Integrated Demand Management: Concept and Procedures

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NASA Airspace Operations and Safety Program
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Contents

Executive Summary

This report provides a comprehensive description of the Integrated Demand Management concept.

Motivation for work: NASA's Integrated Demand Management (IDM) research explores the idea that, under certain conditions, time-based flow management (TBFM) arrival operations can benefit from the coordinated use of a strategic traffic management initiative (TMI) to "precondition" the inbound demand. The research was motivated by the observation that TBFM was usually turned off during convective weather, even in facilities where it was routinely used. Our hypothesis was that strategic adjustments to the inbound traffic so that it provided a better match to the off-nominal changes in capacity observed during these conditions could enable TBFM scheduling to continue to provide effective support for arrival traffic management.

Concept: IDM proposes that a TMI (e.g., a Collaborative Trajectory Options Program, or CTOP) be used to adjust the rate and/or geographic distribution across flows of the traffic inbound to a high-demand, TBFM-managed airport before that traffic reaches the TBFM planning horizon. After this strategic preconditioning, TBFM can then tactically fine-tune the demand to deliver a well-managed, orderly feed to the destination airport. Coordinated use of these two flow management capabilities is intended to improve system performance in terms of:

- ***Equity*** of ground delay assignment, avoiding excessive ground delay for TBFM-scheduled departures, without penalizing longer flights;
- ***Throughput,*** by distributing traffic to maximize use of available capacity;
- ***Predictability*** for operators, providing advance notice about the impact on individual flights;
- Increased ***flexibility***, supporting operator mitigation strategies such as slot swapping or trajectory options;
- ***Efficiency*** of flight operations, using ground delay more effectively and reducing airborne delay.

Concept development: The concept was developed and tested using a series of progressively more complex use cases. Each involved a TBFM arrival scenario that we believed could benefit from a strategic pre-conditioning initiative designed to achieve one or more of the following improvements to the incoming demand: better coordination between the TBFM-scheduled departures and longer flights, better distribution of the inbound traffic across multiple arrival gates, reduced periods of excess demand at airport and/or arrival gates, and better-controlled impact of en route convective weather on arrival traffic throughput. NASA research conducted over the past several years indicates that strategic pre-conditioning can accomplish these objectives and support the system performance improvements listed above.

A common feature of the different IDM use cases is their operational organization into three distinct phases or planning horizons: (1) an initial strategic planning phase, during which the CTOP or other TMI is developed and initiated; (2) an TMI execution phase, before the aircraft reach the TBFM scheduling region; and (3) a tactical phase that begins roughly 1-2 hours before arrival, where

TBFM scheduling and metering are used to manage delivery of the traffic to destination airport. This document provides a general description of IDM operations as organized by these three phases.

Introduction

Motivation

NASA's IDM research explores the idea that, under certain conditions, time-based flow management (TBFM) arrival operations can benefit from the coordinated use of a strategic traffic management initiative (TMI) to "precondition" the inbound demand. The research was motivated by the observation that TBFM was usually turned off during convective weather, even in facilities where it was routinely used. Our hypothesis was that strategic adjustments to the inbound traffic to better match the off-nominal conditions would enable TBFM scheduling to continue to provide effective support for arrival traffic management.

Background

NASA Ames researchers working under the Airspace Operations and Safety Program developed a near- to mid-term concept called Integrated Demand Management (IDM). The objective of IDM is to improve National Airspace System (NAS) performance when the capacity of airspace resources serving major high-volume airports is insufficient for the expected demand, resulting in bottlenecks that often have a NAS-wide impact. Reasons for these demand/capacity mismatches can vary from structural limitations (such as limited surface capacity at the airport or airspace complexity in the Northeast Corridor), to wind-related capacity changes, to the more severe, dynamic and less predictable mismatches that occur with convective weather. IDM introduces an approach to improving system performance in the NAS during situations like these through strategic coordination of these two major traffic flow management capabilities.

NextGen Traffic Flow Management in the NAS

NextGen traffic management tools and procedures associated with the strategic Traffic Flow Management System (TFMS) and the more tactical TBFM system both provide capabilities for managing flows into capacity-limited resources by managing the 4-D trajectories of flights within those flows. These capabilities were developed for and continue to be used in different operational contexts and timeframes, however, with TFMS used by airline operators and NAS-wide traffic planners primarily during pre-flight planning, and TBFM used by controllers and local facility traffic managers near the end of the flight. Plans for improving both systems, many of which are in the FAA's implementation pipeline or already in use, suggest increasing overlap in operational time horizons, especially as TBFM scheduling extends further out from the destination airport. To a large extent, however, these two systems still represent separate and uncoordinated solutions to different aspects of the traffic management problem. One significant NextGen challenge is to figure out how to effectively integrate them.

Time-Based Flow Management (TBFM)

TBFM, the more tactical of the two systems, was designed to improve traffic delivery into a capacity-constrained airport. It has since been enhanced to also support metering into high-volume en route and departure flows. TBFM works by building arrival time schedules to Constraint Satisfaction Points (CSPs) such as metering arcs, meter fixes, or runways. TBFM uses a first-come, first-served policy to establish an arrival sequence for inbound flights based on their estimated times of arrival (ETAs) at the CSP, then assigns a scheduled time of arrival (STA) to each flight that satisfies the CSP's inter-arrival spacing requirements. The flight sequence and assigned STA for individual flights adjust continuously as ETAs change until the flight crosses the TBFM freeze horizon, defined as a particular time or geographic distance from the CSP. At this point the STA is frozen and will no longer change without a manual action by a controller or traffic manager.

When en route facilities are metering, air traffic controllers are responsible for issuing clearances to absorb any TBFM-assigned airborne delay needed to meet the assigned STA. The resulting STA conformance is usually within a minute or less. Current TBFM adaptations may have freeze horizons located 120-400 nm from the airport, which makes the effective planning horizon for TBFM roughly 45-90 minutes before landing.

Departure times for TBFM-scheduled departures (flights that take off from airports inside or near their destination's TBFM freeze horizon) are obtained using a TBFM departure scheduling function that assigns a departure time which corresponds to an available arrival slot.

Traffic Flow Management System (TFMS)

TFMS includes a set of NextGen planning tools and capabilities that support a Collaborative Decision Making (CDM) approach to traffic flow management. Under CDM, Traffic Management Initiatives (TMIs) issued by the Air Traffic Control System Command Center (ATCSCC, or Command Center) enable system users and air navigation service providers (ANSPs) to develop and implement NAS-wide solutions to disturbances in the system. When airport capacity falls below the expected demand, for example, the Command Center can initiate a Ground Delay Program (GDP), which generates Expect Delay Clearance Time (EDCT) advisories to reduce arrival demand by delaying inbound flights at their departure airports. Under a GDP, operators are provided advance notice about the reduced airport capacity and associated departure delays, and have an opportunity to 'swap slots' (exchange GDP-assigned arrival times) among flights to reduce the impact on their operations. The Airspace Flow Program (AFP) is another TMI that uses EDCTs to reduce demand through a congested or weather-impacted region of airspace, which is designated as a Flow Constrained Area (FCA).

The IDM concept leverages a new TMI called the Collaborative Trajectory Options Program (CTOP) which can use multiple FCAs to build a more complex characterization of the reduced-capacity problem. The CTOP also provides operators the opportunity to submit a preference-weighted set of route alternatives for each flight called a Trajectory Option Set (TOS). CTOP-specific TFMS automation references the TOS to select a user-preferred combination of ground delay and route when building its solution, instead of relying solely on ground delay, which enables the CTOP to automatically re-distribute traffic to take advantage of available capacity on under-utilized routes.

Like TBFM, these three TFMS programs (GDP, AFP, CTOP) all use scheduling to regulate access to a capacity-limited destination; however, unlike TBFM they are initiated and applied well before departure. Their control mechanisms are significantly different from TBFM, with GDPs and AFPs relying exclusively on EDCTs as their primary intervention, and CTOP adding pre-departure re-routes as a second method for geographically redistributing demand. All of these interventions are made at least 45 minutes before takeoff, with no further action taken to control the aircraft's arrival time at the target airport or FCA. The CTOP planning window and control opportunity close roughly 45 minutes before departure, often hours before the flight will arrive at the controlled destination. A reasonable expectation for CTOP conformance to the target arrival time at the destination is therefore no better than roughly +/- 15 minutes, according to subject matter experts (SMEs).

Comparison of TFMS and TBFM

TFMS and TBFM were designed for different purposes and operational contexts. These differences – in planning horizons, control mechanisms, phase of flight or physical location where control actions are executed, and achievable conformance accuracy – mean that each system is better-suited to different aspects of the arrival management problem.

TFMS has a significant advantage over TBFM with respect to the amount of delay it can manage, since its control actions are taken before departure and the delays are absorbed on the ground. Using CTOP route assignments, traffic demand can be redistributed or balanced across multiple sectors, fixes and arrival gates. TFMS also has two advantages with respect to operator impact: (1) its planning horizon is often hours before departure, so operators have time to plan how to minimize the impact of flight delays on their operations, and (2) it provides them a way to directly manage those delays by swapping arrival time slots to favor higher priority flights, or modifying routes to avoid congested airspace. However, its coarse and indirect pre-departure control mechanisms can over or under-deliver to the targeted capacity, a target which, since it is set hours in advance, may itself be poorly matched to actual capacity when the traffic arrives.

In contrast, airborne delay provides a more tactical and precise control mechanism. Thus, TBFM can be a more effective and precise tool for managing the final stage of traffic delivery to the airport because of its shorter planning horizon (giving it better information) and finer control precision (less than a minute vs. quarter hours or more). There are practical limits, however, to the magnitude of arrival time adjustments that can be managed using airborne delay. Since most flights are airborne when they enter the TBFM scheduling region, this means that TBFM-scheduled close-in departures that attempt to join heavy arrival flows may receive large, last-minute ground delays to avoid causing excessive airborne delay.[2,3] In addition, first-come, first-served scheduling is insensitive to operator priorities; TBFM schedules are generally less visible, stable and predictable from the operators' perspective; and TBFM provides operators no mechanism to manage the impact of flight delays on operations.

Rationale for IDM

Integrated Demand Management (IDM) proposes that reconciling the strategic and tactical flow management interventions supported by TBFM and TFMS can provide a more satisfactory solution to capacity bottlenecks encountered in the NAS. Leveraging the complementary features of each system can improve system performance in a number of ways, including:

- ***Equity*** of ground delay assignment: A strategic TMI can reduce excessive ground delay for TBFM-scheduled departures by providing space for them in the overhead stream and by increasing the pool of flights subject to delay to include departures from airports outside the TBFM freeze horizon.
- ***Throughput:*** Airport and airspace throughput targets can be more reliably achieved by distributing traffic to maximize use of available capacity; for example, rerouting arrival traffic away from a capacity-limited arrival gate to an underutilized alternative can help maintain airport throughput to a target rate.
- ***Predictability***: Using a strategic TMI to precondition the demand into TBFM provides earlier notice about potential ground delay for individual flights. Operators can manage the impact of a 45 minute GDP departure delay issued hours before departure more easily than a 45 minute TBFM departure delay encountered at the last minute when the flight is ready to depart.
- ***Flexibility***: Strategic TMIs such as GDPs, AFPs and CTOPs are built on a collaborative decision making framework. This provides operators access to delay mitigation strategies such as slot swapping or TOS submission that are unavailable under TBFM.
- ***Efficiency:*** Flight efficiency is improved by using ground delay more effectively and reducing airborne delay.

New tools are not needed to implement this solution; instead procedural adaptation of existing capabilities and operational methods will use each system to its best advantage within its respective domain.

For simplicity, our concept development effort focused on use of CTOP as our TMI of choice, since it provides the most comprehensive set of TFMS capabilities for pre-conditioning the traffic. In contrast to the miles-in-trail, GDP or AFP initiatives that may be used today, CTOP's reroute capability gives IDM a more tailored delivery into TBFM. It might, for example, redistribute demand across several alternative routes, and adjust that distribution as local conditions change. This should provide a more consistent feed into TBFM, allowing it to manage delivery to the capacity-constrained destination more efficiently.

The Integrated Demand Management Concept

The IDM procedural solution for integrating TFMS and TBFM can be summarized as follows:

- Use TFMS (CTOP) to "strategically" manage demand into TBFM, then
- Use TBFM "tactically" to manage delivery to capacity-constrained destination.

How this would work is elaborated in this section, with reference to a particular scenario that was used as a starting point to build out, test and refine the IDM concept.

IDM Scenario: Newark Liberty International Airport

A traffic volume problem at Newark Liberty International Airport (EWR) provided the initial use case for IDM concept development. Among the three major airports that serve the New York (NY) metropolitan area, EWR routinely sees the most varied mix of short-haul and long-haul flights, with a load distribution across its three arrival gates that changes throughout the day. Scheduled demand is often at or near the airport's dual-runway VFR capacity, so adverse winds or reduced visibility can easily reduce capacity well below demand. This is usually managed using miles-in-trail (MIT) spacing to regulate the airborne flow into Time-Based Flow Management (TBFM). However, close-in departures often take a disproportionate share of the TBFM-assigned delay since MIT cannot effectively provide capacity for these flights where they need it within the overhead arrival traffic flow. This inequitable delay impact on short-haul flights is a chronic problem observed at EWR, even during VFR conditions when airport capacity is not a concern.

Instead of using MIT, IDM uses CTOP automation to pre-condition traffic with a program that involves all Newark-bound flights regardless of their origin. Departure times and TOS-derived route assignments are used to distribute flights both temporally and geographically, according to the desired demand allocation across the inbound flows. All of this takes place well before flights enter TBFM. After flights cross the TBFM freeze horizon, this CTOP initiative is replaced by a TBFM arrival schedule based on their destination ETAs at that time.

Using a CTOP instead of miles-in-trail conditioning provides a more precise match of demand to TBFM capacity by coordinating the FCA arrival times of individual flights, thus setting up the conditions for more effective blending of short and long-haul flights. The result is a more predictable and equitable delay impact, better utilization of available capacity, and a net reduction in airborne delay. This concept for CTOP/TBFM integration provides a framework that can be extended to address the more complex and dynamic demand/capacity mismatches associated with convective weather.

Figure 1 provides a high-level illustration of IDM operations for the simple use case described above from the perspective of two inbound flights: a transcontinental flight departing San Francisco International Airport (SFO), and a shorter flight from Raleigh-Durham International Airport (RDU), an origin airport located inside the TBFM freeze horizon.

CTOP automation assigns each flight an EDCT departure time, however the RDU flight's departure will be rescheduled by the TBFM automation as it nears its departure time, since the departure will occur within the TBFM planning horizon. Both flights will also be assigned routes selected from an operator-submitted trajectory option set.

IDM ground-side traffic management operations are summarized in the boxes at the bottom of Figure 1, and described in more detail in the section titled "Ground Operations".

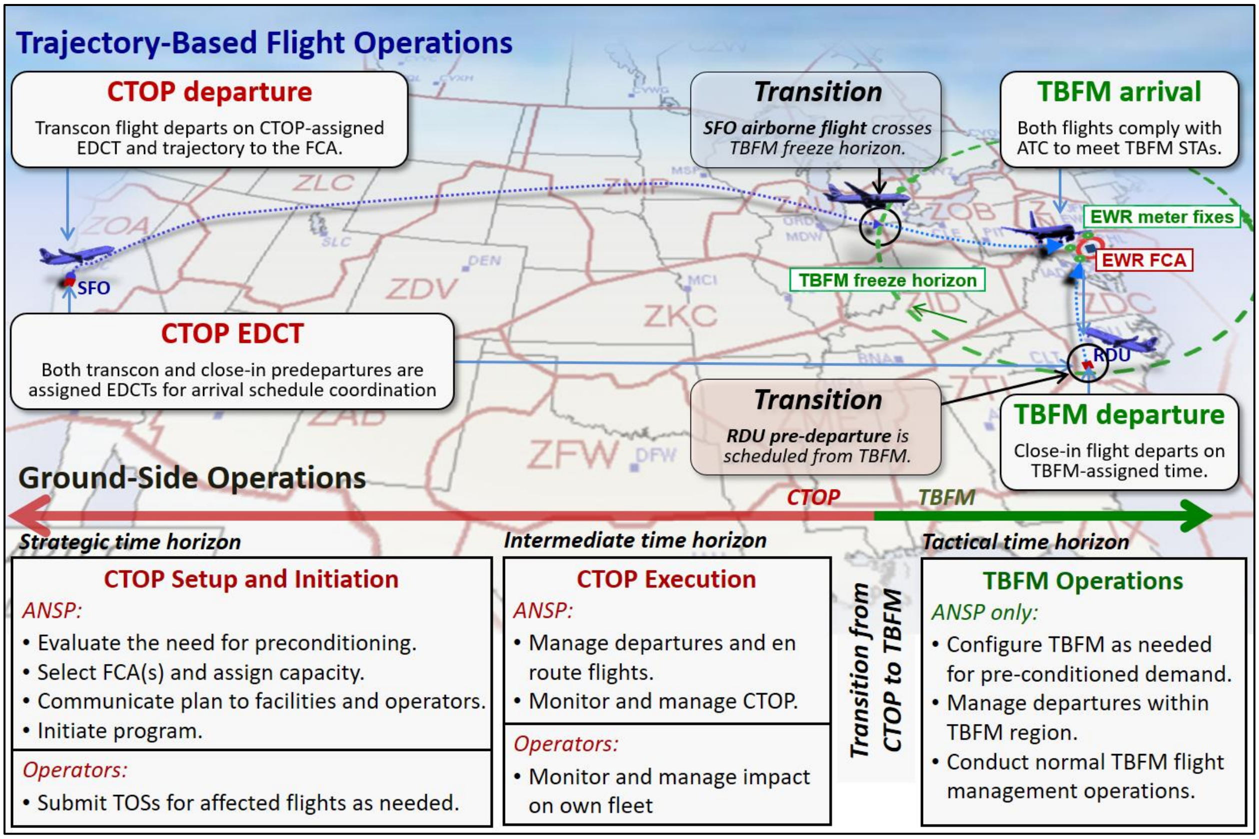


Figure 1. IDM air and ground operations for two sample flights inbound to EWR: a transcontinental flight from SFO a shorter flight from RDU.

Schedule and Constraint Coordination

CTOP and TBFM Control Structures

Under IDM, CTOP uses one or more FCAs to build an initial schedule (or set of schedules) assigning each inbound flight a control time (slot) for a specific constraint such as a freeze horizon, TRACON boundary, meter fix, airport or runway. Figure 2 shows a stylized representation of this as it applies to the simple EWR scenario, with a single FCA surrounding NY TRACON. All aircraft are allocated an FCA crossing time ("slot") based on this schedule, and pre-departures also have an associated EDCT, including those that depart from airports within the TBFM region. This serves two purposes: (1) it adjusts the inbound demand distribution such that airborne demand does not block access to close-in (TBFM-scheduled) departures, and (2) it makes the adjustment in the strategic timeframe using the TFMS CDM framework, giving operators advance notice and an opportunity to manage the impact on their operations.

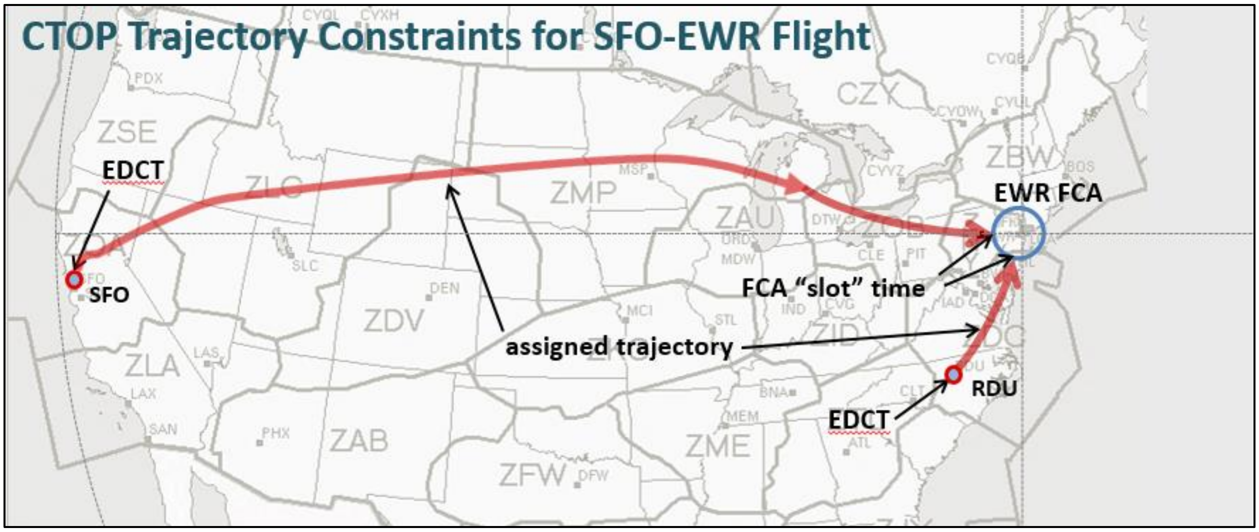


Figure **2. IDM CTOP structures, with trajectory constraints for two sample flights.**

The IDM setup for EWR TBFM uses a custom research adaptation that has been configured with Extended Metering (XM) schedules in the adjacent, first tier ARTCCs that feed the Meter Fix (MF) arrival schedules. Figure 3 provides a simplified representation of these TBFM scheduling structures.

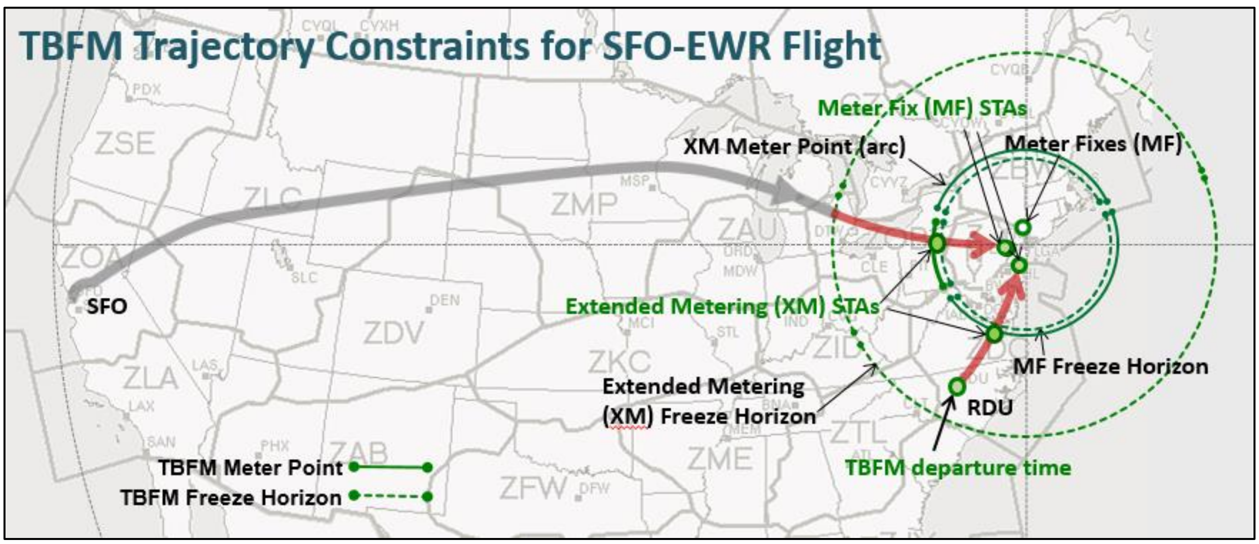


Figure 3. TBFM structures, with trajectory constraints for two sample flights.

Departure Scheduling

Similar to airborne flights, those that are less than 45 minutes from departure when the program is initiated are 'exempt', meaning that the CTOP will not use TOS trajectories or EDCTs to control their FCA entry times. All 'non-exempt' departures are eligible for CTOP route and EDCT assignments. Close-in flights that depart from within the TBFM region will have their final departure time scheduled through TBFM, which uses the CTOP EDCT as a reference.

Ground Operations

As indicated by the boxes at the bottom of Figure 1, the ANSP and airline ground operations that support IDM flight operations can be organized into three phases: (1) CTOP Initiation, a strategic planning phase; (2) CTOP Execution, and (3) TBFM Operations. The CTOP Execution phase applies to flights that are physically outside the TBFM scheduling horizon (or temporally, in the case of TBFM close-in departures). TBFM scheduling become active in phase 3, replacing the CTOP as the controlling entity. This section describes the activities associated with each of these phases, how they differ from current-day operations, and who is involved.

1. Strategic Time Horizon: CTOP Setup and Initiation

1.1. CTOP Setup

1.1.1. Evaluate the need for preconditioning

This phase begins when facility traffic managers responsible for TBFM arrival management determine that a CTOP or other pre-conditioning TMI may be needed, hours before the arrival period under concern. Traffic managers at the facility and the Command Center determine where and when a strategic intervention would be useful, based on forecast demand and capacity estimates. This assessment take into account the forecast winds and weather conditions at the airport and in the upstream airspace, and identifies which resources may have insufficient capacity for the expected demand. Based on this assessment a TMI might be proposed to meet one or several objectives, such as to manage the arrival demand to a reduced airport acceptance rate (AAR), to redirect traffic away from a capacity-limited arrival gate, to coordinate access between internal departures and longer flights, or to manage the impact on capacity and route availability of en route convective weather.

1.1.2. Select FCA(s) and assign FCA capacity values

After evaluating the problem the CTOP needs to address, the Command Center traffic manager chooses an FCA or set of FCAs that best support its demand management and load distribution objectives. These will be used to control and distribute demand into the destination airport, inbound sectors, and/or arrival gates, and to reserve gate and airspace capacity for the TBFM-scheduled close-in departures. Since the airport demand represents the sum of the demand across all of the arrival gates, there may be a need to assign FCA capacity values that manage the demand through each arrival gate as well as the total demand across all gates to insure that the airport itself is neither over nor under loaded. While these entries can be computed manually, an "FCA Balancing Algorithm" developed by NASA streamlines this process.

The traffic manager may use TFMS tools to model and compare outcomes for different alternative solutions before completing the setup.

1.1.3. Communicate plan to facilities and operators

Airline operators and ANSP facilities are notified before the CTOP is initiated.

1.1.4. Develop and submit Trajectory Options Sets as needed

Airline operators will review the FCAs and their assigned capacities, and assess the impact on flights that are included in the CTOP. They may then develop and submit trajectory option sets which include their outcome preferences so that CTOP can provide a solution that, to the extent possible, accommodates their preferences regarding ground delay and trajectory tradeoffs for each flight.

1.2. Initiation

The planner runs the CTOP automation and initiates the program. Exempt flights are reserved a "slot" that corresponds to their current estimated time of arrival at the FCA. All non-exempt pre-departures are assigned an EDCT, and flights that have submitted trajectory option sets are also assigned a route selected from the TOS that represents their lowest cost option that meets CTOP scheduling objectives.

What's new: While the methods and procedures for using CTOP are unchanged, the specific application – using CTOP for TBFM pre-conditioning – is new. Introduction of the FBA to facilitate CTOP capacity assignment is also new.

Who is involved: The parties involved include traffic managers at ARTCCs responsible for controlling TBFM at the destination airport, a traffic manager ("planner") at the Command Center, and airline ATC coordinators and dispatchers responsible for the affected flights.

2. CTOP Execution

CTOP execution activities involve controlling individual flights according to the CTOP, managing CTOP impact on airline operations, and monitoring and managing the CTOP itself.

2.1. Manage departures and en route flights

Tower controllers manage the aircraft's departure in conformance with its assigned EDCT. Once airborne, IDM flight handling should resemble management of flights on National Route Program (NRP) routes (i.e., leave flights alone to the extent possible) to improve their conformance with the intended 4D trajectory.

2.2. Monitor and manage CTOP

CTOP automation monitors the conformance of the predicted demand at each FCA to the target capacity values, and if preset over- or under-delivery thresholds are exceeded, will initiate an automatic revision to the CTOP to bring the demand closer to the target value[1]. Traffic managers also monitor for changes in capacity forecasts due to weather or for other reasons, and may change CTOP parameters and initiate a manual revision as needed. Both manual and automatic revisions provide updated trajectory assignments and/or EDCTs to non-exempt flights included in the program.

2.3. Operators manage fleet impact

Airline dispatchers monitor the status of all involved flights and may swap flights or revise TOSs to manage the impact on their operations.

[1] A suggested enhancement to this functionality would provide the option of instead alerting the traffic manager when conformance falls out of range and allow the human to decide whether a revision is needed.

What's new: CTOP automatic revision exists, but its proposed use in a 'monitor-and-alert' mode is new. Use of NRP-like procedures to improve passive schedule conformance is new.

Who is involved: Tower controllers and traffic management at the departure airport; TRACON and en route controllers, and traffic management coordinators; pilots, dispatchers and/or ATC coordinators at flight operations centers; Command Center traffic/flow planner.

3. CTOP-to-TBFM Transition

3.1. Airborne transition

Flights that transition to TBFM while airborne appear on the TBFM timeline with an unfrozen STA shortly before crossing the outermost TBFM freeze horizon. After crossing the freeze horizon, they have a frozen STA and have transitioned to TBFM traffic management protocols. This transition from CTOP to TBFM should be seamless and transparent to both flight crew and controllers.

3.2. Predeparture transition

Non-exempt pre-departures that are included in an IDM CTOP will be assigned an EDCT even if their departure airport is within the TBFM freeze horizon. As flights from these airports that are internal to TBFM prepare for departure, controllers will obtain a TBFM departure time that supersedes the EDCT.

What's new: The transition has no apparent impact for an airborne flight. The idea of deliberately assigning an EDCT using a strategic TMI with the intent to assign a new TBFM departure time later may be new, however it's operationally straightforward, and compatible with how both systems operate today.

Who is involved: Traffic managers and controllers managing flights where the transition occurs.

4. TBFM Operations

4.1. Configure TBFM for pre-conditioned demand

Under IDM, traffic managers may choose to modify the TBFM setup for the preconditioned demand. For example, the matrix buffer setting can be used today to reduce the arrival rate in order to avoid overloading the TRACON. Since IDM pre-conditioning controls the rate of demand delivery into the system, and reduces the likelihood of gate, fix or TRACON overload, this precautionary use of the matrix buffer may no longer be needed. Traffic managers may choose to alter their setup of TBFM after reviewing the changes in demand characteristics provided by preconditioning.

4.2. Manage departures within TBFM region

Tower controllers from airports inside the TBFM freeze horizon call the en route facility to request departure times when an aircraft is ready to depart. As in today's operations, traffic managers either use the IDAC (Integrated Departure Arrival Capability) interface or the departure scheduling interface accessed through TBFM to schedule these departures.

In addition, it is also recommended that TBFM departure-scheduling should NOT default to prioritizing airborne flights, but instead allow pre-departures to compete for slots on a first-come first-served basis, unless it results in excessive airborne delay. This change in procedures is strongly recommended, since the IDM inbound flow has been pre-conditioned to deliberately include slack capacity to accommodate the TBFM-scheduled departures. This practice will help the pre-departure capture its intended slot and avoid a possible loss of arrival throughput.

4.3. Conduct normal TBFM flight management operations

TBFM metering operations are unchanged under IDM. Controllers manage the traffic in their sectors to absorb the delays shown on their displays.

What's new: Possible change in decision criteria for setting inter-arrival spacing matrix buffer; changes to departure scheduling regarding prioritization of pre-departure and airborne flights.

Who is involved: Air traffic controllers and traffic managers at the facilities responsible for TBFM scheduling and metering to the destination airport.

Summary

The operational description in this document highlights how the IDM concept builds upon already existing tools and procedures, and also indicates where tool enhancements could facilitate conduct of IDM operations. However, enhanced tools are not a requirement for concept introduction. In fact, initial deployment that focused on training procedures and rationale for coordinated use of TFMS and TBFM, *without* changes to existing tools, might be a simpler way to introduce and to familiarize traffic managers with the idea of preconditioning. The concept and procedures described in this document can hopefully provide useful guidance for introduction of IDM into field operations in the near future.

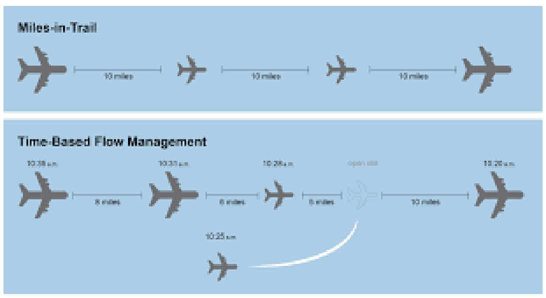
Appendix A: Acronyms

AAR	Airport Acceptance Rate
AFP	Airspace Flow Program
ANSP	Air Navigation Service Provider
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
CDM	Collaborative Decision Making
CSP	Constraint Satisfaction Point
CT	Crossing Time
CTOP	Collaborative Trajectory Option Program
EDC	En Route Departure Capability (TBFM)
EDCT	Estimated Departure Clearance Time
ERAM	En Route Automation Modernization
ETA	Estimated Time of Arrival
FCA	Flow Constrained Area
FEA	Flow Evaluation Area
GDP	Ground Delay Program
GUI	Graphical User Interface
HITL	Human-in-the-loop
IDM	Integrated Demand Management
MACS	Multi-Aircraft Control System (NASA ATC simulation platform)
MF; MFX	Meter Fix (TBFM)
MIT	Miles in Trail
NAS	National Airspace System
nCTOP	NASA CTOP emulation
nm	Nautical mile
PGUI	Planview GUI (TBFM)
RTA	Required Time of Arrival (assigned to aircraft)
STA	Scheduled Time of Arrival
TBFM	Time-Based Flow Management
TBO	Trajectory Based Operations
TFMS	Traffic Flow Management System
TGUI	Timeline GUI (TBFM)
TMI	Traffic Management Initiative
TRACON	Terminal Radar Approach Control
XM; XMP	Extended Metering; Extended Metering Point (TBFM)

Appendix B: Background on TBFM and TFMS

Time Based Flow Management (TBFM)

TBFM is a foundational element to the Next Generation Air Transportation System (NextGen). TBFM is a Traffic Flow Management automation system designed to regulate the flow of air traffic to a meter fix or arc based on time. Its time-based airborne metering and departure scheduling capabilities are designed to replace distance based Miles-in-Trail restrictions.



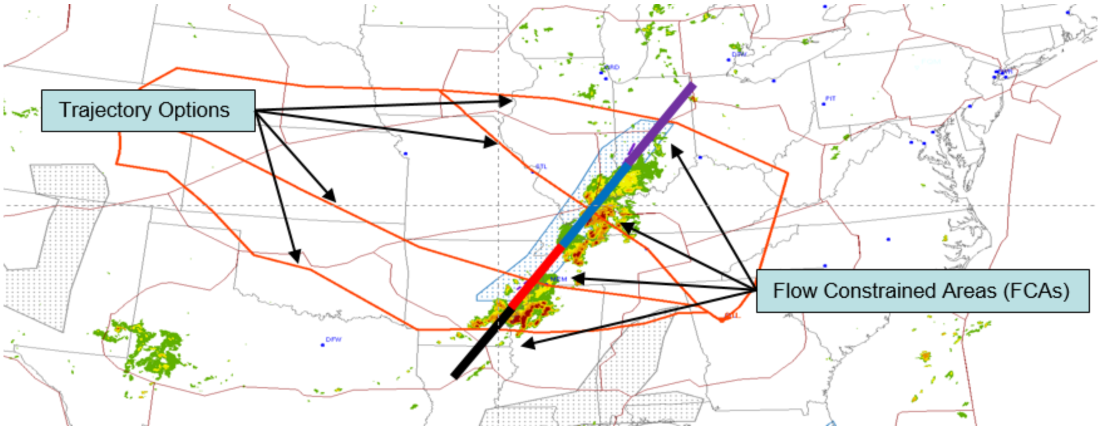
Airborne Metering: TBFM calculates delays that need to be absorbed by airborne flights in order to achieve desired spacing at the runway or a designated deconfliction point. These delays can be displayed at appropriate ARTCC controller positions; the controller decides how to best apply or absorb the desired delay (e.g., speed adjustment, vectoring, or holding).

Departure Scheduling: For flights departing into the arrival stream, TBFM can determine where the departure will fit into the arrival stream, and calculate any appropriate ground delay which will enable the flight to merge smoothly into the arrival stream.

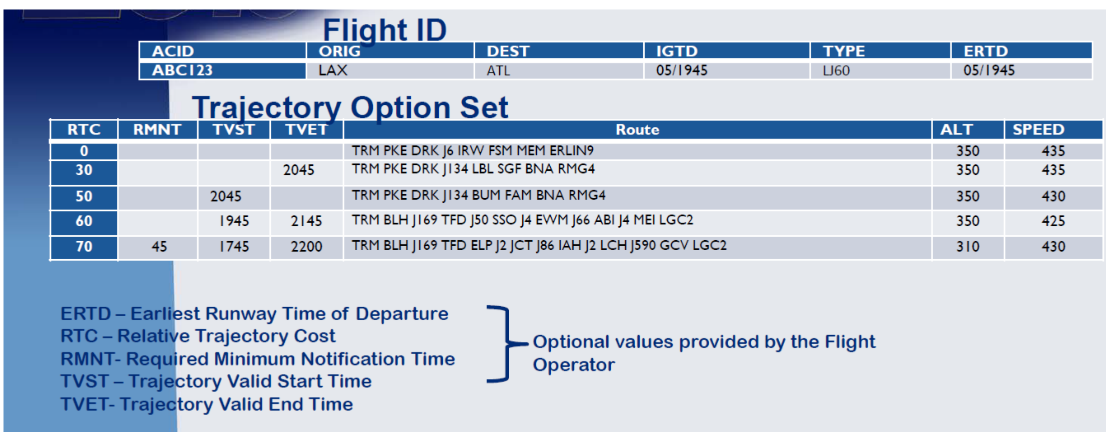
Traffic Flow Management System (TFMS)

TFMS is a foundational element to the Next Generation Air Transportation System (NextGen). TFMS is a decision support tool used for planning and mitigating demand-capacity imbalances in the National Airspace System (NAS). The TFMS encompasses over 30 user/data interfaces such as the Traffic Situation Display (TSD) and the Flight Schedule Monitor (FSM). Traffic managers use TFMS to implement Traffic Management Initiatives (TMIs) such as Ground Delay Programs (GDPs) and Airspace Flow Programs (AFPs). The newest TMI is the Collaborative Trajectory Options Program or CTOP.

Collaborative Trajectory Options Program (CTOP) - A type of Traffic Management Initiative (TMI) which leverages one or more Flow Constrained Ares (FCAs) to identify demand. Then, based on customer preferred options, as specified in a Trajectory Options Set (TOS), it assigns either a route to avoid the FCA, or a route and EDCT to meet an allocated slot time within the FCA.



Trajectory Options Set (TOS) - A message sent by the NAS user to TFMS defining a group of preferences for how they would like to see a specific flight managed. These preferences are defined through a combination of routes and/or altitudes and/or speeds with each trajectory being weighted through the use of flight operator submitted preferences.



Flight ID

ACID	ORIG	DEST	IGTD	TYPE	ERTD
ABC123	LAX	ATL	05/1945	LJ60	05/1945

Trajectory Option Set

RTC	RMNT	TVST	TVET	Route	ALT	SPEED
0				TRM PKE DRK J6 IRW FSM MEM ERLIN9	350	435
30			2045	TRM PKE DRK J134 LBL SGF BNA RMG4	350	435
50		2045		TRM PKE DRK J134 BUM FAM BNA RMG4	350	430
60		1945	2145	TRM BLH J169 TFD J50 SSO J4 EWM J66 ABI J4 MEI LGC2	350	425
70	45	1745	2200	TRM BLH J169 TFD ELP J2 JCT J86 IAH J2 LCH J590 GCV LGC2	310	430

ERTD – Earliest Runway Time of Departure
RTC – Relative Trajectory Cost
RMNT- Required Minimum Notification Time
TVST – Trajectory Valid Start Time
TVET- Trajectory Valid End Time

Optional values provided by the Flight Operator