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METRON HARMONY: INTEGRATED AIR TRAFFIC FLOW MANAGEMENT

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Metron Aviation's Harmony solution provides Air Navigation Service Providers (ANSP), aircraft operators and airport operators an Integrated Air Traffic Flow Management (I-ATFM) system for enhancing safety and improving efficiency and predictability from gate-to-gate, ensuring fair and equitable use of all airspace and enabling future curb-to-curb efficiency improvements.

This document establishes Metron Aviation's vision for I-ATFM, describes the role of Metron Harmony in supporting key functions performed across the entire spectrum of Air Traffic Management (ATM) and demonstrates the vision through operational scenarios associated with the challenges facing the aviation community.

Metron Aviation's vision for I-ATFM is consistent with the ICAO Procedures for Air Navigation Services – ATM – Doc 4444 key terminology and concepts.

Impact of I-ATFM

The vision of I-ATFM described in this document represents a future state for the safe, efficient, predictable and collaborative flow of aircraft through the air traffic system from gate-to-gate. Metron Harmony supports not only the vision as documented here, but also recognizes that transition is necessary from current operations to an I-ATFM system. Transition from, and integration with, legacy systems can be accommodated by Metron Harmony. Also, identifying the as-is and to-be architectures, systems, operational procedures, participants and roles and responsibilities is also supported by Metron Aviation.

Fundamental Integrated ATFM Functions

I-ATFM is a system-wide, full spectrum approach to addressing the complex operational issues facing air transportation service providers and users. The I-ATFM system encompasses the organizations, individuals, processes, data and tools associated with the safe and efficient flow of air traffic from gate-to-gate. This includes ANSP authorities with regional/multi-national, national, en route, terminal/approach and/or Air Traffic Control (ATC) tower responsibilities; aircraft operators including commercial, military and general aviation; and airport operators.

Metron Aviation's vision extends the common definitions of ATFM which address Strategic, Pre-Tactical and Tactical phases of ATM performed by the ANSP in collaboration (e.g., Collaborative Decision Making (CDM)) with aircraft operators and airport operators. The extensions recognize that the fundamental functions associated with ATFM apply to all authorities and phases. Additionally, a system that is targeted to a single domain (e.g., arrival management), or the integration of two domains (e.g., integrated arrival and departure management), is a locally optimized solution that limits the overall improvements to safety and efficiency that can be achieved from a truly integrated ATFM system that seamlessly gathers data and provides the right information to the right user at the right time.

The fundamental functions of Integrated ATFM are:

- Specify Capacity of Resources
- Predict Demand on Resources
- Determine Capacity/Demand Imbalances
- Evaluate Alternative Traffic Management Initiatives (TMI)
- Perform Collaborative Decision Making
- Initiate, Monitor and Modify TMI(s)
- Report Metrics and Analyze Performance

The functional flow of Integrated ATFM is shown in Figure 1.

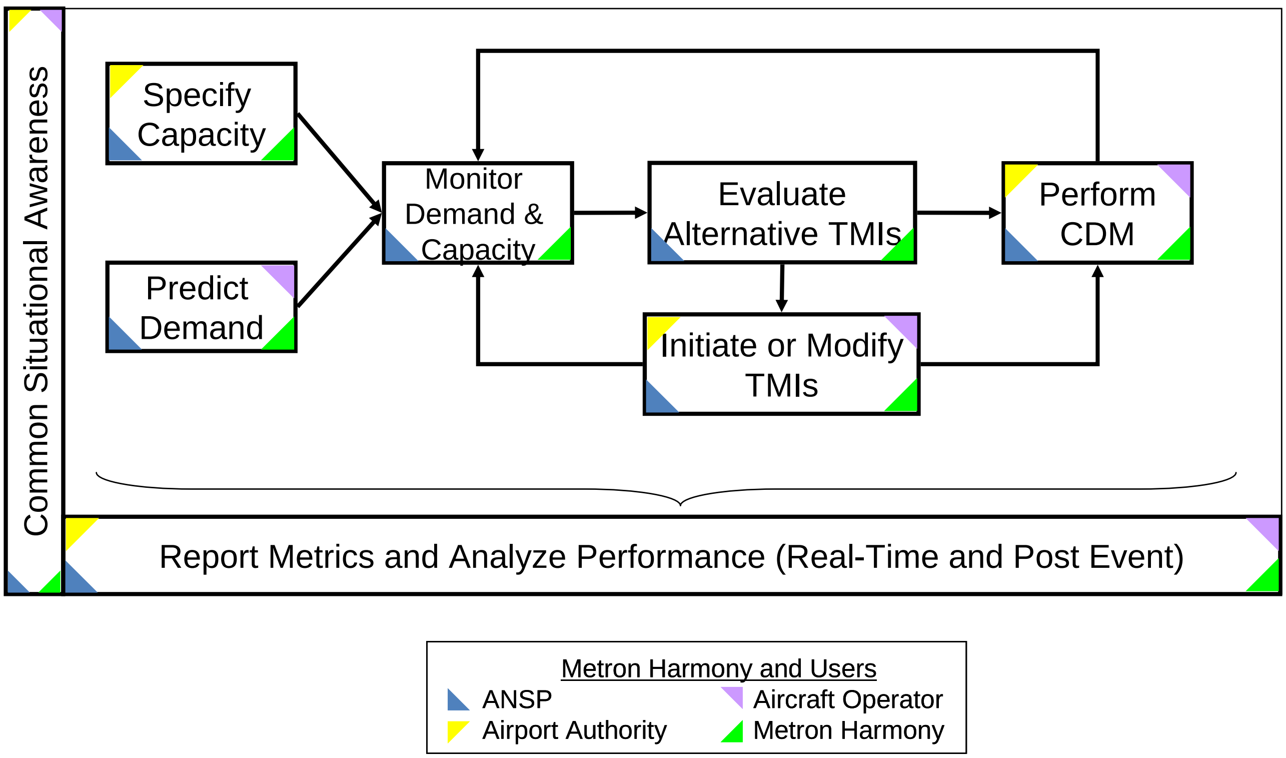

Figure 1 - Integrated ATFM Functional Flow

Specify Capacity of Resources

All authorities are faced with the responsibility for the management of limited resources when focusing on the optimization of their operation. While the range of resources varies based on authority, understanding and specifying the capacity of each resource is a critical responsibility and the first step in applying I-ATFM. Table 1 provides examples of the resources controlled by various authorities involved in I-ATFM and candidate measures of capacity that can be specified by the responsible authority.

Table 1: Candidate Capacity Measures

Authority	Resource	Candidate Measure(s) of Capacity
National	Airspace	• Published routes • Re-route alternatives that cross FIR boundaries
National or En Route	Special Use Airspace	Availability of Special Use Airspace for standard operations
En Route	Airspace (e.g., Sectors)	• Maximum allowable aircraft in the sector • Miles in Trail (MIT) or Minutes in Trail (MINIT) separation requirements
En Route or Terminal	Fix or Stream	Separation requirements (distance or time) for aircraft flying over a common fix or part of a common stream of traffic
Terminal	Airspace (e.g. approach control airspace)	• Maximum allowable aircraft (arrivals, departures, or both) in the terminal environment • Maximum allowable aircraft (rate) over an arrival or departure gate (subset of terminal airspace) • Miles in Trail (MIT) or Minutes in Trail (MINIT) separation requirements at discrete locations within terminal airspace
ATC Tower/Airport	Airport	• Arrival rate, departure rate, and/or operations rate for the airport • Arrival and departure slot allocations
ATC Tower/Airport	Runway	• Arrival rate, departure rate, and/or operations rate for the runway • Aircraft eligible to use runway for arrival and/or departure operations • Aircraft separation (e.g., wake turbulence category minimum separation)
ATC Tower/Airport	Maneuvering Area	• Maximum number of taxiing aircraft (Off blocks but not taken off or landed but not In blocks) • Taxi route availability and eligibility
ATC Tower/Airport	Gate access	Eligible parking area(s) for arrival aircraft
Aircraft Operator or ATC Tower/Airport	Maneuvering Area	Maximum number of taxiing aircraft (Off blocks but not taken off or landed but not In blocks)
Aircraft Operator	Gate access	Eligible parking area(s) for arrival aircraft

Metron Harmony supports I-ATFM capacity specification by providing context to specific user interfaces to accept capacity inputs and modifications. Users are only provided access to modify capacities associated with the specific resources that the user is the managing. This includes airport runway configuration and arrival/departure rates for ATC Tower authorities; departure fix or en route MIT restrictions for En Route authorities and sector traffic count alert thresholds for en route and/or national authorities.

As shown in Table 1, all authorities have a role in specifying the capacity of one or more resources. Additionally, specifying the capacity of a resource can occur in the Strategic, Pre-Tactical and Tactical phases of I-ATFM.

For example, during the Strategic phase, the design (or redesign) of airspace is at the front end of specifying capacity. The analysis and simulation associated with airspace design activities result in a capacity expectation for the airspace. The design of Area Navigation (RNAV) and Required Navigation Performance (RNP) routes are also strategic capacity specifications. Through the use of RNAV/RNP routes, the predictability of aircraft may result in an adjustment to the capacity of the surrounding airspace. Metron Harmony provides leading edge environmental modeling that complements Strategic airspace modeling to ensure that noise and emissions requirements for airspaces and procedures are satisfied. Additionally, the planning and design of support for special event operations (e.g., Olympics, World Cup, air shows) or special use airspace definitions specifies the expected capacity of the airspace and airport resources during these events.

During the Pre-Tactical and Tactical phases, specifying capacity can be associated with a response to irregular operational conditions. For example, adverse weather, winter operations, or runway closures due to maintenance or equipment issues result in the reduction in capacity of a specific resource. Specifying the adjusted capacity and duration of the change is the responsibility of the steward of that resource.

During the Tactical phase, I-ATFM includes scheduling departures to a common departure fix, into an overhead stream, or into the arrival stream of a nearby airport which involves the specifying of a capacity for the associated resource. The capacity may be a MIT or MINIT restriction for a common departure fix that one or more airports must adhere to for merging traffic. Additionally, I-ATFM includes arrival sequencing and scheduling based on time-based metering principles. Specifying the capacity of relevant arrival resources including runways, airports, terminal areas and en route arrival merge points are critical components of building an efficient arrival schedule. Capacity specification of runway utilization includes operational procedures and restrictions associated with determining efficient runway allocations for arrivals and departures.

I-ATFM actions include Strategic schedule planning, Pre-Tactical adjustments based on equipment availability and Tactical gate pushback (“off block”) times to minimize taxi out times. Gate capacity also influences efficient gate utilization for inbound aircraft. In addition to parking gate capacity, specifying the capacity associated with access to the movement areas is also a component of I-ATFM.

Predict Demand on Resources

A resource is only constrained when the demand on the resource exceeds the capacity. Identifying the demand on resources is a fundamental I-ATFM function for Strategic, Pre-Tactical, Tactical and Post Operations phases. This includes the critical capability to provide a predictive component associated with each phase.

With access to aircraft operator schedules, filed flight plans, active flight data from aircraft operators, ANSPs and airport operators, weather forecasts and resource definitions (e.g., aeronautical information), the predicted demand on resources as a function of time can be determined. I-ATFM is based on providing a common operating picture to all users of the predicted demand on potentially constrained resources. Predicted demand includes expected departure and arrival related operations in the parking and movement areas; departure operations; merging of departure and en route traffic; en route flows; and arrival operations. For every resource that has a specified capacity, I-ATFM provides a corresponding prediction of the demand for the resource over a time horizon consistent with the operational decisions associated with the resource.

Metron Harmony supports I-ATFM demand prediction by providing context-specific user interfaces to show resource loading with respect to time and the specified capacity. For each resource, the demand prediction is provided in the same units of measure as the capacity specification in order to simplify capacity and demand comparisons. For example, a runway resource may show a virtual queue of aircraft scheduled to use the runway for departure or arrival operations; an arrival merge point may show the unconstrained Estimated Time of Arrival (ETA) of expected aircraft; or an airport may show a time history of expected arrival or departure operations as a function of time.

I-ATFM acknowledges that demand prediction spans all phases and is of interest to the entire aviation community. For example, during the Strategic phase, initial demand forecasts from aircraft operators are used to formulate airport and airspace design changes to prepare for the predicted fleet mix and operations. Additionally, strategic slot allocation benefits from initial demand forecasts to align schedule intentions with available slots. During the Pre-Tactical phase, predicting the demand at an aggregate level for resources including airports or en route sectors provides insight into potential operational issues that may occur if not addressed. Aggregate predictions are used in the Pre-Tactical phase due to uncertainty in the predictions associated with pre-tactical lead time (e.g., one day). Tactically, demand prediction includes flight specific details associated with the demand at any operational resource including common departure fixes, en route sectors, terminal area transitions, maneuvering areas and aprons.

Determine Capacity/Demand Imbalances

I-ATFM provides the decision support and operational information necessary to take action whenever the predicted demand exceeds the expected capacity of any resource. Just as important for efficiency and safety, I-ATFM provides information so that action is not taken prematurely or unnecessarily. With access to system-wide capacity constraints and demand predictions, I-ATFM can determine and alert relevant authorities and operators to current or future conditions where such an imbalance exists.

Metron Harmony supports I-ATFM capacity/demand imbalance determination by providing context specific user interfaces and alerts to show resource loading with respect to time and the specified capacity. For each resource, the demand prediction is provided in the same units of measure as the capacity specification in order to simplify capacity and demand comparisons. For example, traffic counts, traffic rates, queue size, delay time and slot or gate availability can all be used to compare demand to capacity. In addition to Pre-Tactical and Tactical capacity/demand imbalance determination, Metron Harmony supports Strategic ATFM capacity/demand imbalance such as strategic slot allocations where modifications to existing strategies can be evaluated with Metron Harmony to determine impacted slots or flights. Capacity/demand imbalance decision support includes departure queue size(s) and thresholds for ATC Tower authorities and aircraft operators; Scheduled Time of Arrival (STA) and associated delay absorption for en route authorities; and indications of overloaded en route sectors and airports for en route and national authorities.

Evaluate Alternative TMIs

Once a capacity/demand imbalance has been identified that requires action, I-ATFM considers a wide range of TMIs to address the imbalance. In addition to traditional ATFM TMIs - MIT, MINIT, ground delay programs, ground stops, re-routes, flight level capping and airspace flow programs, I-ATFM includes open slot identification, determination of scheduled times of arrival and resource allocation (e.g., runway allocation or fix balancing). Metron Harmony supports the evaluation of I-ATFM alternatives with context specific information and modeling. For example, in the Pre-Tactical and Tactical phases when there are sufficient aircraft contributing to the imbalance that are still on the surface at the departure airport, Metron Harmony provides “what-if” modeling of candidate programs. This modeling of TMIs determines candidate sets of Calculated Take Off Times (CTOT) that efficiently address the imbalance while satisfying the constraints associated with the imbalance (e.g., airport arrival rate).

Collaborative Decision Making

Collaborative Decision Making (CDM) is a well-established component of improving the operational efficiency of air transportation. Through the sharing of data, information and tools, ANSPs, aircraft operators and airport operators work together to identify solutions to issues that reflect the inputs and preferences of all parties. I-ATFM extends the involvement of aircraft operators and airport operators to all facets of ATFM and

ATC. With access to relevant and alternative TMIs being evaluated by the ANSP, CDM participants provide updated operational intent, feedback and recommendations based on their specific business model. Actions taken by CDM participants in response to planned or actual ANSP actions are shared throughout the system to maintain the common operational picture and situational awareness that drives CDM efficiency and safety. Metron Harmony supports CDM through the automation of data sharing, "what-if" scenarios, receipt of updated flight intent information and communication of planned and actual TMI(s).

For example, in Pre-Tactical and Tactical evaluations of a capacity/demand imbalance at an airport, the ANSP may be evaluating a ground delay program to smooth the demand. Metron Harmony shares these alternative programs with the CDM participants and supports the independent modeling of the impact and potential actions that the CDM participant may employ to be compliant with the program. These actions range from the acceptance of the flight specific CTOTs to the cancellation of targeted flights to the substitution of flights under the control of the CDM participant to better align operational decisions with the available capacity identified by the ANSP. Additionally, CDM participants may modify flight intentions with re-routes (lateral path changes) or altitude capping to remove a flight from the constraints imposed by the TMI.

In the Tactical phase, access to accurate discrete event times (e.g., off blocks, take off, landing and in blocks) improves the situational awareness and tactical planning of ANSPs and CDM participants. When I-ATFM time based metering is used to address an operational capacity/demand imbalance, the flight-specific STAs represent a better arrival estimate than estimate based on trajectory predictions that are independent of the Integrated ATFM control being applied to the flight. Metron Harmony shares this information to all systems and users dependent on arrival time information. Additionally, access to arrival runway information is also provided to CDM participants to enhance situational awareness and improve operational decisions.

Initiate, Monitor and Modify TMI(s)

Once alternative TMI(s) are evaluated and confirmed through the CDM process, the TMI(s) are initiated at the appointed time and the ANSP, aircraft operators and airport operators respond to the specific control actions identified. Throughout the execution of the TMI(s), the capacity/demand situation and the flight-specific adjustments are continually monitored to ensure that the TMI(s) intent is being realized in a safe and efficient manner. This includes the application of the TMI to flights that are intending to operate within the purview of the TMI even if the flight was not part of the original TMI at initiation. The handling of these flights may be subjected to specific business rules to ensure overall system efficiency, safety and equitability.

Metron Harmony supports TMI initiation through the automated determination and communication of the flight-specific controls associated with the implemented TMI(s). For Pre-Tactical and Tactical TMI(s) that assign CTOTs and/or pushback times to impacted flights, the CTOT (and/or pushback) determination and dissemination is automatically conveyed to national and ATC tower/airport ANSP elements and the aircraft operators. For Tactical TMI(s) that impact airborne flights, the flight-specific control is provided to the appropriate ANSP element for action and to all others for situational awareness.

Report Metrics and Analyze Performance

I-ATFM is not limited to the active operational timeframe since the measuring, reporting and analyzing of performance provides an opportunity for continuous operational improvements to efficiency, safety and collaboration. Measuring and reporting on the flight-specific and aggregate performance of the ANSP, the impacts of the TMI(s) and the compliance of the ANSP elements provides a scorecard of how well the system responded to the implemented TMI(s). I-ATFM also includes the analysis of the information, alternatives and responses to determine if the implemented TMI(s) were the most effective available, and what, if any, alternatives could have been implemented instead. This analysis is a valuable training aid for all system participants to improve future decisions and to identify new metrics correlated to system efficiency, safety and equity.

Metron Harmony supports metrics reporting and performance analysis in the Tactical and Post Operations phases. Tactical reporting of compliance and flight-specific impacts helps with the ongoing monitoring and execution of TMIs. The Post Operations reporting and analysis are driven by Metron Harmony's capture of relevant operational data, constraints and control actions. Standard reports (e.g., daily traffic counts, program summaries, aggregate efficiency gains or delays) and ad hoc reports from the operational data provide all authorities with access to relevant performance data. ANSPs can evaluate TMI compliance by internal elements and aircraft operators.

Metron Harmony also includes leading edge environmental modeling that identifies flight path specific noise and emissions contours to support environmental compliance monitoring and analysis of reports of non-compliance. Additionally, as Performance Based Navigation (PBN) routes are evaluated for operational safety and efficiency, the environmental impact due to emissions can be evaluated simultaneously.

Metron Harmony automates delay reporting and other metrics required by the ANSP. Aircraft operators can evaluate decisions made with respect to TMIs and the operational compliance of their own operations.

Metron Harmony also provides operational event playback to visualize the state of the system when the decisions were made to identify possible inefficiencies, training opportunities and business rule adjustments to improve the overall efficiency and safety of the system. This capability allows additional alternative TMI evaluation to occur post operations in order to identify better operational changes to be used in the future.

Metron Harmony Integration

Metron Harmony implements the vision of I-ATFM (See Figure 2). Metron Harmony receives data from external interfaces to drive the functionality and user interfaces. Flight plans and flight data – from ANSPs and aircraft operators – provide access to flight intent critical in predicting demand. Surveillance data provides Tactical aircraft state updates for aircraft on the airport surface as well as airborne in the terminal and en route environment. Weather data provides forecasted and actual atmospheric conditions and weather events that support identifying capacity impacts as well as flight predictions. Aeronautical information provides access to static aeronautical data including airspace boundaries, routes, airports, navigational aids, waypoints and dynamic data associated with Notices to Airmen (NOTAM).

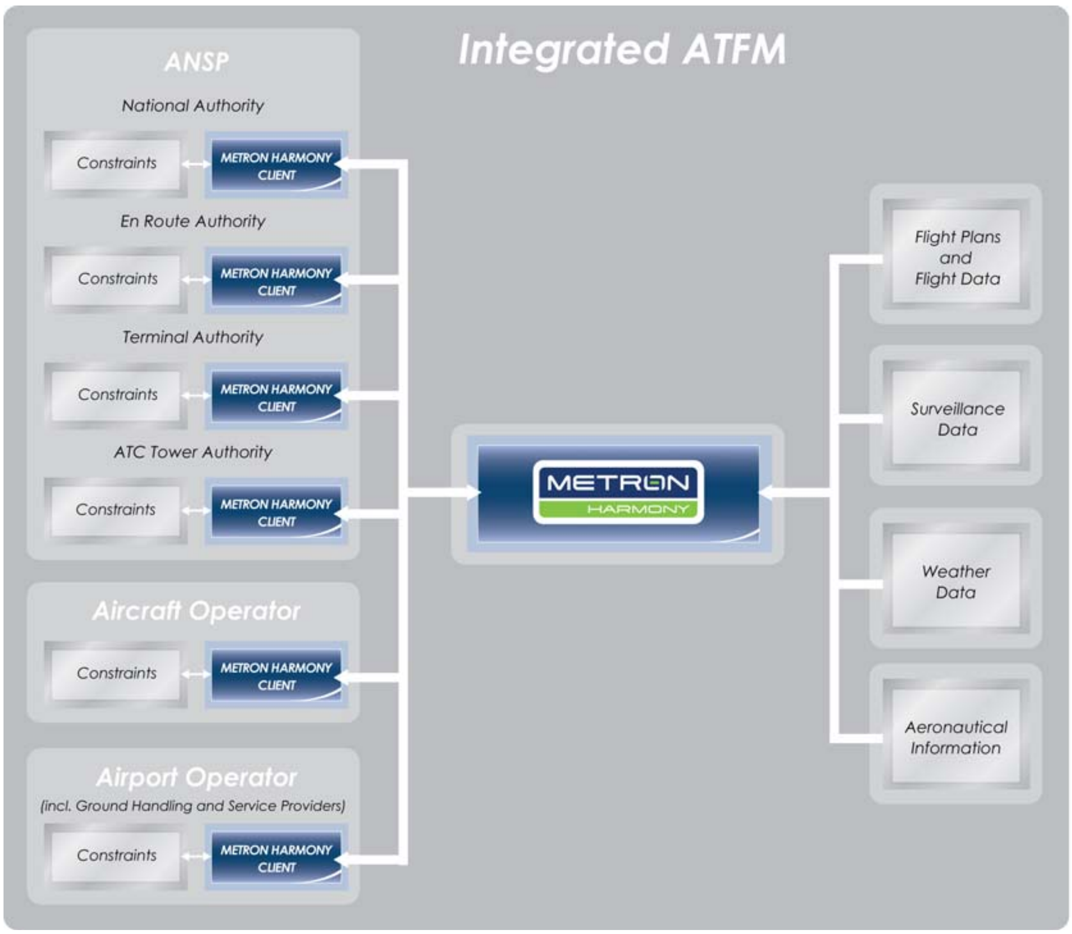

Figure 2 - Metron Aviation's I-ATFM Vision

Through the combination of system-wide and authority-specific web-enabled interfaces and displays, Metron Harmony can be configured to ensure that I-ATFM constraints are set by the appropriate steward of the constraint and available to all authorities and algorithms dependent on this information. For example, if an ATC Tower authority is responsible for determining the arrival rate of an airport, then the user interface at these facilities provides access to set and modify this constraint and the corresponding time that the specified constraint is valid. From this single point of entry, all prediction and scheduling algorithms as well as context-specific displays for all authorities are updated to recognize this change of constraint. The Metron Harmony automated approach eliminates the manual coordination and multiple entries into multiple systems required by standalone, disparate decision support tools.

Operational Scenarios

Following the complete lifecycle of a single sample flight through I-ATFM demonstrates the involvement of the aviation community through all phases. This sample follows a nominal operation of a commercial passenger airline flight.

The lifecycle of a flight begins in the Strategic phase with the aircraft operator determining the need for the flight based on business projections and level of service to be provided. This will identify, at a minimum, the city-pair and class of aircraft from the operator's fleet. If either airport of the city-pair is slot-controlled, the aircraft operator will assign the flight to existing slot allocation or negotiate for the desired allocation. The resulting flight intention is available from various long term scheduling databases for passenger flight schedules.

Once scheduled, the ANSPs and airport operators demand forecasts have visibility into the flight intentions. The Strategic demand forecasts are used to evaluate nominal capacity/demand imbalances so that alternative operational approaches can be addressed well in advance. Additionally, demand forecast trends also support the ANSP and airport operators' long-term planning procedures including budget and capital planning cycles associated with new facilities, modernized automation, staffing resources and training, airspace redesign, runway and/or airport construction, as well as equipage policies.

In the Pre-Tactical phase, the aircraft operator continues to evaluate business needs and near-term operational conditions to determine if the scheduled flight will continue as scheduled. Availability of aircraft and crew due to prior schedule disruptions is one consideration that may impact the schedule operation pre-tactically. If the flight remains scheduled, the ANSP and airport operator demand forecasts include the flight which, taken in aggregate, may be part of a predicted capacity/demand imbalance that is related to weather, special operations, or irregular operating conditions. By participating in the CDM process, the ASNP, aircraft operator and airport operator share in the identification and resolution of capacity/demand issues. While the ANSP and airport operator focus on the aggregate of operations, the aircraft operator can use internal knowledge of specific equipment, crew, schedule connections and business models to determine the preferred alternative for the specific flight. This may include a flight plan change to adjust the lateral route, flight level or departure time to meet the ANSP constraints in a manner that is the most efficient alternative for the aircraft operator. The aircraft operator may also choose to forego a flight-specific change until the specific situation is realized in the Tactical phase.

In the Tactical phase, the aviation community roles are similar; however, the decisions are aided by improved knowledge about actual operations, weather, staffing and equipment availability. Through the CDM process, the aircraft operator continuously works with the ANSP and airport operator to efficiently execute the flight on schedule with minimal disruptions to the specific flight and the overall system. This occurs through the ANSP and airport operator monitoring of predicted demand and available capacity to determine if any other TMI(s) is required for enhanced safety and efficient management of the constraint in the system. If a TMI is necessary, the aircraft operator evaluates flight-specific alternatives to be consistent with the defined constraints while meeting a favorable business result. With all constraints met, the flight operates between the scheduled city-pair. The actual operational events (e.g., pushback, take off, en route transit, arrival and parking) are available throughout the I-ATFM system to ensure that the system-wide demand predictions are updated accordingly in real time.

In the Post Operations phase, the ANSP, aircraft operator and airport operator are all interested in the performance of the overall system and specific flights. For the full lifecycle of a flight, this analysis includes the aircraft operator validating the business need for the flight and using the actual operational data to support future planning. By measuring the performance of the system, as a whole, and through individual flight performance, the aviation community benefits from the data driven decisions supported by Integrated ATFM.

In addition to this nominal operational scenario, the true value of I-ATFM is realized through many operational scenarios that increase the coordination between ANSPs, aircraft operators, and airport operators. The following scenarios are examples of operational scenarios that benefit from I-ATFM.

- Operations Impacted by Adverse Weather (reduced airport capacity)
- Operations Impacted by Adverse Weather (reduced airspace capacity)
- Tactical Loss of Airport Capacity
- Scheduling Departures into Overhead Stream or to a Common Departure Fix
- Sequencing and Scheduling Arrival Traffic
- Staffing En Route Positions Based on Demand
- Tactical Departure Runway Balancing
- Application of TMI(s) to Non-CDM Aircraft Operators
- Support for Special Operations
- Monitor Environmental Impacts
- Evaluate Environmental Impacts of a Proposed RNAV/RNP Route.

For more information, please contact info@metronaviation.com or visit www.metronaviation.com.