Air Traffic Flow Management and Collaborative Decision-Making in the United States of America

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This paper discusses Air Traffic Flow Management (ATFM) and Collaborative Decision-Making used by the Federal Aviation Administration (FAA) in the US. The FAA is sharing this information in hopes that its experience will prove valuable to Air Navigation Service Providers globally as they develop and jointly improve cross-border ATFM solutions that benefit all stakeholders. We hope this paper will also provide valuable information to researchers and academia in support of developing tangible solutions for improving efficiency of cross-border air traffic management.

Key Words: Air Traffic Flow Management, Collaborative Decision-Making, Operational Information System, Performance

1. Introduction

According to IATA, passenger air traffic, measured in revenue passenger kilometers, has already reached or surpassed the pre-pandemic traffic levels in all regions except Asia-Pacific where the same milestone is expected to be reached in 2024. With a forecasted increase between 2.2% and 4.5% per year, demand for air traffic will grow by 4 billion additional passengers globally by 2040.[1)]

Existing air traffic flow management (ATFM) capabilities in many parts of the world are rudimentary and unable to accommodate even today's surges in traffic much less the expected growth. While North America and Europe have built significant ATFM capabilities and infrastructure over time, air navigation service providers (ANSPs) in other regions are still struggling with frequent and large delays from unexpected knock-on effects of large variations in traffic in 'upstream' FIRs.[2)] Even the more advanced providers in a regionally diverse environment often share airspace boundaries with those having less advanced capabilities, so the overall flows and separations must be structured around the lowest capability along any route/flow.

States, administrations, and civil aviation stakeholders uniformly agree that the expected growth of air traffic demands more effective management of imbalances between demand and capacity globally, particularly at major international air hubs and in the associated airspace flows. Under ICAO leadership, aviation stakeholders are working on regional ATFM guidance material globally; for instance, the ICAO Asia-Pacific Regional Office developed an *Asia/Pacific Regional Framework for Collaborative ATFM*[3)] for cross-border, harmonized ATFM concepts, communications, and practices. The latest version of this document, published in October 2022, recognized the progress toward regional harmonization made by many States; however, the overall progress was also determined to be slow and inconsistent across states.

In the US, the Federal Aviation Administration (FAA) manages the largest delegated airspace in the world spanning over 29 million square miles.[4)] Improved and strengthened over decades of experience and collaboration with stakeholders, the FAA's ATFM system and Collaborative Decision-Making (CDM) process continuously evolve, with automation and practices improving through expanded data-sharing and customization to meet local, regional, national, and international flow management needs.[5)]

By sharing information about the FAA's ATFM and CDM, we hope our experience will prove valuable to Air Navigation Service Providers as they work on developing and improving regional and global cross-border ATFM for the benefit of all stakeholders. We hope this paper will also provide valuable information to researchers and academia in support of developing tangible alternatives for improving efficiency of cross-border air traffic management.

2. ATFM in the United States of America

The FAA's ATFM system is responsible for balancing air traffic demand with system capacity to ensure the most efficient utilization of the National Airspace System (NAS). Within the FAA, the Air Traffic Organization (ATO) is responsible for safe, orderly, and expeditious flow of air traffic. The ATO applies minimal delays when needed and through continued analysis, coordination, and dynamic utilization of time-based management (TBM) and Traffic Management Measures[1] (TMMs) and programs.

To maintain the integrity of the air traffic system, the FAA requires facility traffic management personnel to prioritize the use of TBM when evaluating traffic flow management options. TBM is a methodology for aircraft sequencing by assigning crossing times at

[1] Aka, Traffic Management Initiatives (TMIs) in the US

specific points along an aircraft's trajectory. TBM applies time to mitigate demand-to-capacity imbalances while enhancing efficiency and predictability of operations in the NAS. TBM techniques and tools are used only when needed, usually during periods when demand exceeds capacity. However, to sustain operational predictability along with regional or national strategic plans, these tools can also be used during periods when demand does not exceed capacity.

2.1. ATFM hierarchy and organizational roles

As illustrated in Fig. 1, ATFM in the US is executed through several interconnected layers. Facilities within each of these layers have great autonomy for running the operations within but also have a responsibility for coordinating those actions with facilities above and below them.

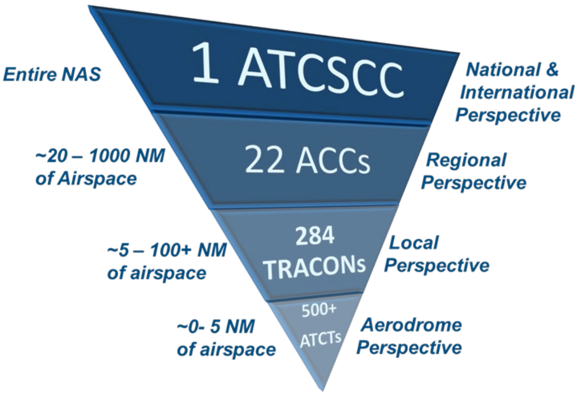

Fig. 1. ATFM Hierarchy in the NAS

Responsibilities for managing air traffic flows are distributed across the following facilities and personnel:

• At ***the national level***, Air Traffic Control System Command Center (ATCSCC) monitors and manages capacity-to-demand imbalances over the entire NAS and coordinates cross-border air traffic flow issues and needs with neighboring ANSPs. ATCSCC also maintains the FAA's Operational Information System (OIS) used for centralized information update and sharing with respect to NAS status, international status, severe weather development, Ops plans, national playbook, and current restrictions.

• At ***the regional level***, Traffic Management Units (TMUs) in twenty-two Area Control Centers [2] (ACCs) monitor and balance traffic flows within their areas of responsibility and in accordance with active traffic management initiatives and programs in the NAS. TMUs ensure harmonized resolutions to both regional and national challenges in unison with ATCSCC and stakeholders.

• At ***the local level***, TMUs in designated Terminal Radar Approach Control (TRACON) facilities ensure that local challenges are addressed in a harmonized manner along with other challenges in the NAS.

• At ***the aerodrome level***, tower personnel work through the overlaying TRACON facilities, if available, or directly with the overlying ACC to address capacity-to-demand imbalances within their areas of responsibility and in a harmonized manner with other concurrent challenges in the NAS.

2.2. ATFM Automation Platforms

ATFM across ACC borders is accomplished through collaboration between all CDM stakeholders. However, when needed, cross-border ATFM is directly managed by TMUs at ACCs and select TRACON facilities that use ATFM automation platforms and tools to help ensure smooth flows across the NAS.

The FAA uses three key automation platforms to conduct TBM. Collectively referred to as the 3Ts, they include Traffic Flow Management System[6)] (TFMS), Time Based Flow Management[7)] (TBFM), and Terminal Flight Data Manager[8)] (TFDM).

Supported by the integration of 3Ts, data-sharing across systems and stakeholders increases situational awareness and improves predictability of operations. This further allows delays caused by capacity-to-demand imbalances to be more efficiently redistributed to prevent congestion and via least costly means (for instance, via ground delays, airborne speed adjustments or en route holding instead of holding and vectoring at low altitude inside arrival airport's terminal airspace).

2.2.1. TFMS Automation System

Operating at the national level, TFMS supports management of capacity-to-demand imbalances across the entire NAS. TFMS creates demand predictions for airspace and airports, and provides common situational awareness of current and forecasted weather impacts, special use airspace, and other constraints in the NAS.

TFMS sets the stage for application of more granular ATFM functions that help manage air traffic flows through individual resources that may be constrained. Air traffic controllers and managers use it to determine TMMs that may be needed to pre-condition air traffic flows for TBM during periods with significant or long-lasting capacity-to-demand imbalances.

The ATCSCC uses TFMS to continuously plan and adjust the collaborative ATFM plan, including to:

• Visualize active and proposed flights on a map;
• Overlay weather on the map;
• Create demand predictions for airspace and airports;
• Provide common situational awareness of current and forecasted weather impacts, Special Activity Airspace or other constraints;
• Support development of strategic TMMs to manage demand-capacity imbalances;
• Implement Ground Stops, Ground Delay, and

[2] Aka, Air Route Traffic Control Center (ARTCC) in the US

Airspace Flow Programs;

• Create and publish Required Routes in response to weather, equipment outage, flow saturation, military activity and space operations;

• Publish advisories for major TMMs, which are sent to all TMUs as well as Nav Canada and CDM flight operators, and are also published on a public website; and

• Log ATFM action and measures, which allows all TMUs to coordinate electronically.

2.2.2. TBFM Automation System

Operating at the ACC level, TBFM is an Arrival Manager (AMAN) automation platform used for focused ATFM through individual NAS resources where merging of traffic flows occurs, including waypoints along the borders with adjacent ACCs. With its scheduling and metering functions, TBFM helps manage air traffic flows by creating resource-specific time-based schedules and provides tools for reliable execution of time-based schedules. TBFM considers individual aircraft trajectories and performance, resource-specific spacing needs, and other factors and conditions in the NAS as needed for a focused ATFM through a specific constraint point.

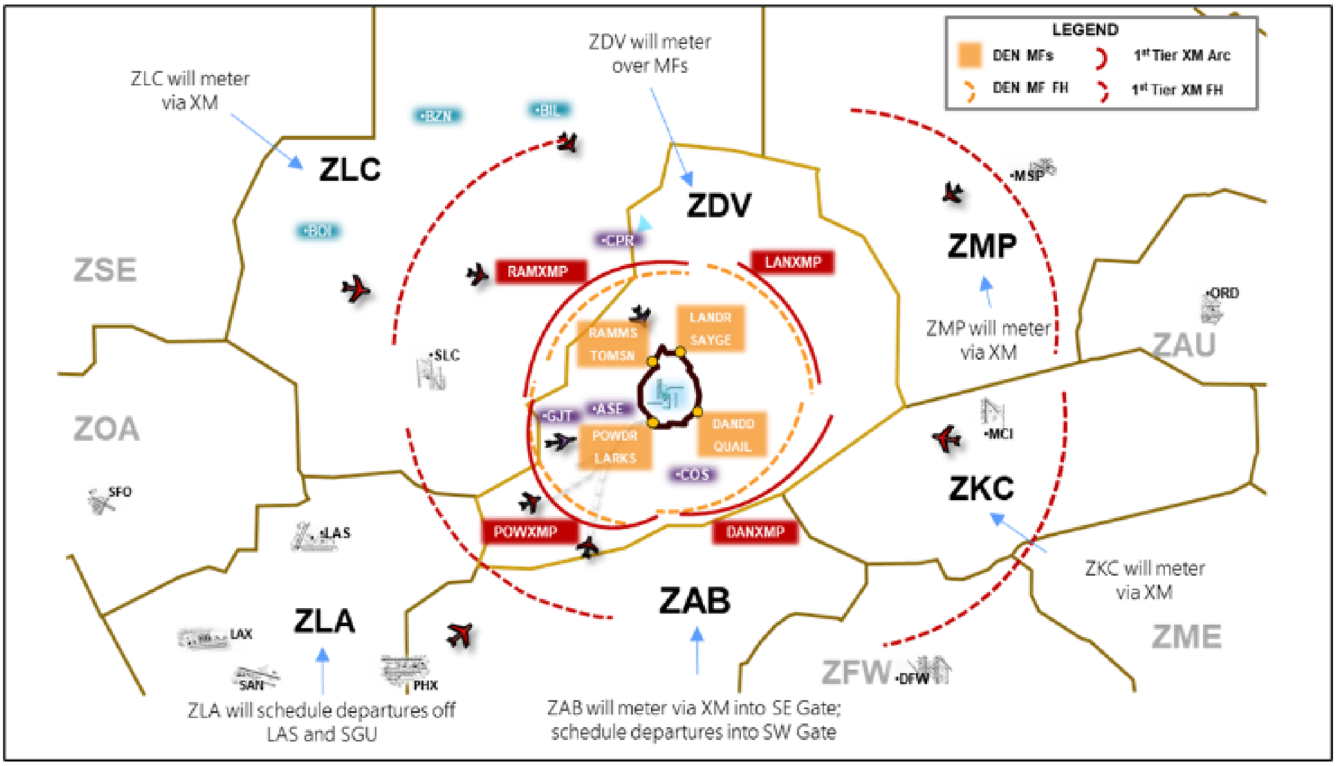

Fig. 2. TBFM Capabilities and Adaptation at Denver ACC

Illustrated on the example of Denver ACC in Fig.2, TBFM system is adapted at each ACC TMU in the NAS based on their local needs. TMUs have the following TBFM tools at their disposal when managing ATFM within ACCs or across ACC boundaries:

• ***Departure Scheduling*** helps determine departure release time (runway-off time) for an aircraft and any ground delay that may be needed for its smooth merging into a specific airborne constraint point. Departure Scheduling can be used for managing flows through multiple constraint points as well as for different types of constraints, including merge points into the overhead stream, merge points along the boundary with downstream ACCs, or merge points at entry to terminal airspace at arrival airports. Departure Scheduling can be coordinated between Air Traffic Control Tower (ATCT) and ACC TMU staff via voice or electronically at select locations in the NAS via Integrated Departure and Arrival Capability TFMS tool.

• ***Arrival Metering*** provides en route controllers decision support tools to manage time-based schedule for airborne flights destined to a specific arrival airport. Arrival Metering maintains a timed sequence of aircraft through individual arrival meter fixes—merge points on entry to terminal area illustrated as orange points along the black line encircling the Denver airport in Figure 2. These sequences include both already airborne aircraft (typically, from origins that are more than 200 nautical miles away from the arrival airport) and those that were integrated by Departure Scheduling prior to their take-off (typically, for airport-pairs within 200 nautical miles of each other). TMU staff sets and manages timed sequences of aircraft for all constraint points within the ACC or the TRACON. Air Traffic Controllers, on the other hand, monitor time-based schedules on their displays only for those merge points that are under their control, and issue clearances to individual aircraft as needed to ensure safety and to comply to time-based schedules as possible between orange dashed-lines (arrival metering freeze-horizons) and merge points in Figure 2.

• ***Extended Metering*** also provides decision support tools to en route controllers to help with managing time-based schedule for airborne flights; however, extended metering significantly increases the distance over which compliance to time-based schedules is managed by introducing additional upstream constraint points illustrated with full and dashed red lines (extended metering arcs and extended metering freeze-horizons, respectively) in Figure 2.

• ***Terminal Sequencing and Spacing (TSAS)*** is a future TBFM tool that the FAA is considering for extending metering principles all the way to the arrival runway. With this tool, it will be possible to introduce additional constraint points inside terminal airspace to help maintain runway assignments and time-based schedules for individual runways. TSAS will provide more accurate trajectory modeling inside terminal airspace, and will consider Consolidated Wake Turbulence separation standard and aircraft equipage such as Performance Based Navigation (PBN) when establishing runway-based aircraft sequences and schedules.

Data sharing occurs between TBFM systems at adjacent ACCs. In addition, ACC TMUs use National Traffic Management Log[9)] (NTML) to coordinate additional flow management activities, including Miles-in-Trail restrictions to manage sector volume and other TMMs. The NTML is a major player in capturing these TMMs, both in terms of their documentation and real-time electronic coordination; note that such information is routed from NTML in TMU to the en route air traffic controllers via Electronic Status Information System. In addition, NTML can also be used by a downstream ACC to request that an upstream ACC reroutes certain flights for sector capacity or arrival fix balancing.

2.2.3. TFDM Automation System

Operating at the airport level, TFDM is a Departure Manager (DMAN) automation platform for airport surface operations management and includes electronic flight strips. Automatic updates to controller displays with the latest flight data delivered through improved Electronic Flight Data (EFD) exchange and Electronic Flight Strips (EFS) will be delivered to twenty-two airports in the NAS. In addition, full TFDM functionality, planned for delivery at twenty-seven sites, also includes:

• Surface and Airport CDM (A-CDM) by providing real-time management of departures as well as management of aircraft movement on airport surface; and

• Integration with TBFM and TFMS to expand information exchange and enable integrated decision-support for cohesive surface and airborne traffic flow management.

Since October 2022, the FAA has deployed TFDM functionalities at nine sites and plans to complete installations at forty more sites across the NAS in 2029.

2.3. Traffic Management Measures (TMMs)

Traffic Management Measures[10)] (TMMs) are techniques used to manage demand with capacity in the NAS. These initiatives contribute to the safe and orderly movement of air traffic. Any TMM creates an impact on customers, so it is imperative to consider this impact and implement only those initiatives necessary to maintain system integrity.

Altitude as a TMM is used to separate different flows of traffic or aircraft flying in close proximity to each other. These measures aim to increase throughput and reduce delays by increasing use of available altitudes. There are three main types of Altitude TMMs used in the NAS:

• ***Tunneling*** are altitude restrictions applicable to arrivals that require aircraft to descend prior to the normal descent point to avoid airspace or traffic constraints. Tunneling may apply to the final segment of the flight or to the entire flight.

• ***Capping*** are altitude restrictions applicable to departures that require aircraft to climb and remain below their requested altitude until they are clear of a particular airspace. Also known as the Escape Routes, Capping may apply to the initial segment of the flight or to the entire flight.

• ***Low Altitude Arrival/Departure Routing*** is a special set of routings with altitude expectations for use in times of capacity constraints in the NAS that requires a written agreement with the customers prior to implementation. These routings may apply to the departure or the arrival phase of flight.

Miles-in-trail (MIT) restriction refers to longitudinal separations in nautical miles between successive aircraft that meet specific criteria relating to their origin or destination airports, or fixes, altitudes, sectors, or routes along their way from origin to destination. MITs are used to apportion traffic into manageable flows, as well as to provide space for additional traffic (merging or departing) to enter the flow of traffic as well as in situations when additional spacing is needed for safe aircraft deviation around weather.

Minutes-in-trail (MINIT) restriction refers to longitudinal separations in minutes between successive aircraft that meet specific criteria similar to those for MITs. MINIT restrictions are normally used in a non-radar environment or when transitioning to or from a non-radar environment.

Fix balancing is used to assign an aircraft a fix other than in the filed flight plan in the arrival or departure phase of flight to equitably distribute demand.

Airborne holding as a TMM is typically used when the weather or congestion conditions are expected to be short-lasting and only where the operating environment can safely accommodate it; holding ensures aircraft are available to fill the capacity at the airport.

Departure Sequencing Program (DSP) assigns a departure time to achieve a constant flow of traffic over a common point. Normally, this involves merging departures from multiple airports through a common point.

TFMS Programs include:

• ***Ground delay program (GDP)*** is administered by the ATCSCC to hold aircraft on the ground prior to take-off to manage capacity-to-demand imbalance at a specific destination. Through assignment of arrivals slots and Controlled Time of Takeoff (CTOT), the program is used to limit congestion and airborne holding at the impacted location. Users are permitted to exchange and substitute arrival slots for their flights congruent with CDM agreements concerning substitutions. Departure-specific CTOT is calculated based on the estimated time en route and the availability of the arrival slot, and can be modified through a coordination the ATCSCC. Due to its importance for ensuring accurate delivery of aircraft to the impacted location, compliance to CTOT is evaluated and reported by airport. The FAA and the CDM community are committed to improving CTOT compliance; in 2023, a compliance rate of 80% or better has been achieved for over 59,000 flights that had a CTOT.

• ***Airspace flow program (AFP)*** assigns specific crossing slots and corresponding CTOTs to manage capacity-to-demand for a specific flow-constrained area (FCA)—a segment of airspace with limited capacity. AFPs may be applied to all aircraft departing airports in the contiguous United States and from select Canadian airports. Aircraft that have been assigned a CTOT in an AFP should not be subject to additional delay. Exceptions to this policy are MITs and departure/en route spacing initiatives that have been approved by the ATCSCC. It is important for aircraft to depart as close as possible to the CTOT to ensure accurate delivery of aircraft to the impacted area.

• ***Collaborative trajectory options program (CTOP)*** is a method of managing demand through constrained airspace that leverages the use of one or more FCAs while considering customer preference with regard to both route and delay as defined in a Trajectory Options Set (TOS). Using algorithms that compare capacity and demand, the CTOP will look at each trajectory option and determine the amount of ground delay that would need to be associated with that option (including zero-delays). CTOP will then assign the most preferred trajectory available. Customers must file flight plans in accordance with the TOS option assigned. Customers may manage their flights through the use of the TOS or through the substitution of flights.

• ***Ground Stop (GS)*** is a process that requires aircraft that meet specific criteria to remain on the ground; the criteria may be airport, airspace, or equipment specific. They are typically issued in severely reduced-capacity situations to preclude gridlocks. GSs normally occur with little or no warning and override all other traffic management initiatives. Aircraft must not be released from a GS without the approval of the originator of the GS. Since GSs are one of the most restrictive methods of traffic management, alternative initiatives must be explored and implemented whenever possible and as appropriate.

Reroutes refer to ATC routing advisories that are issued to ensure orderly flows during times with airspace capacity being restricted by congestion, weather, or activation of special use airspace. Reroutes can be selected using several sources, including precoordinated Playbook Routes or developed specifically to meet a specific need. The required route is closely collaborated with the affected ATCCs, and route advisories are issued by ATCSCC and listed on the OIS.

• ***Integrated Collaborative Rerouting (ICR)*** allows the ATCSCC to identify specific areas that flight operators are encouraged to avoid and TFMS provides lists of flights that enter that area. If enough flight operators do not avoid the area, additional measures will be implemented. This measure is typically used for weather systems in the middle of the NAS.

• ***Pre−departure reroute (PDRR)*** is a capability within TFMS that enables ATC to quickly amend and execute revised departure clearances to mitigate constraints or balance traffic flows. This capability is especially beneficial during periods of severe weather when departure routes are rapidly opening and closing.

• ***Airborne reroute (ABRR)*** is a capability within TFMS that is used for tactical reroutes of airborne aircraft. Traffic management coordinators use TFMS route amendment dialog (RAD) to define a set of aircraft−specific reroutes that address a certain traffic flow problem and then electronically transmits them to ERAM for execution by the appropriate sector controllers.

• ***TOS*** is a message sent to TFMS that specifies route and delay preferences for a flight. While a traditional flight plan contains a single request with a defined route, altitude, and speed, a TOS may contain multiple trajectory options with each one containing a different route, altitude, speed, or minutes of ground delay. Options are ranked in the order of customer preference; in addition to multiple options within a single TOS, each option may also contain start and end times within which each option is acceptable. TOSs are visible to traffic management coordinators for use in PDRR as well as CTOP.

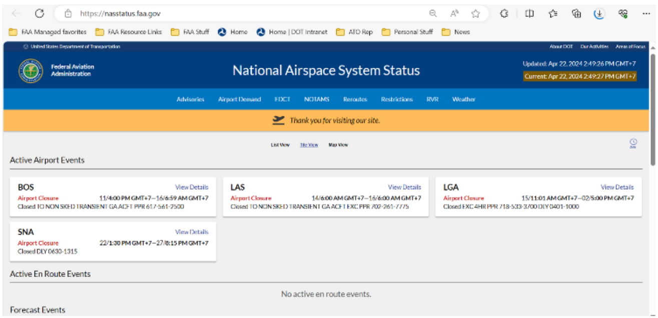

Fig. 3. An Exemplary Screenshot of the NAS Status Webpage

2.4. Publicly Available OIS for Domestic and International Operations in the NAS

With its hierarchical approach to ATFM in the NAS, the FAA maximizes the value of varied accuracy of information and its use across planning horizons from Strategic to Tactical. With Strategic Traffic

Management, the FAA sets the stage for the day-of operation days, even weeks, in advance; the strategic plan is continually updated as new information becomes available, with NAS-wide priorities and flow rates being set on the day-of operation and according to most up-to-date demand and weather forecasts. Tactical Route Management revises the strategic plan on the day-of operation with TMMs and adjustments to flow and flight management as needed to meet regional capacity-to-demand imbalances and operational conditions. Finally, shortly before each departure starts taxing for take-off, Tactical Management of their trajectories is accomplished through TBM as needed to address challenges on the day-of operation.

CDM is not just integral but also a necessary process to establish and maintain common awareness of demand and operating conditions in the NAS. This requires both dynamic and proactive collaboration across the strategic and tactical planning and execution horizons, as well as continuous and transparent review of events and lessons learned. In the early days of CDM, the FAA depended on phone calls between stakeholders and distributed information storage and management. With small investments into developing a web-based platform that integrates information about operating conditions in the NAS, route availability, and equipment status, situational awareness, and effectiveness of traffic management decision-making were greatly improved not just for the FAA but across the stakeholders too. We now conduct a planning meeting via a webinar every two hours so all CDM stakeholders can see the same graphical depictions of weather (actual and forecasted), demand, capacity, and other relevant information. As illustrated in Fig.3, current conditions and restrictions in the NAS are continuously updated and shared with stakeholders via a public *NAS Status* online interface.[11)]

Through partnerships between CANSO, ANSPs and stakeholders in the Latin America and Caribbean (LAC) region, the FAA also contributes to daily updates of publicly available information on CANSO Aeronautical Data Exchange Network of the Americas[12)] (CADENA) —a web-based, regional OIS that includes regional information about ATFM Daily Plan; TMMs; active reroutes and route database; airport delays; advisories; NOTAMs; notifications; contingency forms; airport/airspace capacity; informational material; etc. In addition to consolidating and standardizing the presentation of information that is already available on individual ANSP websites, CADENA restricts data-uploading privileges through access-control protocols that were jointly agreed upon by all stakeholders, and reformats some of the information to present it in consistent and more user-friendly formats such as digital maps.

The FAA provides TFMS and TBFM data to CDM members and Nav Canada via an access-controlled, web-based platform, and is investigating requirements for extending access to other international air navigation service providers (e.g. flight anonymization). This platform does not provide direct access to FAA's operational systems but repackages select data that is ingested from operational systems for stakeholder read-only access on the web-based platform for review and consideration in their decision-making. Finally, TFMS, TBFM, and TFDM data are also available via System Wide Information Management (SWIM) feed for those stakeholders who want to build their own tools to visualize data.

2.5. Plan, Execute, Review, Train, and Improve (PERTI)

PERTI is a data-driven philosophy and process that applies to all aspects of ATFM in the FAA, and aims to improve the use and management of NAS resources.

The FAA uses PERTI process for addressing system constraints, assessing the effectiveness of the measures implemented to address past constraints, and instituting improvements in future planning and execution efforts through the following steps:

- ***Plan*** – Consider the best data available at that point in time, with the understanding that plans will change and react to real time developments;
- ***Execute*** – Follow through on the plan, especially with an eye to the Critical Decision Window so TMMs are not implemented too late to be effective. Timing is key to ATFM. Too-early action unnecessarily delays flights, potentially into weather leading to diversions and diversion recovery. Too-late action runs the risk of not properly mitigating a constraint, also leading to poor results and more drastic TMMs than would otherwise have been needed;
- ***Review*** – Data driven, collaborative review leads to understanding where improvement potential is.
- Train – once the Plan, Execute and Review stages are completed, Training of the ways to improve is key to the last step. If timely feedback and training does not occur, to improvement happens; and
- ***Improve*** – Ultimate goal of the PERTI process is to make systemic, lasting improvements to the ATFM process in the FAA.

2.6. CDM Process in the NAS[13)]

A cornerstone of FAA's ATM, CDM commenced about 30 years ago as an experiment in use of improved data to increase efficiency of GDPs. Prior to the experiment, the FAA relied solely on scheduled flight data to manage GDPs, and did not consider airline, weather, and other operational constraints upstream of the flight to the constrained airport, which led to a poor delivery of GDPs. The successful completion of the experiment led to a new joint government/industry initiative and process, along with new infrastructure and agreements between all stakeholders affected by ATFM in the NAS.

2.6.1. Key Principles of CDM

CDM enables proactive collaboration across all of its members based on a common awareness of demand and operating conditions in the NAS. It is supported by an established data infrastructure and interfaces along with agreed-upon procedures and processes for each member to contribute their plans and other relevant information as they become aware of it. While the interfaces have been modernized, data elements expanded and ATFM tools developed and enhanced over time, the underlying concept and its key principles remained the same:

- ***Common awareness of demand***: CDM flight operators submit and update their schedules long before filing flight plans, and the FAA aggregates this data into a common view of demand and shares it with the whole CDM community. In addition to Flight Create, Flight Modify (updated airline times), and Flight Cancel messages that have been supported for a long time, CDM now supports an expanded data set that includes Early Intent messages (including route, attitude, and speed), TOS, and the other data elements of A-CDM.
- ***Common awareness of operating conditions in the NAS***: the FAA aggregates information about airport construction projects, special events, temporary flight restrictions, equipment outages, weather and other relevant information into a common view of operating conditions, and shares it with the whole CDM community;
- ***Dynamic and proactive collaboration***: CDM community participates in the planning process, and each member brings their perspectives, forecasts, and operational insights to the discussion, including flight operators, ATCSCC and traffic management coordinators from the FAA Enroute and Terminal facilities who jointly participate in the development of ATFM plans and implementation of ATFM measures. In specific circumstances, primarily winter weather, airport authorities also join the planning webinars; and
- ***Continuous and transparent review of events and lessons learned***: with a goal of improving efficiency and effectiveness of ATFM management and coordination, CDM planning and responses to disruptions and capacity-to-demand imbalances in the NAS are continuously scrutinized and discussed with CDM members, and past lessons learned are considered and incorporated into current planning decisions.

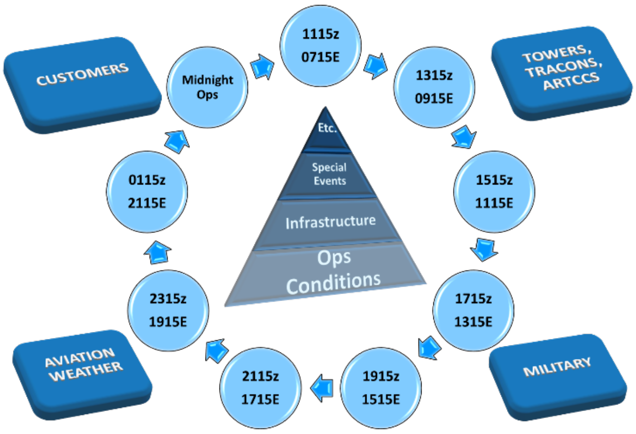

Fig. 4. Collaborative Decision-Making Process

4.2. CDM Sub-Teams and Projects

As a CDM member, flight operators participate in sub-teams and projects to collaboratively work with the FAA to improve systems and develop new concepts and technologies. All teams include Subject Matter Experts from both industry and the FAA. Each team is led by co-leads, one from the FAA and one from industry. The current sub-teams include:

- ***Flow Evaluation Team (FET)*** – Focuses on improving traffic flows using current technologies;
- ***Future Concept Team (FCT)*** – Focuses on new ATFM technologies;
- ***CDM Automation Team (CAT)*** – Focuses on algorithms and automation to improve the automation and keep it current with changing conditions;
- ***Weather Evaluation Team (WET)*** – Works on improving forecast tools, incorporating newly developed weather models, and improving tools to evaluate the accuracy of forecasts;
- ***Surface Collaboration Team (SCT)*** – Advises and assists with the design of the FAA D-MAN and Surface Metering automation. Additionally assists with outreach to all relevant parties for the implementation of D-MAN and Surface Metering;
- ***CDM Training Team (CTT)*** – As the other sub teams develop training materials, the CTT assembles and formats the training for use both within the FAA and for CDM flight operator refresher training;
- ***Stakeholder Engagement Team (SET)*** – Focuses on CDM flight operator involvement with the advanced plan and the post-operational review. Primarily focuses on operator data being incorporated with FAA data to present a comprehensive picture of the operational day. Develops visualization techniques that incorporates both FAA and Flight Operator data for easy understanding and comprehension; and
- ***Ad-Hoc Teams*** – as conditions warrant, ad-hoc teams are formed to collaborate on efforts that do not fit into the predefined teams.

2.6.2. CDM Collaboration

In additional to electronic collaboration via OIS, human collaboration follows the following cadence:

- ***Strategic*** – regular coordination among members to address known constraints, and discuss past management actions, including:
  - Monthly coordination through a National Collaborative Forum to share information about upcoming construction projects and their impacts, special events, and new technologies;
  - Seasonal preparation in the spring for severe weather (thunderstorm) season and in the fall for "Snowbird" season where large numbers of travelers fly south in search of warm weather; and
  - Annual review is conducted with operational and delay data for the previous year reviewed and discussed, looking for ways to improve.
- ***Pre-Tactical*** – each day at 1830Z, an advanced plan for the next day-of operation is collaborated via webinar with all CDM members, ATFM units, meteorologists and airport authorities, as needed. Supported by the Continuous Planning Portal, an automated website accessible only to the CDM partners,

the webinar is used to coordinate operational information that carries through to the tactical plan, including:

- Identification of system constraints and potential TMMs;
- Coordination of critical decision windows for TMM implementation; and
- Publication of the advanced plan for review and distribution throughout participants' organizations.

• ***Tactical*** – planning webinars to coordinate weather, special events, and other developments as they occur on the day-of operation, including:

- As illustrated in Fig 4, regular webinars for the full CDM community: conducted 8 times a day between ATCSCC, Flight Operators, ATFM units, and airport authorities, as needed;
- Special webinars for a subset of CDM community that is affected by a particular TMM: conducted as needed to coordinate, implement, and update the details of the TMM between a smaller group of affected operators, along with the traffic coordinators from the ATCSCC, affected ACCs, and neighboring ANSP;
- Hotlines are means for ad hoc coordination; established to deal with developments outside the scope of regular or special webinars, they are typically regional and driven by outages and weather. Hotlines have unique characteristics and procedures; the typical hotlines include those for ATCSCC, ATFM Units ATC units, and Flight Operators for the following regions: New York, DC Metro, Florida, Texas, and Chicago.

• ***Post Event*** – the review of effectiveness of plans and TMM implementation, including delays and other impacts to the NAS and flight operators. Key to understanding and improving CDM and ATFM in the NAS, post-even reviews include:

- Daily National System Review, conducted by the ATCSCC Quality Control office at 1400Z each weekday, reviewing the previous day (or days on weekends and holidays). Flight operators are full participants in the review.
- Monthly Review at the National Collaboration Forum, a look at the previous month in data, always looking for ways to improve both operations and the data so the data can inform the problem and possibly point to solutions.
- Annual Review at the National Performance Review in the fall. An in-depth review of the previous 12 months.

CDM continues to evolve as new technologies, and global and regional disruptions and challenges appear on the scene.

3. Conclusion

The FAA's existing infrastructure and framework for ATFM have been built over several decades. Through collaboration with stakeholders, ATFM in the US continuously evolves, with automation and practices improving through expanded data-sharing and customization to meet local, regional, national, and international flow management needs and goals. With this paper, we invite regional stakeholders to learn from our experience as it has demonstrated successful ATFM across ACC boundaries. The FAA ATFM practices are flexible and adaptable, and we welcome opportunities to share information and work together with ANSPs and civil aviation stakeholders on harmonization of modernization of air navigation services globally.

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