with the FIM speed.

4.3.2 Standalone RTA Operations

The RTA operational goal is to improve the delivery accuracy at MRPs using the aircraft's TOAC capability. In a TBO environment, RTAs are consistent with the STAs at those points.[24]

The RTA operation can begin as soon as an aircraft crosses a TBFM scheduling freeze horizon and TBFM assigns an STA for the downstream MRP. For those flights that are RTA capable, ATC can issue an RTA clearance to the flight crew to use the TOAC capability to meet their STA (i.e., the RTA in the clearance) at the MRP (i.e., the RTA point in the clearance).

RTA operations are executed along a flight's cleared navigation route. If the STA cannot be met along the flight's current route using speed changes alone, the en route controller will need to first issue a new navigation clearance, reflecting the path stretch calculated by the automation, to absorb the delay. An RTA clearance may then be issued along the new route to precisely meet the STA at the RTA point. ATC may also provide a combined path-stretch solution and RTA clearance.

The flight crew executes the RTA clearance until crossing the RTA point. ATC can cancel an RTA operation at any time and use the TBFM DSTs to determine speed changes, altitude assignments, and path changes to meet the STA at the MRP.

The high-level RTA concept is depicted in Figure 4-1. First, the TBFM-generated schedule is determined (left-most figure). A notional controller meter list with advisories display, prototyped as part of previous RTA research, shows which flights are RTA capable. Controllers can issue RTA clearances, path stretches, and/or use TBFM-generated speeds, as appropriate. The flight crew enters the RTA clearance, speed, and/or new route clearance (determined by the path stretch function in the ground-based automation) in the flight-deck system. The flight guidance system executes the controller-issued clearance, and ATC monitors each flight as it progresses to its MRP.

[24] Past research has explored how to determine the RTA if there is no navigation point on the TBFM meter arc. In those cases, the RTA value may be adjusted to be equivalent to providing the STA on the TBFM meter arc. More details may be found in [54].

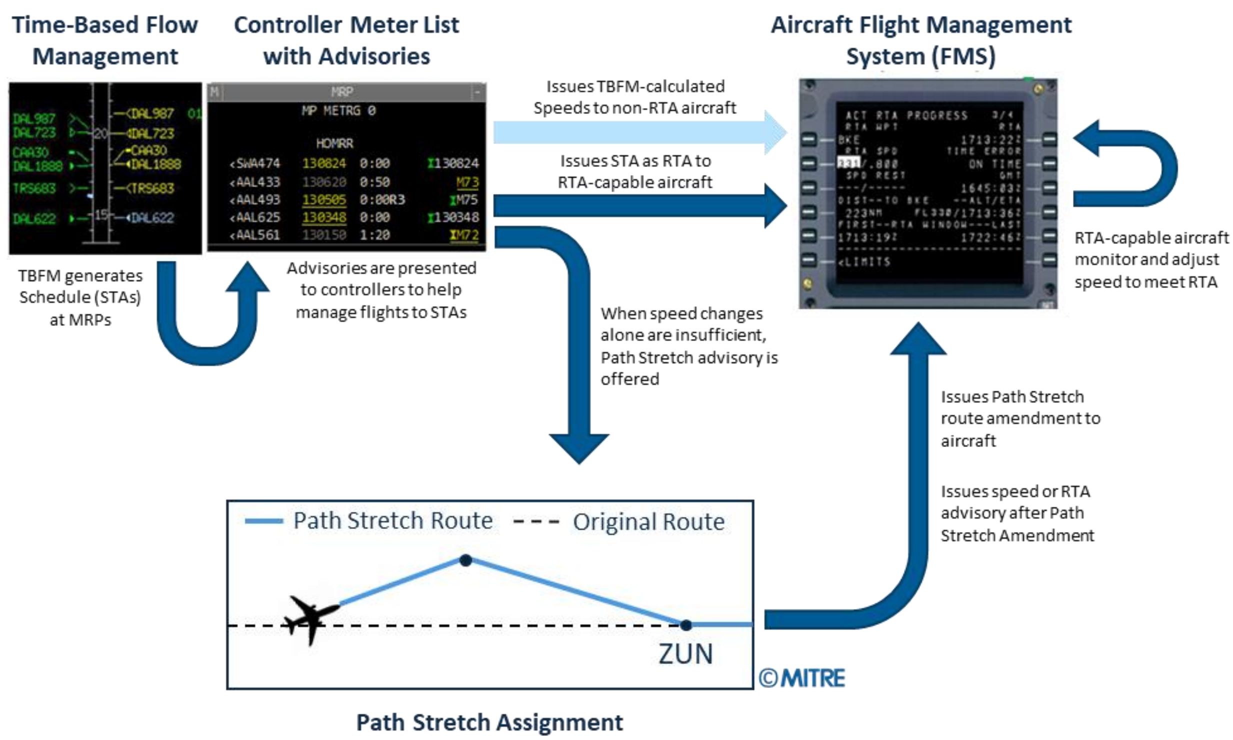

Figure 4-1. RTA Operational Concept Utilizing TBFM Capabilities.

4.3.2.1 Operational Overview

This section provides a summary of initiating, executing, and canceling RTA operations with an emphasis on the role of ground-based automation in an arrival TBO environment.

Pre-Initiation: The decision to employ RTA operations includes factors such as the expected traffic flows and capacity and demand. RTA operations will only be used after coordination with the facility, training, and at the direction of the Traffic Management Coordinator (TMC).

RTA Clearance Initiation: Based on the TBFM MRP schedule and aircraft capabilities, the ground automation will determine whether an RTA clearance is feasible. If an RTA clearance is not feasible along an aircraft's current route, a path stretch solution may be computed. If the RTA-capable flight is also data link communications-capable, a combined path-stretch/RTA clearance may be uplinked to the flight. Otherwise, the path stretch may be issued first and followed by an RTA clearance once the flight crew has entered the new navigation route.

Figure 4-1 shows a notional meter list display for ATC. This display provides speed advisories and/or path stretch solutions for non-RTA Aircraft. RTA-capable flights are denoted, and in those cases, path stretch solutions are also shown when speed changes alone are insufficient. When issuing RTA clearances, controllers can use the speed advisory information to estimate the initial speed change they might see once the RTA is executed.

Execution and Monitoring: Once the RTA clearance has been communicated to the flight crew, the flight is labeled in the automation and on the controller displays as being in an active RTA operation.

The pilot will input the RTA clearance information, including the RTA and RTA point, into the TOAC capability. The system provides an initial speed change required to achieve the RTA. If the flight crew accepts the initial speed, they execute the operation so the flight guidance system can begin to control the aircraft to the TOAC speed. TOAC speeds will vary over the course of the flight in response to operational uncertainties, such as forecast wind and temperature errors, not known at the time of the initial speed calculation.

During the RTA operation, ATC's traffic awareness is supported by ground-based automation, as needed. As the RTA operation progresses, TBFM continues to calculate the difference between the ETA and STA at the MRP and provides the controller with the meet-time error at that point (i.e., the DCT).

On the flight-deck, the FMS will continue to adjust the speed to keep the FMS-calculated ETA at the crossing point equal to the RTA (within tolerance). The flight crew can monitor any speed changes.

Cancellation: At any time, ATC has the option to cancel an active RTA clearance which will clear the active RTA indication on the controller display. This will allow for the subsequent issuance of a new RTA clearance, speed, or path stretch.

On the flight deck, once an RTA is completed (either cancelled early by ATC or cancelled when crossing the RTA point), the FMS will prompt the crew to select a new speed. The FMS will maintain the last TOAC speed until a new speed is selected (either manually or by the navigation procedure).

4.3.2.2 RTA Cruise and Arrival Operations

The use of RTA operations in TBO environments is limited to en route airspace. Previous research has studied RTA operations in extended metering environments to manage flights to en-route meter arcs (i.e., level flight and crossing multiple sectors) and during descent to the MF, as illustrated in Figure 4-2.

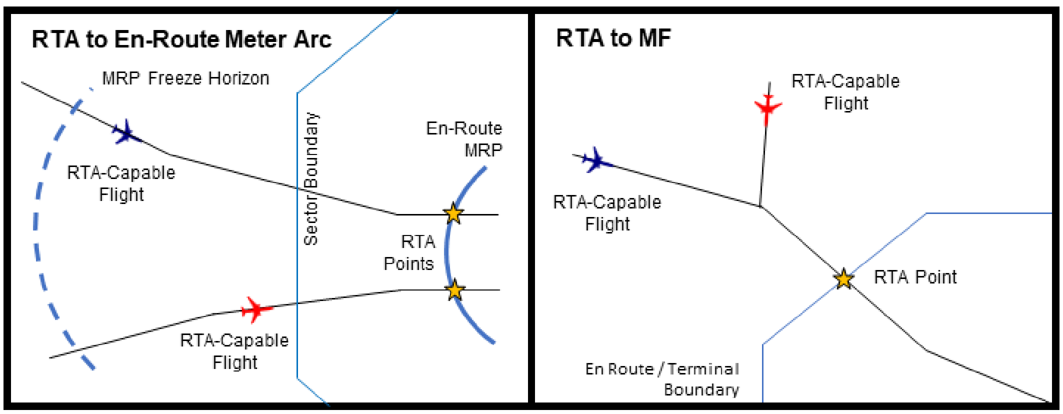

Figure 4-2. Depiction of RTA Operations During Cruise and Arrival Operations.

In extended metering operations, RTA operations may be used to manage flights to their STAs at en-route meter arcs more precisely than when using ground automation DSTs alone. The TOAC speed guidance is responsive to changing ETAs resulting from changing wind conditions, reducing ATC interventions to account for those operational uncertainties. The RTA clearance may be issued in a sector upstream of the MRP. Therefore, ground automation must support ATC awareness of which flights are conducting RTA operations as flights are handed off across sector boundaries.

The RTA point issued in the RTA clearance must be a point known to the FMS navigation database. In the absence of a named waypoint on the flight's route and coinciding with the TBFM MRP, ATC may issue the RTA point in a place-bearing-distance format, which defines a point relative to a named waypoint. This format may be communicated to the flight crew by voice or a Data Comm ATN B2 message.

In arrival operations to the MF, RTA operations may be used to precisely meet their MF STAs. The RTA clearance would be provided prior to TOD and the RTA operation would terminate at the MF.

4.3.2.3 Ground-based Automation System Functions

Figure 4-3 illustrates the various air and ground system components comprising RTA operations in a TBO environment, the information flows between each, and the method of information sharing. Ground-based automation is envisioned to implement RTA-related functions to set up and help controllers monitor the conduct of RTA operations. An extended and arrival metering environment, including path stretch, is expected to provide a baseline environment in which RTA-capable flights may be cleared to conduct RTA operations. This environment provides a set of DSTs that help manage RTA-capable flights in the same environment as unequipped flights being managed to their STAs by ATC.

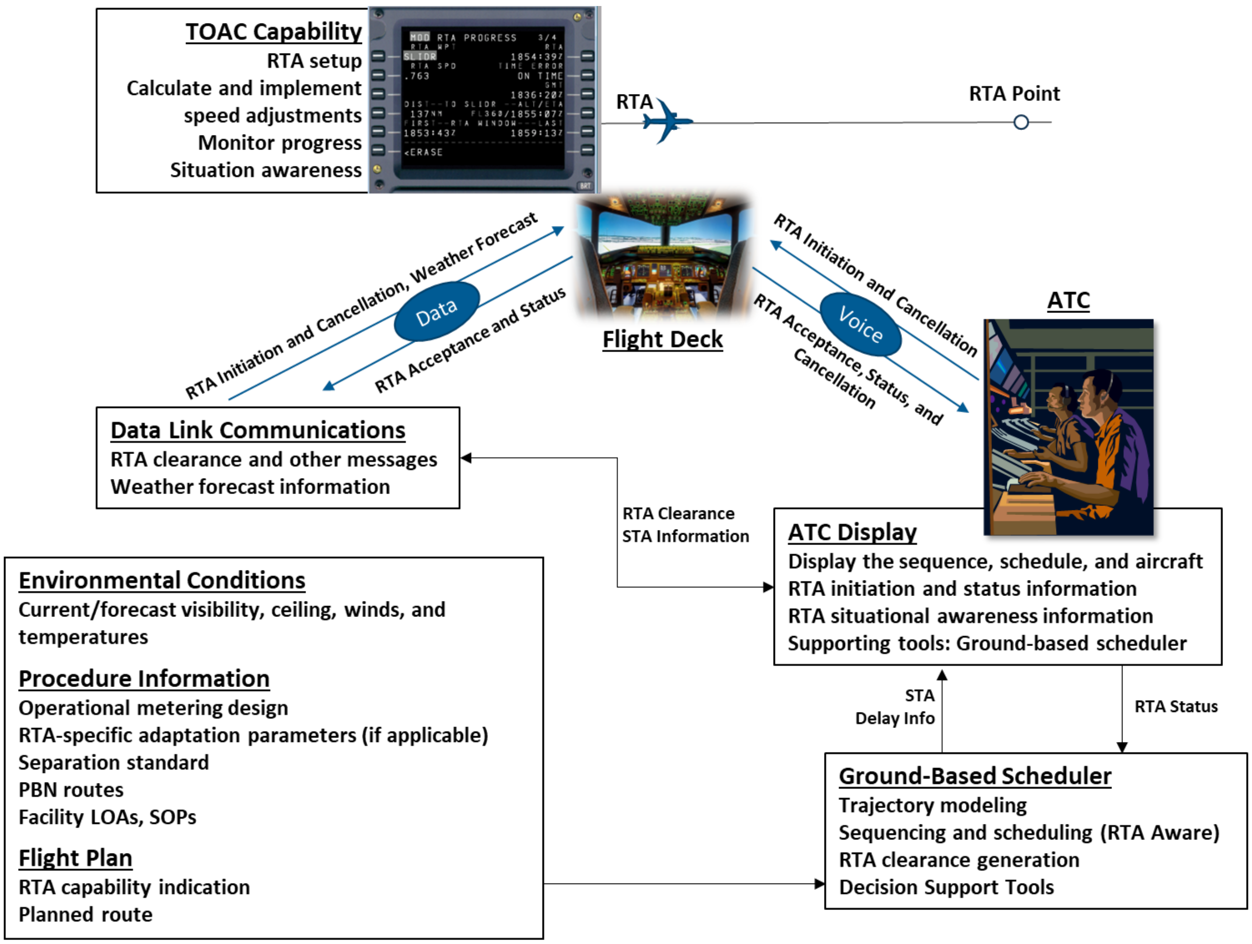

Figure 4-3. System Diagram of RTA Operations in a TBO Environment.

4.3.3 Standalone IM Operations

IM uses ground automation, flight-deck capabilities, and procedures to support the flight crew-managed relative spacing of aircraft. In this context, relative spacing refers to directly managing the interval between two aircraft, as opposed to specifying crossing times over static points (i.e., an STA for each aircraft, such as in a metering operation). An IM operation involves ATC, assisted by automation, clearing an IM-capable aircraft to achieve and/or maintain a desired ASG, based on the TBFM-generated schedule, relative to a Lead Aircraft. The ASG is achieved at the CP and/or maintained for a specified route segment to the PCP.

The IM clearance information for IM-capable flights is displayed to ATC and controllers may communicate the IM clearance to the flight crew of the IM Aircraft via voice or data link communications, when available. The flight crew on the IM Aircraft confirms then enters the IM clearance information into the FIM capability or direct loads it from the data link communications system. If the FIM capability determines the IM clearance is valid (e.g., the data in the Lead Aircraft's ADS-B Out message must be of sufficient quality), FIM speeds are displayed to the flight crew, who then begin implementing them.[25] The IM operation continues until reaching the PCP or until canceled by ATC.

The FIM capability must support different IM clearance types, which govern the IM Aircraft's spacing behavior. Flight crews will input the IM clearance type issued by the controller. FIM capability functional behavior with respect to each type is described in detail in DO-328B [20]. The two[26] of interest to this document are:

- **Cross**. Used when a particular spacing value is desired at a specific location (i.e., the CP) for any route geometry. If desired, spacing can be maintained after that location (when the IM and Lead Aircraft are on the same route or parallel routes) until the PCP.
- **Maintain**. Used when a particular spacing value is desired as soon as practical and then maintained. The controller can either clear the IM Aircraft to maintain a specific ASG or its current spacing relative to the Lead Aircraft. This clearance type only applies to aircraft pairs on common, parallel, or near parallel[27] routes.

Due to the increased spacing precision afforded by IM, the candidate IM Aircraft's STAs are scheduled closer in time to the candidate Lead Aircraft than they would otherwise be if IM were not used (this is referred to as IM-aware scheduling). This decreased spacing is a key feature in enabling higher throughput to the runway. Other advantages include increased predictability of the overall arrival flow, which should increase the number of aircraft that remain on their planned routes, as defined by their RNAV arrival and approach procedures. Additionally, IM should reduce the number of trajectory interventions needed to manage the arrivals, thereby reducing communications loading and workload.

4.3.3.1 Operational Overview

New procedures and phraseology will be required to implement IM operations. The aircraft-centric steps to initiate, execute, monitor, and terminate IM operations are described in detail in DO-328B [20]. This section provides a summary with an emphasis on the role of ground-based automation in an arrival TBO environment.

Pre-Initiation: The decision to employ IM operations considers factors such as the expected traffic flow, capacity and demand, current and forecast environmental conditions, and facility adaptations. Various

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[25] Retrofit FIM capabilities have required the flight crew to manually enter the FIM speeds into the flight guidance system. Future forward-fit capabilities may directly integrate the FIM speeds with the flight guidance system, allowing more frequent FIM speed changes.

[26] DO-328B defines three additional clearance types: IM Turn, Final Approach Spacing, and Capture then Maintain. IM Turn is not likely to be used in the United States and is thus not considered within the scope of this ConOps. The Final Approach Spacing clearance is only designed to be used on the intermediate final approach segment and thus past the point where RTA operations are likely to terminate. It therefore does not need to be specifically considered for an integrated RTA and IM operation. Capture then Maintain clearance is a particular case of Maintain, and all the considerations for Maintain described here apply. Therefore, it also does not need to be specifically addressed in this document.

[27] Near-parallel routes are defined in DO-328B as having a 10-degree or less course angle difference.

parameters are adapted in the ground automation, including which arrival flows will use IM, which runway configurations and separation standards will be employed, and spacing buffer values used for IM-aware scheduling. The ground automation accounts for aircraft capabilities when building an arrival schedule, identifying pairings, and preconditioning arrival flows.

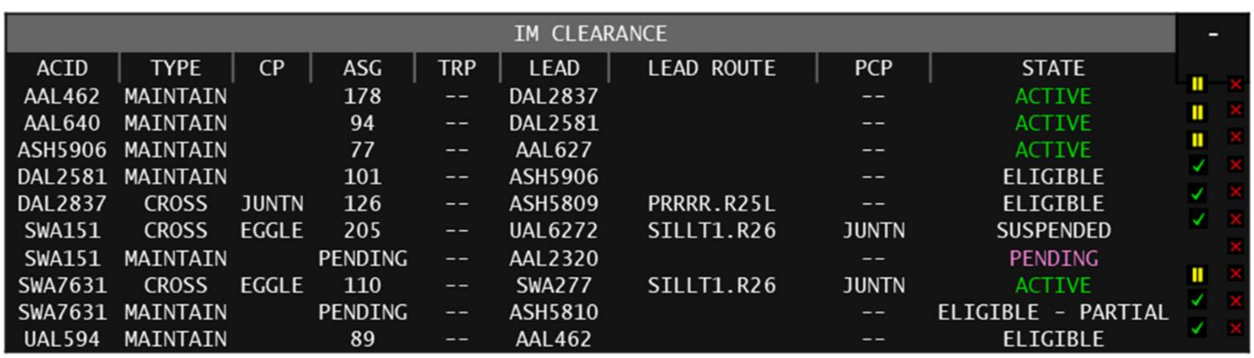
IM Initiation: The ground automation will propose IM clearances at the appropriate level of complexity for the communications medium (i.e., voice or data link). It also identifies and displays the appropriate IM clearance information. When the controller determines that the proposed clearance is consistent with their operational objectives, they provide it to the flight crew via voice or data link communications (when available and required or desired).

The necessary IM clearance information depends on the clearance issued and operational objective. Individual elements described earlier include the IM clearance type, Lead Aircraft, ASG, and CP. Other elements are:

- **Traffic Reference Point (TRP)**. A point where the Lead Aircraft's ETA is calculated as part of the spacing interval calculation for the Cross clearance type. This point is required when the IM and Lead Aircraft are on non-coincident (non-merging) routes for the entire IM operation.
- **Lead Aircraft IFPI**. Lead Aircraft route information used by the FIM capability to generate a predicted trajectory for the Lead Aircraft.
- **PCP**. The point on the IM Aircraft's flight path where the IM operation is specified to normally end.

Points such as the CP, TRP, and PCP can be conveyed via the IM clearance, published procedure, or defaulted by the FIM capability (as defined in [20]).

Figure 4-4 depicts one possible approach for providing IM clearance information on an en route controller's En Route Automation Modernization (ERAM) display. Sometimes referred to as an IM clearance window, it includes all clearance elements a controller would need to provide to the IM Aircraft. The left-to-right order of the elements is intended to be consistent with the order of the elements issued in the IM clearance. The window also indicates the state of an aircraft given an IM operation (i.e., eligible for a clearance, actively executing a clearance, waiting to be provided an ASG [pending], or suspended). The window also provides interactive functionality that allows a controller to accept, suspend, or cancel clearances. A full description of this functionality, and a similar approach to presenting IM information on a STARS display, is available in [46].


IM CLEARANCE

ACID	TYPE	CP	ASG	TRP	LEAD	LEAD ROUTE	PCP	STATE
AAL462	MAINTAIN		178	--	DAL2837		--	ACTIVE
AAL640	MAINTAIN		94	--	DAL2581		--	ACTIVE
ASH5906	MAINTAIN		77	--	AAL627		--	ACTIVE
DAL2581	MAINTAIN		101	--	ASH5906		--	ELIGIBLE
DAL2837	CROSS	JUNTN	126	--	ASH5809	PRRRR.R25L	--	ELIGIBLE
SWA151	CROSS	EGGLE	205	--	UAL6272	SILLT1.R26	JUNTN	SUSPENDED
SWA151	MAINTAIN		PENDING	--	AAL2320		--	PENDING
SWA7631	CROSS	EGGLE	110	--	SWA277	SILLT1.R26	JUNTN	ACTIVE
SWA7631	MAINTAIN		PENDING	--	ASH5810		--	ELIGIBLE - PARTIAL
UAL594	MAINTAIN		89	--	AAL462		--	ELIGIBLE

Figure 4-4. Notional IM Clearance Window on an ERAM Display.

When ATC provides the IM clearance and the flight crew accepts, the IM operation can begin immediately with no further communications required. Alternatively, a controller may issue an Expect

IM clearance[28] and withhold the ASG (to avoid unintentional premature initiation of the IM operation). This allows a flight crew to prepare the FIM capability before IM is intended to begin and allows IM clearance information to be communicated during a less busy time for the controller and flight crew. Then, at the desired start of the IM operation, ATC provides the ASG over voice. Flight crew acceptance of this message constitutes acceptance of the IM clearance, and the IM operation begins. An Expect IM clearance can be provided to an IM Aircraft already executing an IM operation; however, only a single Partial IM clearance can be accommodated by the FIM capability at a time.

While many IM applications will be possible using clearances delivered using voice communications, IM-related data link communications messages, including IM clearance and flight crew response messages, have been defined in the RTCA/EUROCAE avionics standards for Data Comm ATN B2. The use of data link communications also allows for the direct loading of IM message information into the FIM capability as well as support for the population and generation of downlink messages. The timeline for implementation of Data Comm ATN B2 messages is currently undefined.

Execution and Monitoring: Once initiated, the FIM capability provides FIM speeds to the flight crew until cancellation at the PCP. The flight crew is required to follow the FIM speeds and not modify them based on other information. If they are unable to fly a FIM speed based on safety or operational considerations (e.g., turbulence), the flight crew notifies ATC. The controller will then determine whether to suspend the operation until conditions change or amend or cancel the IM clearance.

Controller surveillance displays will provide IM status information to ATC as well as additional functions to suspend, resume, or cancel an IM operation.

When an IM clearance is being executed in a TBO environment, the controller manages the IM Aircraft to the STA by ensuring the Lead Aircraft is compliant with its STA. Concurrently, ground automation monitors IM operational progress and if conditions change (e.g., due to a TBFM rescheduling event), automation will either suggest a clearance amendment to the controller or recommend the operation be cancelled.

Cancellation: The IM operation is nominally terminated when the IM Aircraft reaches its PCP, prompting the FIM capability to remove the FIM speed from flight-deck displays. ATC can cancel IM at any time and resume conventional control prior to the PCP. This might result from, for example, a Lead Aircraft route change, a TBFM reschedule event, or traffic conflicts. If cancelling early, the controller provides a speed and/or navigation instruction to the flight crew, updates the ground automation as needed, and returns to non-IM operations.

4.3.3.2 IM Cruise Operations

IM can be performed in cruise and arrival and approach phases of flight to increase overall flow efficiency. IM operations will enable more precise spacing between aircraft, which can increase throughput. In addition to the throughput benefits, ATC workload will be reduced as inter-aircraft spacing does not need to be actively managed from the ground. In general, during the en route cruise phase of flight, IM can help achieve a time-based spacing objective based on the TBFM schedule.

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[28] The FIM avionics standards use the term “Partial IM Clearance” to represent a specific communication by a controller of all IM Clearance information except the ASG. Controllers routinely prepare flight crews for eventual ATC instructions with “expect” communications. In this document, “Expect IM clearance” is used to refer to the controller communication while “Partial IM clearance” is used to refer to accommodation of the Expect IM Clearance in the avionics for future use.

Aircraft equipped with IM can be given clearances to merge with a desired time-based spacing objective at a desired location (typically a route merge or an en-route MRP).

In metering operations, IM may be used to manage flights to en-route meter arcs more precisely than when using ground-based automation DSTs alone. The closed-loop nature of IM allows for more speed adjustments to be made for a given flight segment to achieve a desired spacing interval than can be reasonably provided by ATC. The use of the FIM capability is expected to result in more precise spacing than is possible in the current environment, where the frequency of trajectory corrections that can be communicated by the controller (in response to uncertainties that arise) is constrained due to workload.

IM operations can begin as soon as an IM Aircraft crosses a TBFM scheduling freeze horizon and TBFM has assigned an STA at the MRP for both the IM-capable aircraft and the candidate Lead Aircraft (leading aircraft in sequence at the subject MRP). IM operations may be used when aircraft are on the same or different routes if both aircraft are scheduled to the same MRP. When specific initiation criteria are satisfied (e.g., the desired spacing may be satisfied with speed changes alone and the aircraft are within ADS-B In range), the ground automation will present a complete IM clearance on to the controller. The ASG will be the difference in the STAs of the IM and Lead Aircraft at the MRP. At their discretion, ATC may issue an IM clearance to the flight crew to use the FIM capability to achieve the desired spacing at the MRP.

The FIM capability requires the Lead Aircraft's IFPI. Due to the nature of routes crossing meter arcs, the Lead Aircraft's IFPI as well as the definition of CPs, PCPs, and TRPs (as applicable) may be complex. Complex IM clearances are expected to only be provided using data link communications (not voice). In these cases, the ground automation will inhibit proposal of complex clearances to controllers for IM Aircraft that have not filed as data link communications capable.

A TBFM rescheduling event may result in changes to the aircraft sequence or differences in an IM pair's ASG. Controllers will be notified if the automation recommends a change to an active IM clearance or if a clearance is no longer valid due to changes in STAs or the sequence and should be canceled. If a change is proposed, the controller may choose to cancel, amend, or continue the IM operation. Controllers may cancel IM operations any time their objectives change or if they prefer another method to achieve their objectives.

4.3.3.3 IM Arrival and Approach Operations

IM applications are typically defined by IM clearance type, desired initiation and termination locations, route and runway (if applicable) geometries, and the available ground automation. As shown in Figure 4-5, IM arrival and approach applications can support spacing from a Lead Aircraft going to the same corner post for operations ending in en-route airspace[29], the same runway, a dependent parallel runway, and crossing or converging runways. IM operations to dependent parallel and crossing and converging runway configurations are called Dependent Staggered Approaches (DSA) and Dependent Crossing and Converging Runways (DCCR), respectively.

[29] In Figure 4-5, the location of the CP, used by the FIM capability, is shown in the logical location based on the operational application. In the Same Corner Post example in the upper-left panel, the CP is shown at what would be the MF on the en-route/terminal boundary.

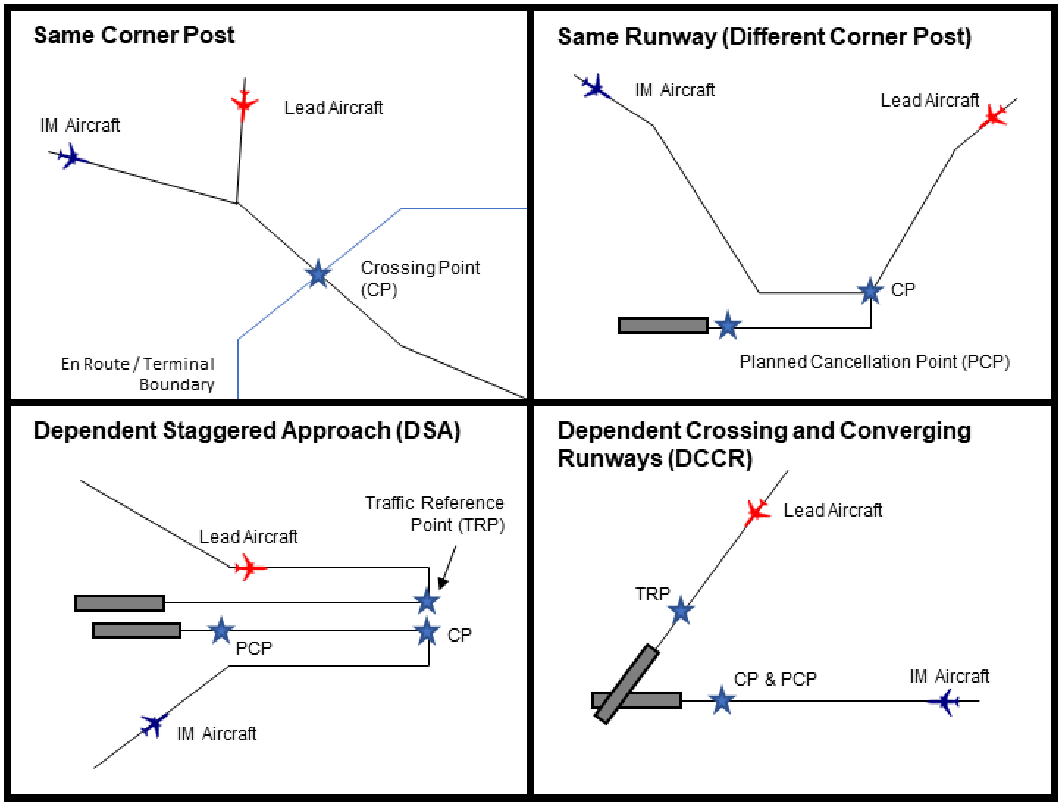

Figure 4-5. Illustration of the Range of IM Operations Supported by DO-361A.

A detailed description of an initial, integrated IM and terminal metering operation to same runway arrivals is available in [47]. A research summary and operational description of arrivals to dependent parallel runways is available in [48].

IM arrival and approach operations are expected to be deployed in environments that contain multiple arrival routes entering a terminal airspace and wherein extended and arrival metering and possibly terminal metering operations are in effect. An aircraft pair must be within ADS-B In range at the time the controller provides the IM clearance. However, the IM Aircraft and Lead Aircraft can be on different routes and do not require a common route segment. IM clearances will be proposed by ground automation based on the Lead and IM Aircraft routes and adapted rules.

FIM speeds are provided so the IM Aircraft will cross the CP at a time interval equal to the ASG after the Lead Aircraft crossed the CP (or TRP if on non-coincident routes). Because the IM Aircraft and Lead Aircraft may be on different routes prior to the CP (and TRP, if applicable), the FIM speeds are based on the predicted spacing at the CP. Between the CP and the PCP, FIM speeds are provided to precisely maintain the ASG.

4.3.3.4 Ground-based Automation System Functions

Figure 4-6 illustrates the various air and ground system components comprising IM operations in a TBO environment, the information flows between each, and the method of information sharing. Ground-based automation systems are envisioned to implement IM-related functions to set up and help controllers monitor the conduct of IM operations. Note that the Lead Aircraft only broadcasts ADS-B Out and does not need to be aware of its involvement in an IM operation.

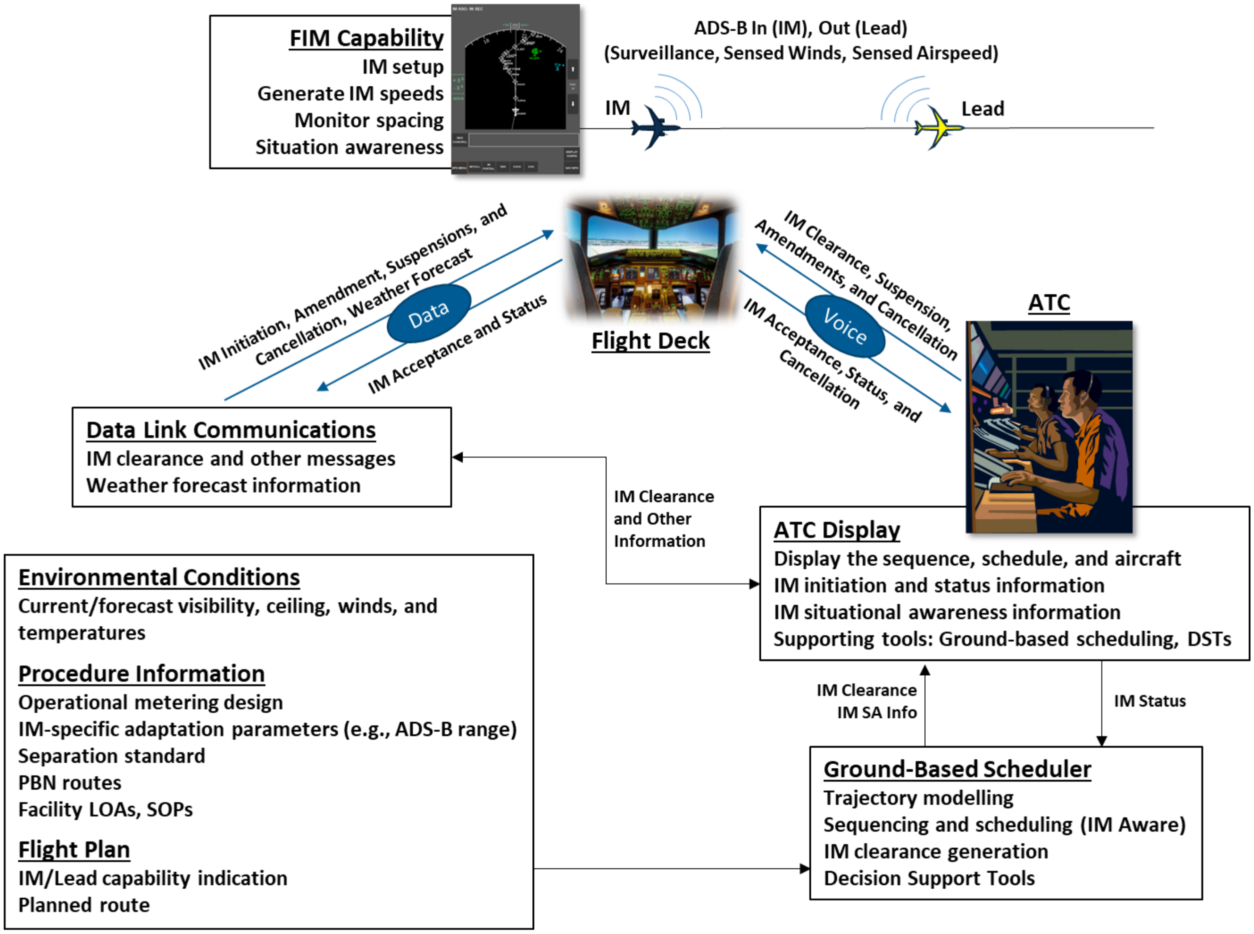

Figure 4-6. System Diagram of IM Operations in a TBO Environment.

Within the ground system, the IM clearance generation function proposes compatible aircraft pairs for IM operations based on relevant factors including applicable runway configuration, aircraft capabilities, applicable separation standard, and whether speed changes alone are sufficient to achieve the spacing goal. The ASG is equivalent to the difference in STAs between the Lead and IM Aircraft at the applicable MRP. For IM operations continuing into the terminal, this is expected to be near the Final Approach Fix (FAF). The ground automation generates an IM clearance and checks whether the initiation criteria, such as the IM Aircraft being within ADS-B range of the Lead Aircraft, are met. If so, the IM clearance information is proposed to ATC via the appropriate controller display system. IM clearance amendments are presented to ATC, as needed.

4.3.4 Integrated RTA and IM Operations

This ConOps describes the use of RTA and IM operations in the same airspace, meaning some flights may be conducting RTA operations, some flights may be conducting IM operations, and some flights may be managed without the use of flight-deck capabilities to achieve their STAs. In all cases, the operational objective is to keep flights on their planned routes as often as possible during higher-density operations, thereby improving throughput at airspace constraint points, flight efficiency, and flight predictability.

4.3.4.1 *Criteria for Selecting RTA versus IM Operations*

For RTA+IM-capable flights, the choice of one operation versus the other is based on several criteria. These include the availability of the operation (i.e., RTA is only available in en route airspace while IM is available in en route and terminal airspace), the initial distance between an RTA+IM-capable aircraft and its Lead Aircraft, the complexity of the clearance information and the means of communicating the clearance (e.g., voice vs. data link communications), and the demand at an MRP.

Figure 4-7 illustrates a notional flow chart for determining when an RTA operation or an IM operation is appropriate when aircraft are capable of both operations.

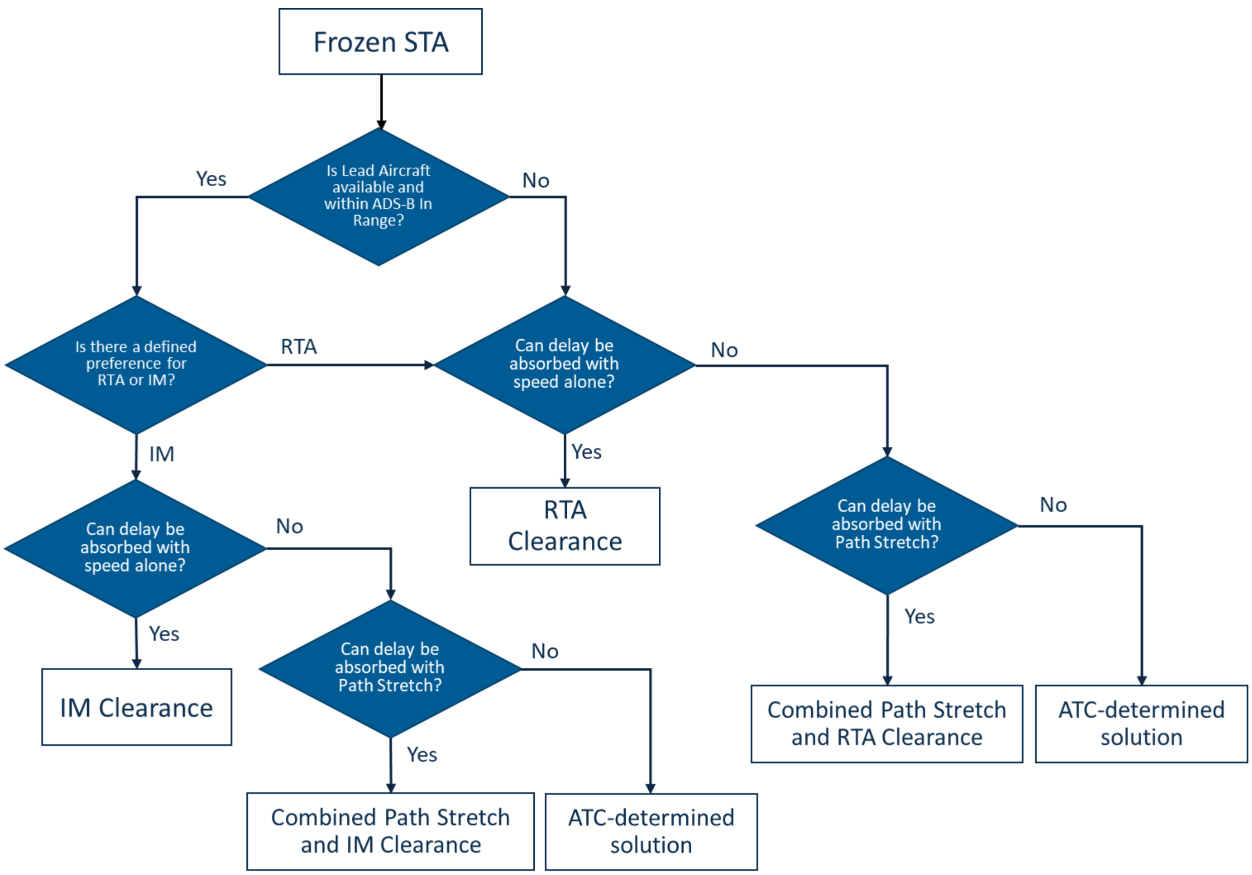

Figure 4-7. Logical Flow Chart to Determine Whether to Use RTA or IM Operations for RTA+IM-Capable Aircraft.

As an example of the criteria selection, if an aircraft is more than 90 NM (or 70 NM in airspace with high spectrum congestion like the Northeast Corridor) from its preceding aircraft, starting an RTA operation may be preferred over waiting until the leading aircraft is within ADS-B In range to initiate an IM operation. Or, if the leading aircraft for an RTA+IM-capable flight has complex IFPI (e.g., it is currently on a path stretch) and ATC must communicate the clearance by voice, an RTA operation may be preferred over IM, at least until the Lead Aircraft's IFPI is simpler. In both cases, an Expect IM clearance may be used to set-up a follow-on IM operation after the completion of the RTA operation and the aircraft are within range (the flight-deck interface will support entry of a Partial IM Clearance during an active RTA or IM operation). As another example, during high-demand periods, ATC may prefer using IM operations so that the trailing aircraft is responsive to the Lead Aircraft's behavior reducing the likelihood of ATC interventions between the IM and Lead Aircraft.

As shown in Figure 4-7 and described previously, RTA and IM clearances may also be combined with path stretch. For IM operations supported by data link communications, ATC may incorporate the Lead Aircraft's path stretch route into its IFPI. However, if only voice communications are available, ATC may wait until the Lead Aircraft is direct to a named waypoint on a procedure before issuing the IM clearance. In another case, a candidate IM Aircraft may require a path stretch to absorb excess delay. In any of these cases, an IM clearance may be delayed, and an RTA operation may be considered instead, with a possible transition to IM afterwards.

A transition from an RTA operation to an IM operation could happen by first clearing an RTA+IM-capable flight for an RTA operation in en-route airspace (e.g., before its proposed Lead Aircraft for an IM operation is in ADS-B In range). That flight then receives an IM clearance when the Lead Aircraft is in range, or the RTA operation is cancelled when the IM-capable aircraft sequences the MF and an IM clearance is then issued in the terminal.

4.3.4.2 Aircraft Roles

In this envisioned environment, a flight conducting an RTA operation may also serve as a Lead Aircraft in an IM operation. Conversely, an RTA operation may follow an aircraft conducting an IM operation, which may comprise a single IM pair or the end of a string of IM operations (i.e., comprising multiple IM pairs). Figure 4-8 illustrates different cases when the leading and trailing aircraft are conducting RTA and IM operations. Limits on the TOAC and FIM speed guidance are based on requirements in the applicable avionics standards, DO-236() and DO-361()[30], respectively, and FAA regulatory documents (e.g., TSOs). Avionics standards, FAA regulatory documents, air traffic orders, and the AIM would need to be aligned before these operations may be deployed in the NAS.

[30] The () notation is used to refer to the latest version of the avionics standards. As the TOAC and FIM standards may be updated based on this ConOps, the current standards may not yet reflect final requirements on TOAC and FIM speed guidance limits.

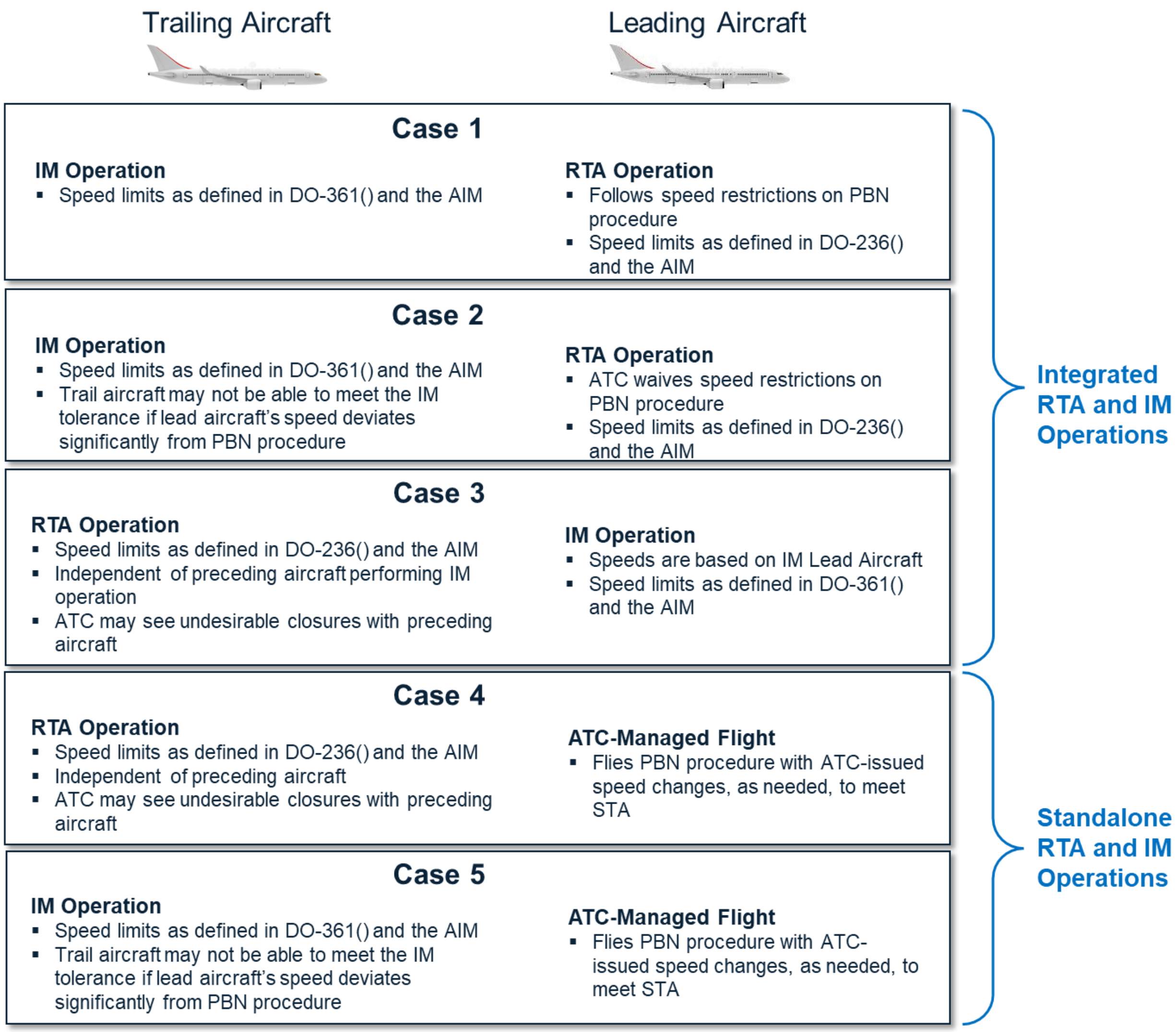

Figure 4-8. Combinations of Leading/Trailing RTA and IM Operations.

In Cases 1 and 2, the leading aircraft is conducting an RTA operation, and the trailing aircraft is performing an IM operation. In both cases, the IM Aircraft will be responsive to speed changes made by the RTA Aircraft. If the leading aircraft adheres to the PBN speed restrictions, as captured in Case 1, the trailing aircraft should be able to meet the ASG within tolerance because it can more accurately predict the Lead Aircraft's trajectory and the leading aircraft's speeds will not exceed the IM Aircraft's speed limits as imposed by the FIM capability. However, if ATC waives the PBN speed restrictions, as shown in Case 2, then the IM Aircraft may not meet the ASG within tolerance if the RTA Aircraft's speed profile deviates significantly from the published PBN speed restrictions and exceeds the speed limits imposed by the FIM capability.

In Case 3, the Lead Aircraft is conducting an IM operation, and the trailing aircraft is performing an RTA operation. The IM Aircraft's Lead may be conducting an IM operation as well, meaning the RTA Aircraft is following the last aircraft in a string of IM operations. In this case, the RTA Aircraft will attempt to meet its STA regardless of what the preceding aircraft does. If the IM Aircraft's Lead is on schedule, the IM Aircraft will also be on schedule and should present no conflict with the succeeding RTA Aircraft. However, if the IM Aircraft's Lead Aircraft is behind schedule, the IM Aircraft will also be behind schedule and the RTA will not adjust for this difference, potentially causing an undesirable closure between the two aircraft. In cases where the IM Aircraft is performing a Cross clearance (which attempts to meet the spacing goal by the CP and not before it), there may also be issues for a following RTA Aircraft as the IM Aircraft attempts to meet the spacing over the course of the operation and not right away. Potential variabilities in how TOAC speeds are calculated to meet the RTA at a downstream point could cause undesirable closure rates in some cases. This should be the subject of further analysis.

In Cases 4 and 5, RTA and IM operations follow ATC-managed flights, respectively. In Case 4, the RTA operation is independent of the leading aircraft, whereas the IM operation in Case 5 will be responsive to the leading aircraft's speed changes.

Consistent speed limits on the TOAC and FIM speeds help ensure spacing objectives can be met. In the case of an IM operation following an RTA operation, the IM operation will be feasible unless the RTA Aircraft exceeds the upper or lower speed limits on the FIM capability for an extended time. In the case of an RTA operation following an IM operation, ATC should not need to intervene in the RTA operation unless the IM Aircraft's Lead Aircraft is excessively late relative to its STA. As noted in Section 4.3.1, ATC always remains responsible for separation and is expected to intervene in the RTA and IM operations before spacing issues become separation violations.

4.3.4.3 Concept Areas Requiring Further Harmonization

While the overall objective of integrated IM and RTA operations is to maximize commonality and expected behaviors, there are some inherent conceptual differences that should be reconciled. One of the most important is required performance. As noted in Section 1.2.2, the RTA tolerance is 30 seconds (95%) for RTA points in level flight (e.g., RTA points at en-route meter arcs) and 10 seconds (95%) for RTA points during descent (e.g., RTA points at MFs). As noted in Section 1.2.3, the IM tolerance is 10 seconds (95%) for all IM operations.

Another difference is that the FIM standards preclude IM operations during the climb as Lead Aircraft trajectories are typically more variable and requirements and algorithms for level and descending flight have not been proven to work during climb. Additionally, no clear operational benefits to using IM operations during climb were identified during the avionics standards development. RTA operations, however, would not be subject to the same problem as they do not require the calculation of a Lead Aircraft trajectory. Therefore, it is possible that RTA could be used during the climb phase of flight, though this operational use has not yet been defined.

IM also includes functions for controllers to suspend and resume an active operation and amend an active clearance. These functions have not been defined for RTA and controllers will need to be aware of potential differences between the operations. For example, as described in DO-328B [20], most elements in an IM clearance may be changed by the controller. For example, to be consistent with IM, it is recommended that clearance amendments be supported; however, possibly not for the RTA Crossing Point (CP) element. If the CP needs to be modified, it would likely be more logical to cancel the RTA clearance and issue a new one.

Relatedly, IM also allows for controllers to change an IM Aircraft's navigation clearance under some conditions without necessarily cancelling the IM operation. In this event, the controller is expected to first instruct a suspension of the IM operation and then amend the navigation clearance, amend the IM clearance as needed to account for the navigation clearance change, and then clear the IM operation to resume. Also, in the IM concept, an ATC speed instruction cancels any active IM operation. If the controller does not explicitly communicate the cancellation when providing a speed, the flight crew is expected to suspend the IM operation and not resume until ATC clears them to do so. Unlike with IM, there is no clearly defined cancellation requirement if a new navigation clearance or ATC speed is issued during an active RTA operation. Therefore, it should be considered whether navigation clearance changes that would cancel an IM operation should also cancel any active RTA operation.

RTA and IM operations will also need further considerations on their use of forecast winds and temperatures, especially for retrofit FIM implementations. A single flight deck should ideally have the same forecast winds and temperatures across all systems. However, forecast winds and temperatures need to be entered manually into a CDTI for a retrofit FIM capability. A process may be needed to ensure that these forecast winds and temperatures are the same as those used by a TOAC capability residing in the FMS.

Another consideration is that the IM concept defines procedures for flight crews if they are unable to comply with the IM clearance. Here, the flight crew's main obligation is to follow the FIM speeds and notify ATC if they have reason to not be able to fly a particular speed or receive an alert telling them that the operation has become infeasible (i.e., the FIM capability "infeasibility check" [22]). They are not responsible for ensuring they achieve or maintain the ASG within tolerance. The TOAC capability, however, is hosted in an FMS with speeds implemented by the flight guidance system. For these operations, the flight crews do not manually implement speed adjustments and the FMS TOAC function returns an "unable" alert if it determines that the crossing time can no longer be met. This may result in differences in how controllers need to monitor and cancel the two operations if needed. Therefore, the related operational requirements and cancellation procedures need further definition.

4.4 Supporting Infrastructure

The necessary infrastructure, summarized here, must be in place to support successful RTA and IM operations. As noted previously, the ground-based automation functionality described here is not currently deployed, and the FAA does not currently have funding allocated for such enhancements.

Ground-based automation changes supporting RTA and IM clearance generation and monitoring must be in place before RTA and IM operations can be conducted as described in this ConOps. Changes are expected to TBFM, ERAM, and STARS, or their equivalent systems, to support the functionality as described in Section 4.3 and summarized here. Interim operations, preceding the end-state operations described here, may be possible with a sub-set of the ground-based automation changes, but capturing these possible operations is out of scope for this document.

PBN procedures must be in place to support RTA and IM operations. At this time, PBN procedure design characteristics that support TBM operations are expected to be sufficient for RTA and IM operations. These design characteristics are briefly described in Section 2, but are generally intended to provide trajectory predictability using fully defined routes to the runway and procedural altitude and speed restrictions to bound uncertainties in the vertical and speed profiles, respectively. Further details on recommended procedure design characteristics are provided in [49] and [50].

To support capability aware scheduling, clearance generation, and controller situation awareness, ground-based automation will require knowledge of flight-deck capabilities, which indicate flight-deck equipage (data communications, TOAC, and/or FIM capability) as well as flight crew training to execute RTA and/or IM operations. ADS-B In flight-deck capability indicators have been defined for Field 18 in the International Civil Aviation Organization (ICAO) flight plan [51, 26]. A similar solution has been proposed for TOAC [52].

Automation systems should also consider compatible route elements and other constraints when determining candidate IM pairings and clearance information and ensure initiation criteria are met, including a route conformance check and a prediction that the clearance is feasible prior to sending proposed RTA or IM clearances to the display platforms. Awareness of data link communications capabilities for an aircraft or facility may be used to filter candidate RTA and IM operations based on their clearance complexity. Those clearances that are too complex for voice communications alone must be provided via data link communications, and therefore, should be limited to data link communications-capable aircraft. Additionally, the ground automation may provide a capability for facilities or controllers to adapt preferences for the display of automation-generated speed advisories and proposed RTA and IM clearances when all or some may be available, or one is active, for a given flight.

In the event of a rescheduling event, an individual aircraft flight plan amendment or route change (such as path stretch), or similar changes to the metering schedule, ground automation should re-evaluate all active and pending IM and RTA operations. If any of the active or pending automation-generated information elements have changed, an indication and the updated information should be provided to the controller display platforms. If the controller cancels the active clearance, new RTA and IM clearances may be proposed. As the effect on active operations should be evaluated before any changes are made to the schedule, active RTA and IM operations should be identified to TMCs.

The automation system should provide a capability for controllers to indicate active RTA or IM operations (i.e., those in which they provided an RTA or IM clearance to an aircraft) as well as capabilities to indicate to a downstream controller active operations and available clearances (i.e., newly proposed clearances or those that were rejected or ignored by the previous controller) no later than handoff of the aircraft.

Once an RTA or IM operation is active, the automation system should provide means to indicate a clearance has been canceled either by the controller or automatically once the RTA point or IM PCP has been sequenced. Once an operation has ended, display indications should be removed, and the cancellation should be communicated to other systems monitoring the operation. If new or amended information is received from the scheduling system, the controller display system should provide unique indications to the controllers that highlight the change in the information. Lastly, terminal controllers will need information related to active IM operations that were initiated in en route airspace and continue into the terminal. This includes identification of a Lead Aircraft that is part of an active IM operation prior to receiving the IM Aircraft.

5. Operational Scenarios

5.1 Scenario Assumptions

The scenario in this section illustrates the combined use of RTA and IM operations and expected variations in RTA and IM operations when integrated with extended metering operations (level flight) and arrival metering operations (during initial descent) to the TRACON. The scenario contains several aircraft to illustrate expected operational conditions resulting from variables like aircraft equipage, route geometries, and other traffic. The scenario is designed to provide an overall air traffic operations perspective, spanning multiple controller stations, rather than from the perspective of a single flight crew or single ATC position.

The scenario in this section assumes the following about the operational environment:

- Aircraft are assumed to be RTA-capable, IM-capable, RTA+IM-capable, or not capable of either. An aircraft's flight plan contains information to indicate whether the flight can conduct RTA or IM operations. Ground-based automation systems will accept the flight plan and indicate to controllers if a flight is RTA and/or IM capable. This capability is based on equipage, flight crew training, and any relevant authorizations.
- A path stretch solution will be proposed if speed alone is not sufficient to meet a flight's STA at an MRP (e.g., a meter arc or MF).[31] After a path stretch is executed, any speed solution can be used, including automation-generated speed advisories, RTA operations, or IM operations. If a Lead Aircraft is executing a path stretch and if the IM Aircraft is not equipped with data link communications, ATC may wait until the Lead Aircraft is direct to a named waypoint on a procedure to issue the IM Clearance to the IM Aircraft. This simplifies the Lead Aircraft IFPI that must be communicated in the IM Clearance.
- ATC DSTs, RTA, and IM will all be available to controllers when feasible. Ground-based automation may provide ranked solutions (e.g., see Section 4.3.4.1).[32] After controller acceptance of a feasible solution, ground-based automation indicates active operations on all involved aircraft.
- Ground-based automation will only propose an RTA and/or IM clearance to controllers if it determines the clearance will be feasible. Although controllers should check the clearance information for obvious errors or operational incompatibilities, they are not responsible for validating the likelihood of aircraft successfully achieving the goal. For example, it may be difficult for controllers to evaluate the effects of winds on different routes when the IM Aircraft and Lead Aircraft are merging at a downstream point.
- Ground-based automation has the information required to generate RTA clearances, in which the crossing time is equal to the STA at the MRP. Ground-based automation is aware of aircraft

[31] The use of TOAC and FIM capabilities is not dependent on the path stretch capability being available. ATC-issued vectors could be used in place of path stretch solutions to absorb delays when speed solutions alone are not sufficient. However, RTA and IM operations cannot begin until the aircraft has a defined navigation route, which means RTA and IM operations should not start until the aircraft is direct to a named waypoint on its procedure. Similarly, if a Lead Aircraft is on an ATC-issued vector, the Lead Aircraft's IFPI in the IM Clearance must be unambiguous and the IM operation cannot begin until the Lead Aircraft is direct to a named waypoint on its procedure.

[32] Further research is needed on how ground-based automation should display feasible solutions (i.e., an automation-calculated speed, an RTA operation, and/or an IM operation) to ATC based on facility preferences and other factors.

performance capabilities and will ensure there is adequate time prior to the MRP to achieve the RTA using speed adjustments only.

- Ground-based automation has the information required to generate IM ASGs, based on the schedule. Ground-based automation is aware of aircraft performance capabilities and will ensure there is adequate time prior to the CP for the IM Aircraft to achieve the ASG using speed adjustments only.
- The TOAC and FIM capabilities have access to updated forecast wind and temperature information.
- In the event of an off-nominal RTA or IM clearance cancellation, controllers maintain the aircraft sequence with or without the help of ground-based automation.
- All aircraft are broadcasting ADS-B Out.
- The ground-based automation employs RTA- and IM-aware scheduling, as appropriate, such that applicable STAs are scheduled closer together in time than they would otherwise be due to the availability of RTA and IM operations.

Additional scenario-specific assumptions are described in the following section when relevant.

5.2 RTA and IM Operations in an Extended and Arrival Metering Environment

This scenario takes place in the cruise and arrival phases of flight, including the descent to the MF. The scenario includes both RTA and IM operations in conjunction with the use of path stretch, and an active RTA Aircraft participating as the Lead Aircraft in an IM operation. As the RTA and IM operations progress, controllers monitor participating aircraft relative to other traffic in their airspace and their operational objectives. Controllers may suspend or cancel an RTA or IM operation at any time if the situation warrants or their objectives change.

A generic airspace and metering environment is depicted in Figure 5-1 for aircraft arriving to the depicted airport. This scenario ends at the MF (ALLIE) located at the TRACON boundary. Two scheduling meter arcs (MRP1 and MRP2) are depicted with corresponding freeze horizons. There are also two STARs supporting arrivals that begin at the point depicted by a star (☆). The airspace is assumed to comprise multiple en route sectors, though they are not separately depicted.

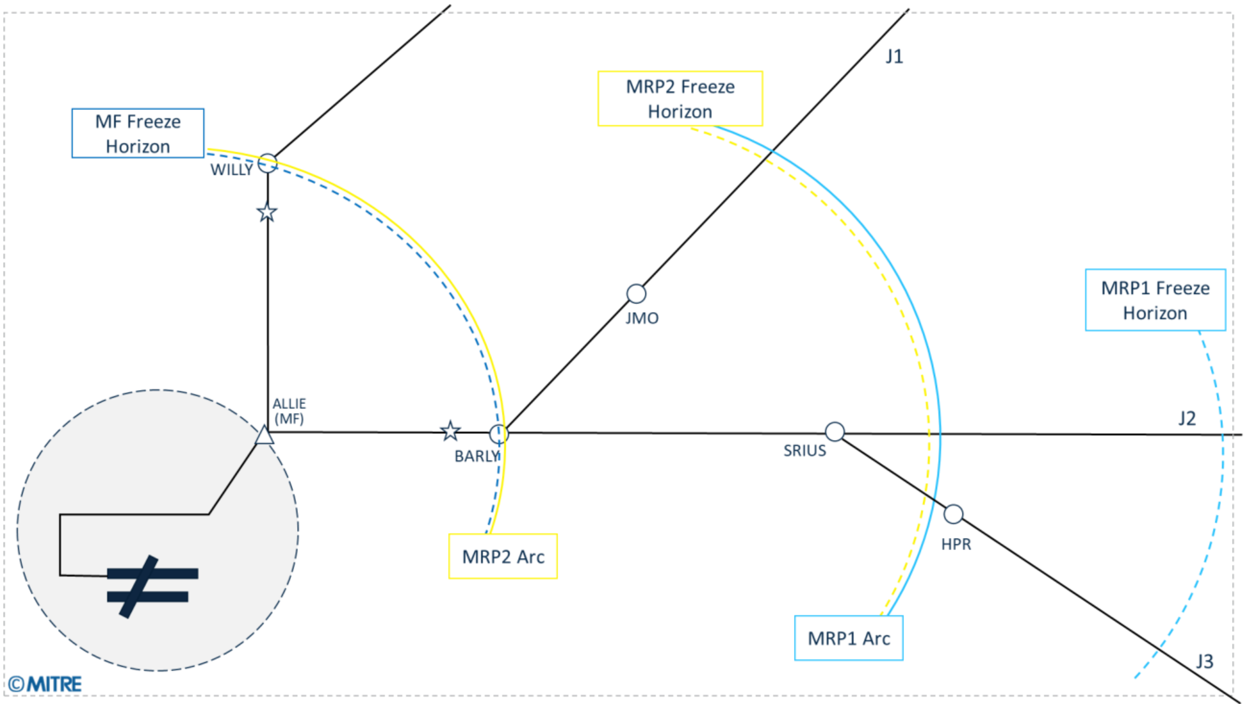

Figure 5-1. Extended and Arrival Metering Environment.

Table 5-1 summarizes the schedule and operations for each aircraft in the scenario. All times are Coordinated Universal Time (UTC). A description of the sequence of events to set up and manage each operation for each aircraft in the scenario follows the table. The following general assumptions apply to the metering environment and consequently the information in the table.

- Distance between meter arcs = 200 NM
- Average speed of flights = 500 kt
- Average flight time between meter arcs = 24 minutes (min)
- Minimum difference in STAs at MRPs = 70 s (equivalent to 9.7 NM)
- Delay that can be absorbed using speed alone = 1.5 min (i.e., the maximum flight time = 25.5 min)

Table 5-1. Arrival Schedule and En Route Operations.

Aircraft	STA at MRP1	STA at MRP2	Same Flight Diff in STAs	Diff in STAs at MRP2	Operations
1	N/A	1300:00z		N/A	RTA at WILLY; follow-on RTA at ALLIE
2	1234:00z	1301:00z	27 min	60 s (but no deconfliction needed)	RTA at MRP1; required flight time > 25.5 min; needs path stretch between MRP 1 and 2; no deconfliction needed at MRP2 relative to Aircraft 1; IM to BARLY, followed by IM to ALLIE

Aircraft	STA at MRP1	STA at MRP2	Same Flight Diff in STAs	Diff in STAs at MRP2	Operations
3	1237:30z	1302:10z	24 min, 40 s	70 s	IM to ALLIE with amendment
4	1238:30z	1303:30z	25 min		Controller assigned speeds
5	1240:00z	1304:50z	24 min, 50 s	80 s	RTA at MRP1; IM to BARLY
6	1241:10z	1306:00z	24 min, 50 s	70 s	Path stretch is needed to MRP 1; IM to MRP1; IM to BARLY
7	1243:00z	1307:10z	24 min, 10 s	70 s	IM to BARLY
8	1244:00z	1309:00z	25 min	110 s	RTA at MRP1; RTA at BARLY

The aircraft in the scenario illustrate aspects of conducting both RTA and IM operations within the same sector and crossing sector boundaries. In real operations, there would be additional aircraft preceding Aircraft 1 and following Aircraft 8, but they are removed from the scenario for clarity.

Figure 5-2 presents the initial conditions for Aircraft 1-3 at the start of the scenario.

Aircraft 1 illustrates the use of an RTA clearance during level flight to an en route meter arc (WILLY on MRP2) and the use of RTA during descent to the MF.

Aircraft 1 is RTA-capable only and was issued an RTA at WILLY (1300:00z) prior to arrival in the airspace. As the controller accepts the hand-off from the issuing facility, the controller recognizes Aircraft 1's active RTA operation on their display and confirms the operation is consistent with their metering objectives. No specific action is taken by the controller with respect to the RTA operation.

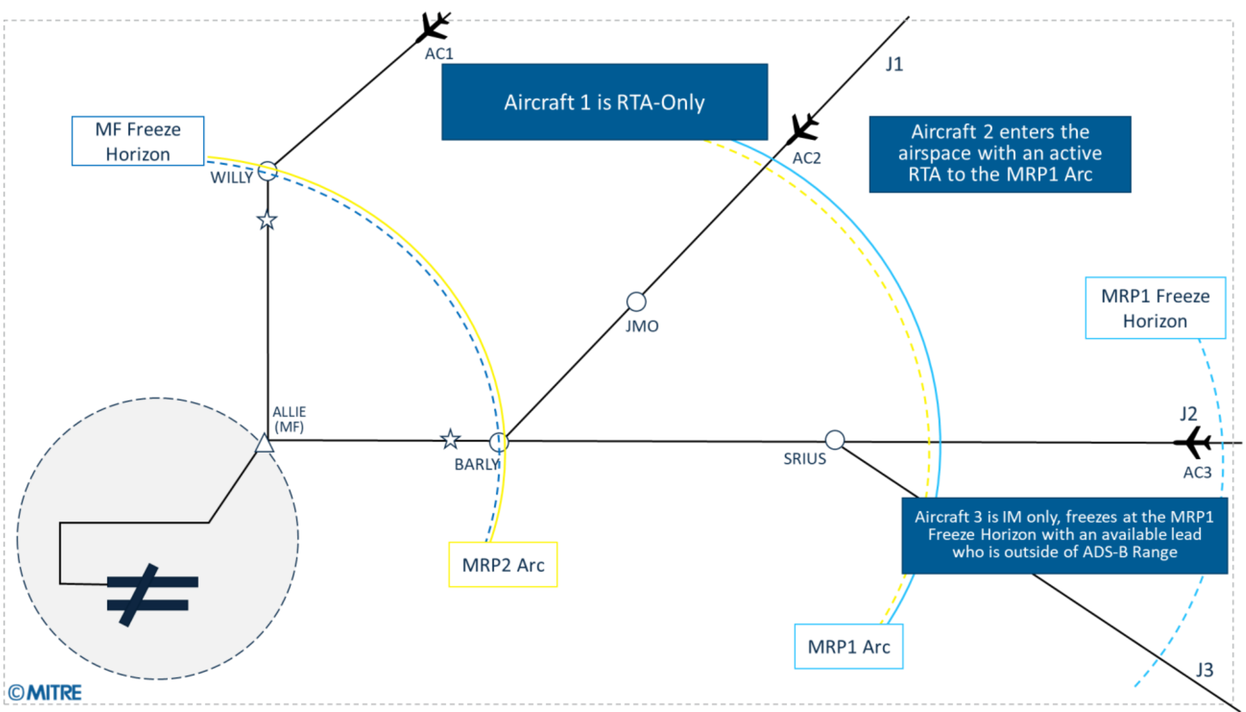

Figure 5-2. Initial Conditions for Aircraft 1-3.

Aircraft 2 illustrates the use of an IM clearance in conjunction with path stretch to meet the required spacing behind a Lead Aircraft performing an RTA operation in another sector's airspace.

Aircraft 2 is RTA+IM capable and enters with an active RTA to the next MRP (1234:00z at MRP1). The controller recognizes the active RTA on the display and confirms the operation is consistent with the current metering objectives. Aircraft 2 completes the RTA operation at the MRP1 and is handed off to the next sector.

After Aircraft 2 crosses the MRP1 Arc and the subsequent freeze horizon for the MRP2 Arc (crossing waypoint BARLY), an IM clearance is available behind Aircraft 1; however, Aircraft 2 has too much delay to absorb with speed alone and a path stretch is proposed to the controller (Figure 5-3).

The issuance of the path stretch satisfies the IM initiation criteria (i.e., after the path stretch, speed alone will achieve the desired spacing), and an automation-proposed IM clearance behind Aircraft 1 ending at the MF is proposed to the controller. The ground-based automation proposes both RTA and IM clearances; however, IM clearances are preferred by the facility and ATC issues the IM clearance recommended by the ground automation (see example in Figure 4-7). The controller may reject or ignore the IM clearance and retrieve the RTA clearance if desired. Because the CP and PCP are co-located and not on the Lead Aircraft's route, Aircraft 2's IM clearance includes a TRP. The controller sends the following IM clearance information via data link communications to Aircraft 2.

- **IM Clearance Type:** Cross
- **Crossing Point:** BARLY
- **ASG:** 60 seconds
- **Lead Aircraft:** Aircraft 1
- **Lead Aircraft Route:** Direct WILLY
- **TRP:** WILLY
- **PCP:** BARLY

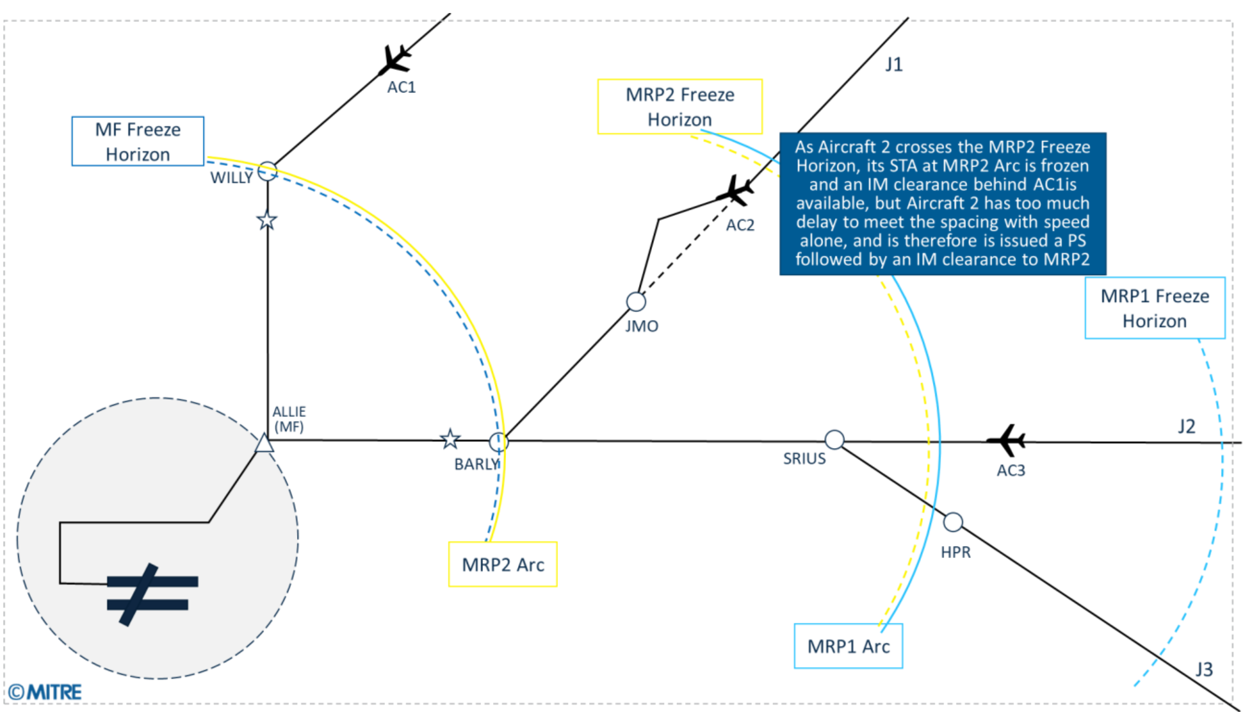

Figure 5-3. Aircraft 2 Path Stretch followed by IM Behind Aircraft 1.

Once the IM clearance is accepted by the flight crew, the controller indicates the clearance is active through their display system and an indication that Aircraft 1 is the Lead in an IM operation is also displayed to the controller who is managing Aircraft 1. Details of the clearance, including the sector with control of the IM Aircraft, are available to the Lead Aircraft's controller through the ground automation and display systems.

Aircraft 2 executes the routing change from the path stretch and follows the FIM speeds to achieve the desired spacing behind Aircraft 1.

Aircraft 3 illustrates an IM-capable aircraft with an identified Lead Aircraft who is outside of the facility-set ADS-B In range. Aircraft 3 must be managed with automation-generated speed advisories until Aircraft 2 is within range and an IM operation can be initiated. Aircraft 3 is later issued an IM clearance amendment to modify the ASG behind Aircraft 2.

Aircraft 3 is IM-capable only and although a Lead Aircraft is identified in the frozen sequence (Aircraft 2), the aircraft are not within the facility-set ADS-B In range specified in the ground automation. Therefore, the IM clearance is withheld from the controller as the initiation criteria are not satisfied. Controllers manage Aircraft 3 with automation-generated speed advisories to achieve the desired arrival time at the MRP1 Arc.

When Aircraft 3's schedule to the MRP2 Arc is frozen, Aircraft 2, executing a path stretch to absorb delay, is now within ADS-B In range (Figure 5-4). Because Aircraft 2 required a route change, an IM clearance involving Aircraft 2 could not be initiated until the route was known. In this case, the route would be known as soon as Aircraft 2 initiated the assigned path stretch. Prior to initiation of the path stretch, the Lead Aircraft IFPI would be incomplete as the point at which the Lead Aircraft leaves the assigned route (J1) on a heading to the point assigned in the path stretch is not pre-defined. An IM clearance is proposed to the controller for Aircraft 3 that includes the route details of Aircraft 2's path stretch. Because Aircraft 2 and Aircraft 3 are on the same route between BARLY and ALLIE, the ground automation proposes an IM clearance with the CP at BARLY and the PCP at ALLIE. The controller sends the following IM clearance information via data link communications to Aircraft 3.

- **IM Clearance Type:** Cross
- **Crossing Point:** BARLY
- **ASG:** 70 seconds
- **Lead Aircraft:** Aircraft 2
- **Lead Aircraft Route:** JMO..BARLY[33]
- **PCP:** ALLIE

The controller with Aircraft 3 indicates the active IM operation in automation and the notification that Aircraft 2 is now both a Lead and Trail in IM operations is observed by the controller managing Aircraft 2. The initiation of Aircraft 2's path stretch was prior to the initiation of Aircraft 3's IM operation and no coordination is necessary between the controllers. In fact, without the execution of the path stretch, it is unlikely the ground automation would have deemed Aircraft 3's IM operation feasible due to Aircraft 2's excess delay and the IM clearance would not have been proposed

[33] While there are other points both before and after this provided IFPI, they are excluded from the communicated IFPI because the operation starts while the aircraft is direct to JMO and ends at BARLY. Therefore, no other IFPI elements are necessary.

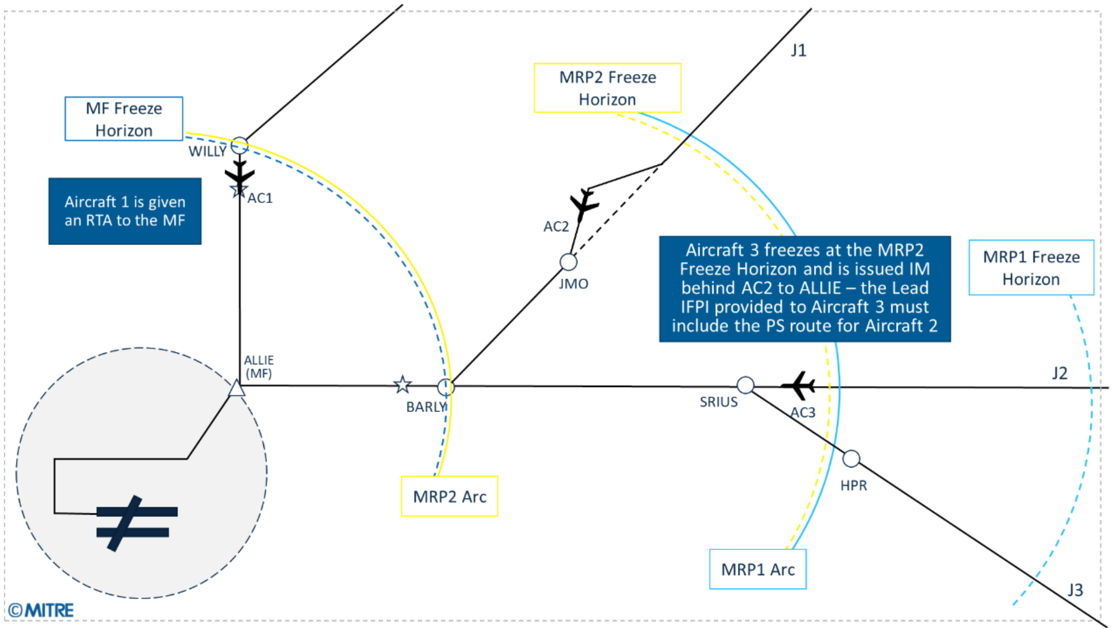

Figure 5-4. Aircraft 3 IM Behind Aircraft 2 (Cross-Sector).

Aircraft 1 completes its RTA operation at WILLY and its schedule at the MF is frozen. The controller issues another RTA to Aircraft 1 to arrive at ALLIE on schedule.

As operations for Aircraft 1-3 progress, Aircraft 4-6 enter the scenario as depicted in Figure 5-5.

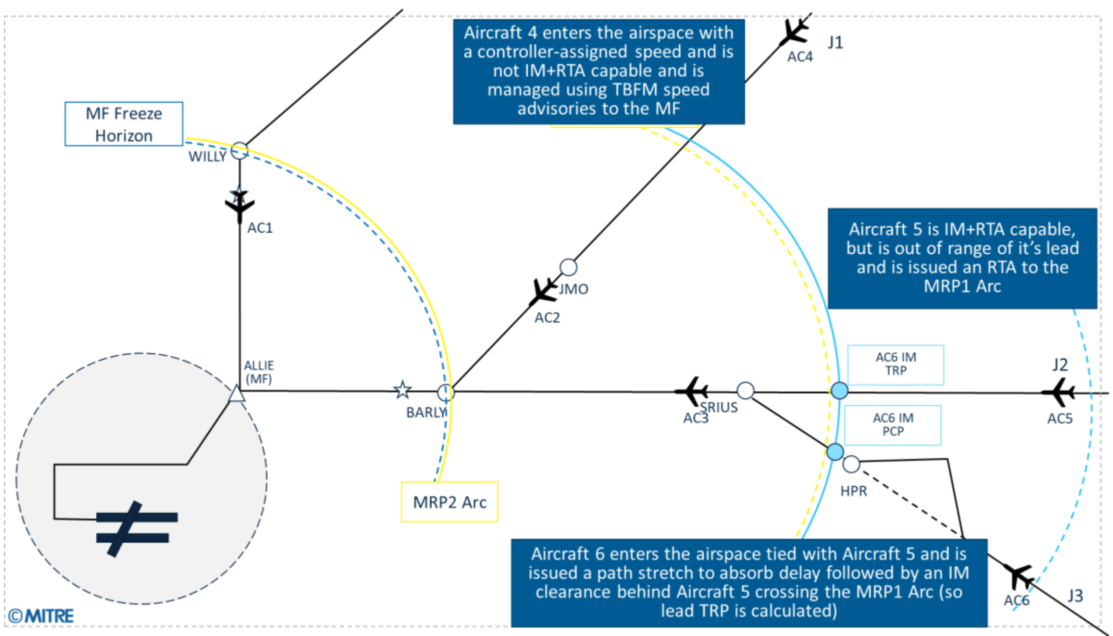

Figure 5-5. Initial Conditions for Aircraft 4-6.

Aircraft 4 illustrates the integration of an aircraft that is neither RTA nor IM capable and must be managed with automation-generated speed advisories and/or other tactical ATC actions.

Aircraft 4 arrives in the airspace and the controller notices that it is neither RTA nor IM capable. The controller reviews the metering information available on their display and uses the automation-generated speed advisories and any required route changes to merge Aircraft 4 behind Aircraft 3 and achieve the schedule objectives at BARLY.

Aircraft 5 illustrates the use of an RTA clearance while an available Lead Aircraft is out of range for IM, subsequently initiating IM when the Lead Aircraft is within range.

Aircraft 5 is RTA+IM capable and as it enters facility airspace, the ground automation has identified an IM clearance to the next meter arc (MRP1), but Aircraft 4 is not within the facility-set ADS-B In range. Therefore, the automation withholds the IM clearance, and an RTA clearance is presented for the controller to consider. As the MRP1 Arc is not near a named fix, the ground automation defines the RTA point as a bearing and distance from SRIUS. The controller then reviews and issues via data link communications an RTA at the MRP1 Arc, using the newly created point, to Aircraft 5: 1240:00z at SRIUS090055. The active indications for the RTA operation are displayed for the controller.

Aircraft 5 follows the TOAC speed guidance and as it reaches the MRP1 Arc, the RTA operation concludes. Aircraft 4 and 5 may come within ADS-B In range prior to the completion of the RTA operation; however, the facility has defined system preferences to inhibit the proposal of IM clearances for aircraft actively performing an RTA operation. Aircraft 5's STA at the MRP2 Arc freezes and Aircraft 5 is then issued a cross-sector IM clearance behind Aircraft 4 (now within ADS-B In range) to BARLY (refer to Figure 5-6).

The controller sends the following IM clearance information via data link communications to Aircraft 5.

- **IM Clearance Type:** Cross
- **Crossing Point:** BARLY
- **ASG:** 80 seconds
- **Lead Aircraft:** Aircraft 4
- **Lead Aircraft Route:** J1.JMO..BARLY
- **PCP:** BARLY

The issuing controller indicates the active IM operation in the automation system and the sector controller with Aircraft 4 notices the Lead Aircraft indication and realizes that only speed changes may be used without coordination. The controllers monitor the separation of aircraft as well as the active IM operations of Aircraft 3 and 5 as they manage the merging and sequencing of Aircraft 3, 4, and 5. Eventually, Aircraft 5's IM operation automatically cancels at BARLY and associated display elements for the clearance and Aircraft 4's and Aircraft 5's roles are removed.

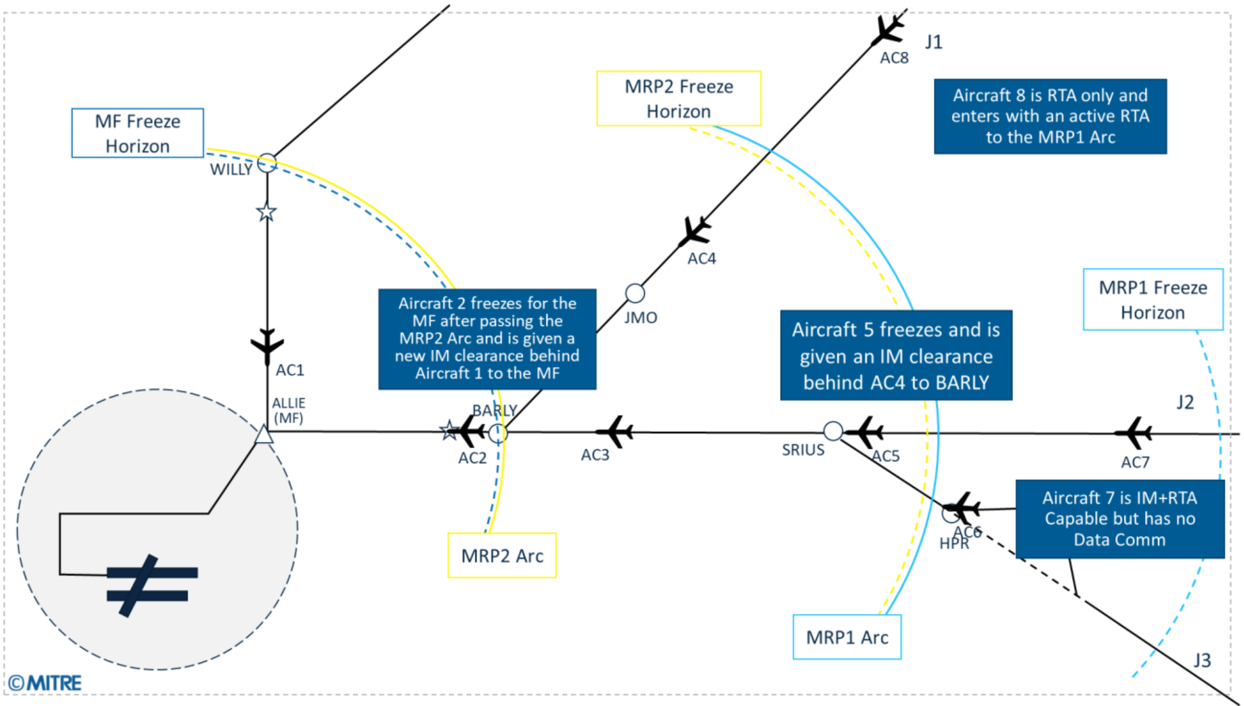

Figure 5-6. Initial Conditions for Aircraft 7-8; IM Clearance for Aircraft 5.

As Aircraft 2 reaches BARLY, it crosses the freeze horizon for the MF, still sequenced behind Aircraft 1, and the difference in STAs at the MF is 60 seconds. A new IM operation is proposed to the controller, who then sends the following IM clearance information via data link communications to Aircraft 2.

- **IM Clearance Type:** Cross
- **Crossing Point:** ALLIE
- **ASG:** 60 seconds
- **Lead Aircraft:** Aircraft 1
- **Lead Aircraft Route:** Direct ALLIE
- **PCP:** ALLIE

Aircraft 2's IM operation will automatically cancel at ALLIE and the associated clearance information, including indication of its role as an IM Aircraft is removed from the display. However, the indication that Aircraft 2 is a Lead Aircraft in an active IM operation with Aircraft 3 is displayed until Aircraft 3's IM operation is cancelled automatically at BARLY, when all display indications for Aircraft 3's IM operation are removed without controller action.

Aircraft 6 illustrates the use of IM after the trailing aircraft is issued a path stretch specifically to absorb delay. Aircraft 6 will perform IM behind a Lead Aircraft that executes an RTA operation to the MRP1 Arc and IM to the MRP2 Arc.

Aircraft 6 is RTA+IM capable and enters the airspace in a virtual tie with Aircraft 5 and is sequenced behind Aircraft 5 in the schedule. Aircraft 6 is issued a path stretch to absorb the delay and a subsequent IM clearance behind Aircraft 5 to the MRP1 Arc. Because of the necessary route change to absorb delay, the IM clearance for Aircraft 6 must be issued after the path stretch. The CP/PCP for the clearance is the intersection of Aircraft 6's route with the MRP1 Arc which is defined in the clearance as an along-track distance from (before) the merge at SRIUS. The TRP is calculated by the ground automation as Aircraft

5's route's intersection with the same arc (displayed to the controller as an along-track distance from the merge at SRIUS). The controller sends the following IM clearance information via data link communications to Aircraft 6 and the active indications for the IM operation are displayed.

- **IM Clearance Type:** Cross
- **Crossing Point:** 55 NM before SRIUS
- **ASG:** 70 seconds
- **Lead Aircraft:** Aircraft 5
- **Lead Aircraft Route:** J2.SRIUS
- **TRP:** SRIUS090055
- **PCP:** 55 NM before SRIUS

After crossing the MRP1 arc, the first IM clearance ends, and Aircraft 6's STA at the second meter arc (MRP2) freezes when Aircraft 6 crosses the MRP2 freeze horizon (Figure 5-7). The ground automation proposes a new IM clearance to the controller following the same Lead Aircraft. The controller issues the new IM clearance, and the operation continues to the MRP2 Arc.

- **IM Clearance Type:** Maintain
- **ASG:** 70 seconds
- **Lead Aircraft:** Aircraft 5
- **PCP:** BARLY

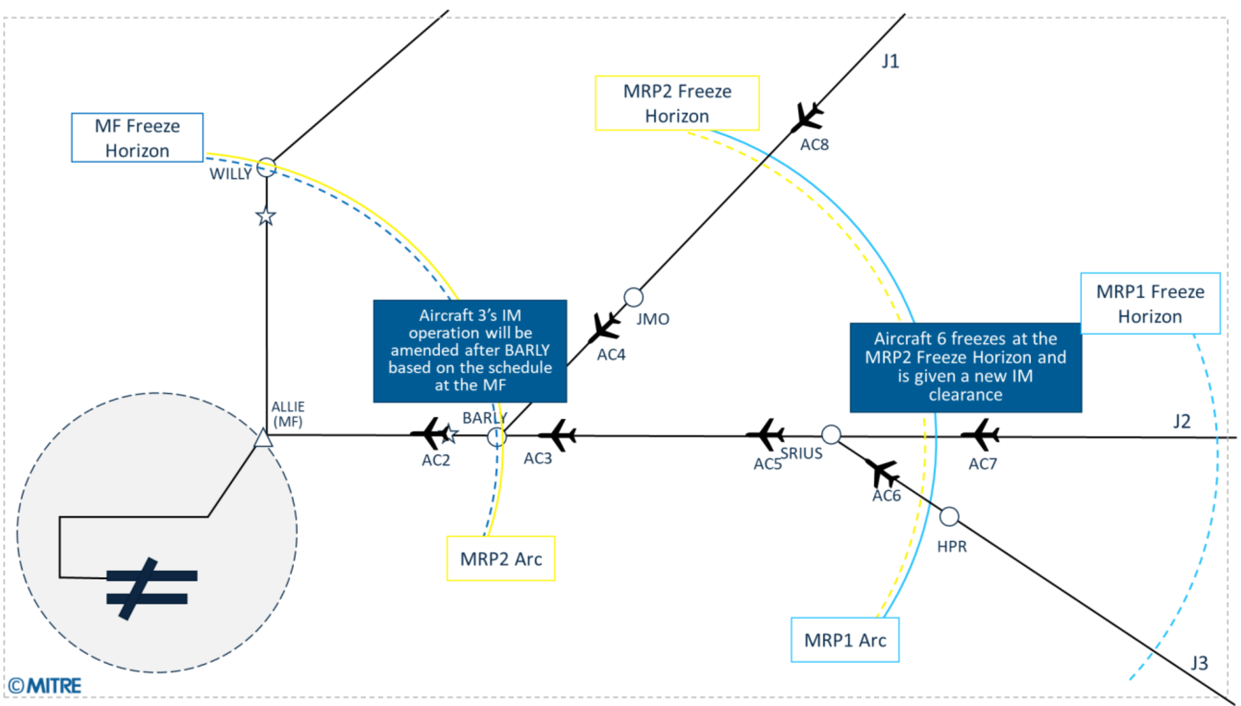

Figure 5-7. New IM Clearance for Aircraft 6.

Controllers monitor the separation of aircraft as Aircraft 6 merges on the same route behind Aircraft 5. The IM operation automatically cancels at BARLY and associated display elements for the clearance are removed.

Aircraft 7 illustrates the implications of the presence of an RTA+IM capable aircraft with no data link communications capability (voice only). In this situation, a complex IM clearance is deferred by the automation until initiating conditions permit a simpler IM clearance to be communicated via voice.

Although Aircraft 7 is RTA+IM capable, it does not have data link communications capability and is therefore limited to IM clearances that can be easily communicated via voice. As Aircraft 7 enters, the automation has defined an IM clearance with complex Lead Aircraft IFPI due to Aircraft 6's path stretch. This clearance cannot be given via voice and therefore the system does not present it to the controller. Based on the controller's workload and Aircraft 7's current position, speed, and metering objective, the controller opts not to provide an RTA via voice and manages Aircraft 7 with automation-generated speed advisories.

After Aircraft 6 completes the path stretch, the IM clearance is simple enough for voice, however, too little time remains before Aircraft 6 crosses the MRP1 Arc and the IM clearance is not presented to the controller for Aircraft 7. After Aircraft 7's STA at the MRP2 Arc freezes, a maintain IM clearance is presented and executed via voice as depicted in Figure 5-8.

AIRCRAFT 7, MAINTAIN 70 SECONDS BEHIND AIRCRAFT 6, CANCEL AT BARLY.[34]

As Aircraft 3 reaches BARLY and its STA at the MF is frozen, the controller amends the ASG to be consistent with the difference in Aircraft 2's and Aircraft 3's STAs at ALLIE.

AIRCRAFT 3, AMEND IM SPACING GOAL TO 60 SECONDS.

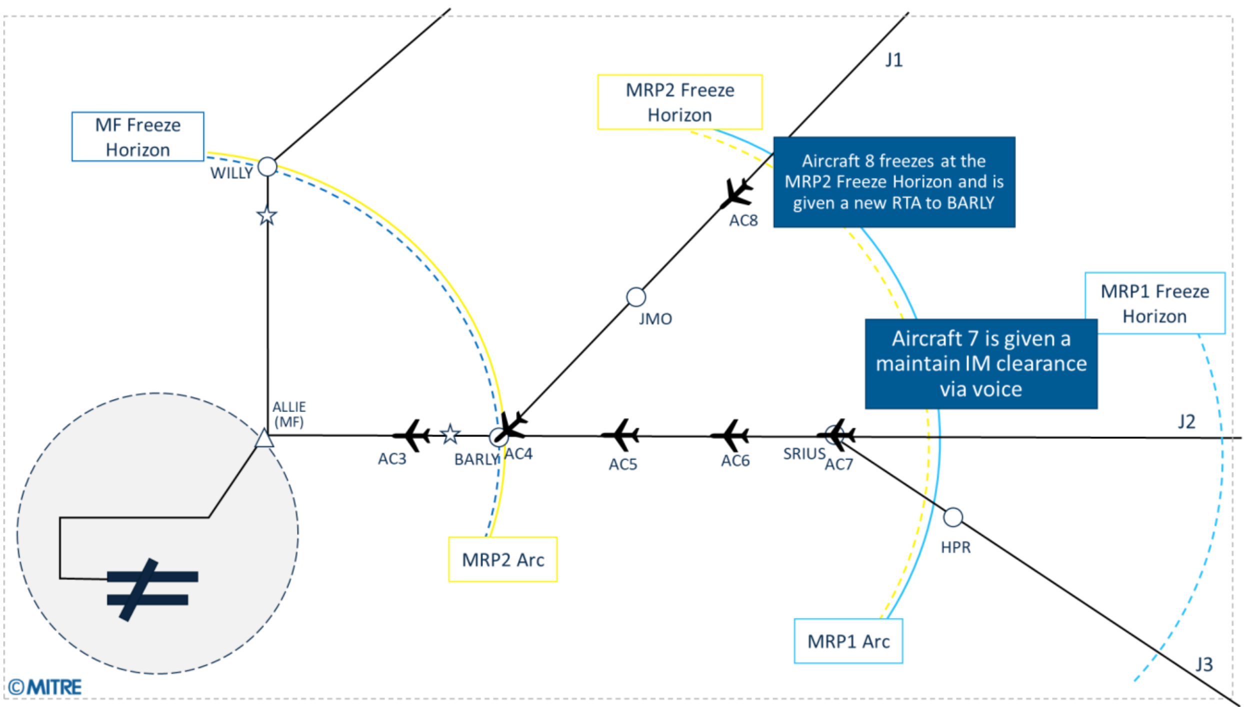

Figure 5-8. Delayed IM Initiation for Aircraft 7 and New RTA for Aircraft 8.

Aircraft 8 illustrates an RTA-only aircraft following an active IM Aircraft.

[34] Scenario phraseology used here is for illustration purposes only. Final voice phraseology still needs to be defined.

Aircraft 8 is only RTA capable and arrives with an active RTA to the MRP1 Arc. The controller recognizes the active RTA operation when accepting the hand-off and confirms it is compatible with their metering objectives. As Aircraft 8's STA is frozen for the MRP2 Arc, a second RTA operation is available for the controller to issue: 1309:00z at BARLY.

The controllers monitor the RTA operation and ensure adequate separation as Aircraft 8 approaches BARLY and eventually merges behind Aircraft 7. At this point in the scenario, a series of active IM operations are progressing, with Aircraft 7 actively performing an IM operation behind Aircraft 6, Aircraft 6 behind Aircraft 5, and Aircraft 5 behind Aircraft 4 (see Figure 5-8). The controllers are only issuing speed commands to Aircraft 4 and monitoring Aircraft 5 through 8 as those speeds are generated by the FIM and TOAC capabilities.

After Aircraft 5-7 cross the MRP2 Arc, their STAs at the MF are frozen. Controllers may issue new IM clearances to those aircraft to achieve or maintain the spacing relative to their respective Lead Aircraft. Because the IM Aircraft and their respective Lead Aircraft are on the same route between BARLY and ALLIE, the controller may issue maintain IM clearances.

6. Summary of Impacts

The proposed benefits of the RTA and IM operations are made possible by the ground-based automation changes described in Section 4.4, changes to air traffic orders (as needed), as well as by equipping aircraft with the TOAC and/or FIM capabilities.

RTA and IM operations will impact NAS operations, requiring new procedures, phraseology, and FAA air traffic personnel training, likely to include air traffic controllers and TMCs at selected facilities and Air Traffic Control System Command Center (ATCSCC) personnel. Expected benefits include increased throughput in high-density operations, improved flight efficiencies, increased predictability of aircraft flows, and reduced controller workload. Successful operations depend on the TBO foundational capabilities, such as TBM and PBN, being in place at busy facilities in the NAS and used regularly.

RTA and IM operations will also impact airlines. To accrue the previously stated benefits, airlines must invest in equipping their fleets with TOAC and/or FIM capabilities, train their flight crews to use the flight-deck capabilities, and update processes for filing flight plans to indicate RTA, IM, and/or RTA+IM capabilities. As described in this ConOps, data link communications can also improve ATC/pilot communications when delivering complex clearance information. Therefore, airlines should also consider plans for investing in data link communications capabilities to maximize potential benefits.

Summary of Open Research Questions

This document has identified several areas where additional consideration and analysis is needed to fully implement integrated RTA and IM operations. These included:

- (Section 4.3.4.2) In cases where the IM Aircraft is performing a Cross clearance, there may also be issues for a following RTA Aircraft as the IM Aircraft attempts to meet the spacing over the course of the operation (versus as soon as practicable). Potential variabilities in how TOAC speeds are calculated to meet the RTA at a downstream point could cause undesirable closure rates in some cases, which should be the subject of further analysis. Additionally, differences in how TOAC and FIM speeds are limited on speed-restricted segments of RNAV STARs should also be considered from flight crew and ATC perspectives.
- (Section 4.3.4.3) The potential use of RTA during climb operations needs to be defined, with controller considerations for knowing constraints on the applicable domain use of each application.
- (Section 4.3.4.3) It needs to be considered whether navigation clearance changes that would cancel an IM operation should also cancel any active RTA operation. Overall, the specific operational requirements and controller procedures to suspend and/or cancel each operation needs to be harmonized between the two applications.
- (Section 4.3.4.3) RTA and IM operations will also need further considerations on their use of common forecast wind and temperature information, especially for retrofit IM implementations.
- (Section 4.4) Interim operations, preceding the end-state operations described here, may be possible with a sub-set of the ground-based automation changes. Further work is needed to define instantiations of potential interim phases.

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Appendix A. Acronyms and Abbreviations

AAR	Airport Arrival Rate
AC	Advisory Circular
ACSS	Aviation Communications & Surveillance Systems
ADS-B	Automatic Dependent Surveillance-Broadcast
AFP	Airspace Flow Program
AFS	FAA Flight Standards Organization
AGD	ADS-B Guidance Display
AIM	Aeronautical Information Manual
AIRS	ADS-B In Retrofit Spacing
AIR	FAA Aircraft Certification Organization
AJM	FAA Program Management Organization
AJV-S	FAA Mission Support-Strategy Organization
ARTCC	Air Route Traffic Control Center
ASA	Airborne Surveillance Application
ASG	Assigned Spacing Goal
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATPA	Automated Terminal Proximity Alert
CAASD	Center for Advanced Aviation System Development
CAS	CDTI-Assisted Separation
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit
ConOps	Concept of Operations
CP	Crossing Point
CRDA	Crossing Runway Display Aid
DCCR	Dependent Crossing and Converging Runways
DCT	Delay Countdown Timer
DSA	Dependent Staggered Approaches
DST	Decision Support Tool
EDC	En Route Departure Capability
ERAM	En Route Automation Modernization
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FANS	Future Air Navigation System
FDMS	Flow Management Data Services
FIM	Flight Deck Interval Management
FMS	Flight Management System

GDP	Ground Delay Program
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organization
IDAC	Integrated Departure/Arrival Capability
IFPI	Intended Flight Plan Information
I-IM	Initial Interval Management
IM	Interval Management
JRC	Joint Resources Council
kt	Knots
LAX	Los Angeles International Airport
MASPS	Minimum Aviation System Performance Standards
MF	Meter Fix
MIT	Miles-in-Trail
MOPS	Minimum Operational Performance Standards
MRP	Meter Reference Point
NAC	NextGen Advisory Committee
NAS	National Airspace System
NATCA	National Air Traffic Controllers Association
NM	Nautical Miles
OEM	Original Equipment Manufacturers
OpSpec	Operational Specification
PBD	Place-Bearing-Distance
PBN	Performance Based Navigation
PCP	Planned Cancellation Point
PHX	Phoenix Sky Harbor International Airport
RF	Radius to Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
SBS	Surveillance Broadcast Services
SC	Special Committee
SESAR	Single European Sky ATM Research
STA	Scheduled Time of Arrival
STAR	Standard Terminal Arrival Route
STARS	Standard Terminal Automation Replacement System
TBFM	Time-Based Flow Management
TBM	Time Based Management
TBO	Trajectory Based Operations
TFDM	Terminal Flight Data Management
TFM	Traffic Flow Management
TFMS	Traffic Flow Management System

TMC	Traffic Management Coordinator
TMI	Traffic Management Initiative
TMP	Terminal Meter Point
TMU	Traffic Management Unit
TOAC	Time of Arrival Control
TOD	Top of Descent
TRACON	Terminal Radar Approach Control
TRP	Traffic Reference Point
TSAS	Terminal Sequencing and Spacing
TSO	Technical Standard Order
UTC	Coordinated Universal Time
VMC	Visual Meteorological Conditions
ZAB	Albuquerque Air Route Traffic Control Center

Appendix B. RTA Capability in Current Fleet

Table B-1. RTA Capability in Current Fleet by Aircraft and FMS Type

Aircraft Type		FMS	RTA Capability
Boeing	B717	Honeywell	Cruise
	B737-4/NG	General Electric	All phases of flight
	B747-8	Honeywell	Cruise
	B757/767 (Pegasus)	Honeywell	Cruise
	B757/767 (Classic)	Honeywell	No RTA Function
	777 (AIMS 1&2)	Honeywell	Cruise
	B787	Honeywell	Cruise
Airbus	A318/319/320/321 FMS1 FMS2	 Honeywell Honeywell	 No RTA Function Cruise
	A318/319/320/321 FMS1 FMS2	 Thales Thales	 No RTA Function All phases of flight*
	A330 FMS1 FMS2	 Thales Thales	 No RTA Function Cruise
	A330 (Pegasus)	Honeywell	Cruise
	A340	Thales	Cruise (manufactured after 2008)
	A380	Honeywell	Cruise
Embraer	E170/192	Honeywell	No RTA Function
Bombardier	CRJ	Rockwell Collins	No RTA Function
McDonnell Douglas	MD80	Honeywell	No RTA Function
Thales FMS2 (Rev 2+ and Release 1A) RTA range of capabilities need additional study.			