

**Project Report
ATC-339-1**

**Operational Usage of the Route Availability Planning Tool
During the 2007 Convective Weather Season**

Executive Summary

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EXECUTIVE SUMMARY

Efficient management of air traffic departing from metro New York (NY) airports during convective weather is one of the most difficult challenges facing the operators of the U.S. National Airspace System (NAS). The high air traffic demand in this complex, capacity-constrained terminal and en route airspace requires quick decisions and extensive coordination amongst multiple air traffic control (ATC) facilities in order to prevent rapid escalation in NY airport departure delays when convective weather occurs in the airspace within several hundred miles of the NY airports.

The Route Availability Planning Tool (RAPT) is an integrated weather / air traffic management (ATM) decision support tool that has been designed to help traffic managers better anticipate weather impacts on jet routes and thus improve NY departure route usage efficiency. RAPT uses deterministic precipitation and echo top forecasts, together with airspace usage and flight trajectory models, to forecast storm blockage for the various NY departure routes, assigning each a status of clear, partially-blocked, or completely blocked by weather as a function of departure time.

In the summer of 2007, MIT Lincoln Laboratory (MIT LL) and the Federal Aviation Administration (FAA) Aviation Weather Office conducted a field study in the NY airspace region to evaluate RAPT technical performance at forecasting route blockage, to assess RAPT operational use during adverse weather, to evaluate the RAPT benefits, and to better understand the overall NY airport departure decision-making environment during severe weather.

The operational test confirmed the validity of the initial operational vision for RAPT and found that RAPT guidance was operationally sound and timely in many circumstances. A technical performance review of the RAPT abilities to accurately determine when and where a route was blocked identified two primary improvement areas – the operational accuracy of the RAPT route blockage model and explicitly accounting for forecast uncertainty in generating route departure timelines.

Real-time RAPT field-use observations were used to estimate RAPT annual delay reduction benefits, as shown in Figure ES-1. RAPT operational benefits included increased departure route throughput, improved route impact timing leading to more efficient reroute planning, and more timely decision coordination. Estimated annual NY departure delay savings attributed to RAPT usage in 2007 totaled **2,300 hours, with a cost savings of \$7.5 M.**

The in-field RAPT usage observations also sought to develop a better understanding of NY traffic flow decision-making during convective weather since the RAPT operational benefits in 2007 were significantly limited by a number of decision-making environmental factors other than departure route blockage by weather. Real-time observations were made of the multi-facility departure management decision chain during convective weather, the ATC concerns, needs, and responsibilities (and how they differ) at specific FAA facilities, and the procedures and pitfalls of the current process for capturing and disseminating key traffic flow management (TFM) information such as route/fix availability and restrictions.

The estimated annual RAPT benefits in NY that should be achievable in the near-term through enhanced user training, route blockage forecast algorithm and display enhancements, and better operational user understanding of the use of RAPT in collaborative, tactical decision-making for NY departure management is on the order of 8,800 hours of delay saved, with a cost savings of \$28 M.

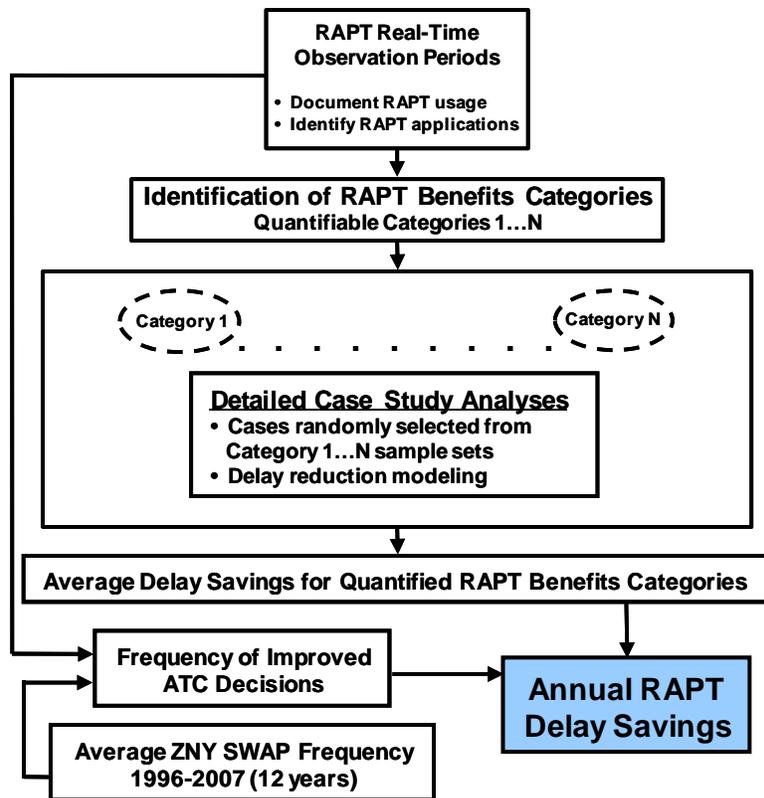


Figure ES-1. Methodology used to estimate annual RAPT delay reduction benefits (SWAP stands for “Severe Weather Avoidance Program”, which is implemented in NY airspace when convective weather causes significant air traffic disruptions).

RAPT Evaluation Results

A RAPT operational-use assessment was conducted at 11 FAA and airline dispatch facilities during 11 convective weather Severe Weather Avoidance Program (SWAP) impact events. The principal results are as follows:

RAPT route blockage forecast algorithm and display enhancement opportunities were identified

The RAPT performance evaluation focused on two critical areas: operational accuracy and improvements needed to increase the realization of RAPT benefits. Operational accuracy is the measure of the ‘correctness’ of the RAPT departure status; verifying that traffic could not flow when routes were forecast to be RED and that traffic should have been able to flow when the forecast route status was GREEN. Identifying potential areas of improvement in the operational accuracy required the consideration of several factors, including the timeliness, applicability, and reliability of RAPT guidance.

In general, the RAPT blockage algorithm performed best in circumstances where there was moderate or high weather coverage. Examples of such weather include solid or ‘gappy’ squall lines, low-topped stratiform weather, or convective cells embedded in regions whose weather was characterized by level 1 or 2 precipitation, even when the convection was unorganized and difficult to predict with a high degree of accuracy. During these types of weather impact events, numerous instances were observed where RAPT guidance played an important role in departure management (Figure ES-2).

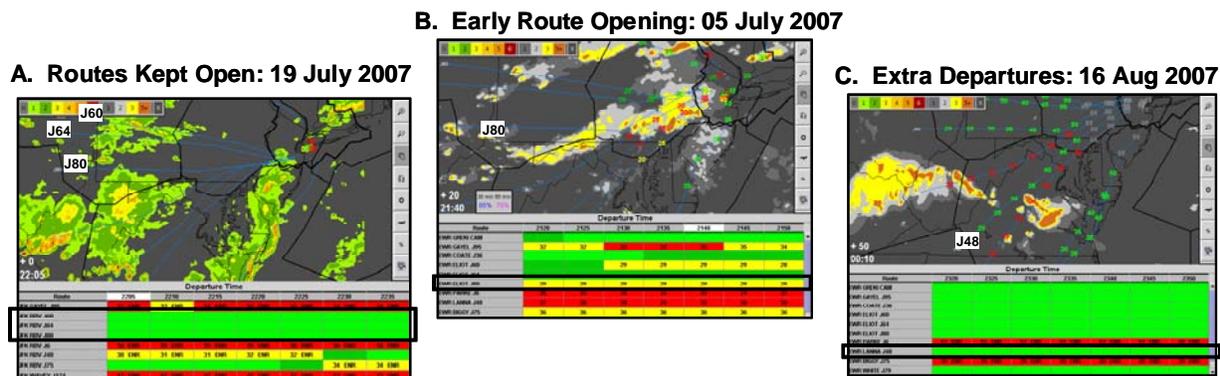


Figure ES-2. Illustrations of documented RAPT usage, demonstrating high RAPT operational accuracy. Black boxes highlight relevant RAPT departure status timelines. In figure (A), departure routes J60, J64 and J80 from JFK airport through the RBV departure fix are kept open since RAPT forecast minimal impact from decaying storm. In figure (B), departure route J80 is opened because RAPT shows YELLOW status with low echo tops (below 30 kft). In figure (C), three extra departures are released along J48 as RAPT predicts a gap between storm impacts.

The RAPT forecasts of route blockage were often inaccurate where route impacts were due to weather characterized by a large spatial gradient in the precipitation or echo top prediction fields caused by strong isolated cells or the leading edge of intense convection.

If RAPT is to be used to anticipate route openings and closings, users must develop confidence in the accuracy of its blockage model, and RAPT must provide users with the information they need to determine when to believe and when to ignore RAPT guidance. It also should provide the user with some objective measure of its performance. The 2007 implementation of RAPT was not particularly transparent; at times, it did not provide sufficient diagnostic information to support its guidance. Potential ways to explain RAPT guidance and to help inform operational users as to why a specific blockage forecast is predicted are to add the ability to show the route boundaries on the animation display and to identify where RAPT thought the blockage was occurring.

Real-time field observations of RAPT usage also demonstrated that some form of an explicit RAPT confidence metric is needed to help users quickly evaluate the quality of RAPT guidance. The accuracy of the convective weather forecasts is a key factor in the overall quality of the RAPT guidance. However, in 2007, there was no explicit consideration of forecast accuracy in providing RAPT guidance nor was there an explicit quantitative metric for the expected RAPT reliability¹. Lacking a reliable measure of

¹ The weather forecasts provided by the Corridor Integrated Weather System (CIWS) do include a real-time performance metric which is the recent accuracy at predicting the spatial locations of high radar reflectivity cells. These CIWS weather forecast accuracy metrics were not translated into RAPT timeline accuracy metrics in 2007.

confidence, users in 2007 were required to develop their own rules of thumb to evaluate the quality of RAPT guidance, a difficult task for traffic managers still learning to use an unfamiliar tool.

Eleven unique RAPT operational benefits categories were identified

Observed RAPT applications included quantifiable departure capacity enhancement benefits [e.g., more timely reopening of departure routes (RO)] and improved collaborative decision-making applications such as increased awareness of departure route impacts caused by weather. In all, 11 unique RAPT benefits categories were identified (Table ES-1).

**TABLE ES-1
Observed RAPT Benefits Categories**

1.	RO	More timely departure route reopenings; eased departure restrictions
2.	RRP	More timely reroute planning or implementation; improved route impact planning
3.	DP	Directing pathfinder requests
4.	DOL	Keeping departure routes open longer
5.	AHD	More timely and proactive resumption of arrival flows; decreased airborne holding; potentially saved diversions
6.	PRSA	Proactive runway sequencing assistance
7.	EP	Enhanced decision-making productivity
8.	I/IC	Enhanced Inter/Intra- facility coordination
9.	SA-1	Enhanced common situational awareness
10.	SA-2	Improved awareness of evolving airspace impacts
11.	SA-3	Decision/plan/information confirmation or evaluation

Benefits categories 1-6 (above) directly result in RAPT-derived delay savings and are therefore considered quantifiable. Of these, four primary departure route management categories (RO, RRP, DP, and DOL) were the focus of the 2007 delay savings analysis. Though more difficult to translate into tangible delay and cost savings estimates, RAPT benefits categories 7-11 are critical to improving decision-making planning and coordination, which in turn increase the likelihood of achieving other RAPT-derived capacity enhancement decisions such as RO or RRP.

The frequency of each type of RAPT application was tabulated for each FAA and airline facility and rolled-up to an annual RAPT benefits frequency estimate based upon the historical average number of NY SWAP days per year (Table ES-2). Quantified RAPT delay savings estimates were determined for the four primary departure management benefits categories (red box, Table ES-2).

TABLE ES-2
Annual RAPT Benefits Frequency per Category*

1. RO	77
2. RRP	70
3. DP	70
4. DOL	19
5. AHD	6
6. PRSA	13
7. EP	410
8. I/IC	384
9. SA-1	717
10. SA-2	595
11. SA-3	480

**Benefit Categories in red box used to estimate annual delay savings*

Estimated annual RAPT delay savings for 2007 were significant

Several RAPT benefits case studies were analyzed in an effort to quantify the delay savings associated with the four primary RAPT departure route management benefit categories. Results show per-use RAPT benefits ranged from 0.9 to 26.7 hours of delay saved, with per-use cost savings ranging from \$2,900 to \$85,000. The large variation in case-to-case delay savings was not surprising given that NY departure delays arise from highly nonlinear queues.

Mean or median (where possible) case study delay savings per benefit category were multiplied by the estimated annual frequency of the various RAPT operational uses to determine the annual 2007 RAPT delay reduction benefits. **Annual RAPT benefits in 2007 totaled 2,300 hours of delay saved, with a cost savings of \$7.5 M.**

Characteristics of the NY air traffic management environment have direct implications on RAPT usability and benefits

Real-time observations of NY SWAP operations helped to better understand the RAPT case study results and highlighted opportunities for improvements in RAPT operational effectiveness, including improving route pathfinder procedures, increasing use of Coded Departure Routes (CDRs), and optimizing the use of miles-in-trails (MIT) restrictions for reopened departure routes.

“NAS Network” factors also had a significant impact on RAPT operational effectiveness. These factors included NY *arrival* flow management, the effect of active ZDC Warning Areas, and airport surface management complexity -- all of which were observed to impact the effective use of available NY departure capacity.

The decision-making environment for NY departure flow management was also very important to overall TFM effectiveness. The ZNY Area Supervisors at times appeared to be key decision-makers for NY departure route usage whose operational acceptance of RAPT will be critical to achieving higher RAPT operational benefits. ZNY Area Supervisors did not have access to dedicated RAPT displays prior to 2007 and training in 2007 for the Areas was limited. Airport surface management is also a key factor in

departure efficiency. Unfortunately, access to RAPT by decision-makers at two key airport towers (EWR and JFK) was quite limited in 2007.

The many lines of communication through which empowered decision-makers at several different FAA facilities coordinate and implement departure flow management decisions is an important factor that has not been considered previously. The capability of RAPT to provide a common awareness of proactive departure flow management opportunities during SWAP may ease planning and coordination complexities often found in this tactical decision-making environment.

A key finding during the RAPT field observations was that traffic managers were unsure of the status of NY departure airspace (i.e., open or closed) an estimated 440 times during the 2007 SWAP season. This airspace status uncertainty arises from the dynamic, ever-changing state of departure route/fix impacts during convective weather, poor information system infrastructure for route status data management, and the high workload associated with cataloguing available routes and tracking airspace status changes.

Potential near-term RAPT benefits are expected to increase

Several observations lead the authors to conclude that the RAPT operational benefits in 2008 and beyond should be higher than were observed in 2007. Increased RAPT usage and operational effectiveness is expected to increase RAPT benefits to over 8,000 hours of delay saved (with a cost savings exceeding \$28 M) in the near-term as the following occur:

A. User experience increases

Operational traffic managers and controllers often used RAPT in 2007 as a confirmation tool – both to help confirm decisions based upon other information and to verify the operational accuracy of RAPT guidance. As user confidence and expertise in the use of RAPT increases, traffic managers are expected to become more aggressive in making proactive NY departure flow management decisions based upon RAPT forecasts for route blockages.

B. Identified RAPT enhancements and technical performance improvements are implemented

Field observations of RAPT performance and user requests for specific enhancements are guiding RAPT algorithm and display enhancement and redesign efforts. By

- (i) improving RAPT route blockage forecasts and the operational accuracy of RAPT guidance,
- (ii) providing explicit information about forecast uncertainty,
- (iii) including additional departure routes deemed important by FAA and airline personnel in the RAPT database,

RAPT will become both more reliable and better tuned to operational needs.

C. Access to RAPT at several FAA facilities improves

RAPT access issues existed at EWR, JFK, and LGA towers in 2007. All three towers accessed RAPT via a thin-client display application installed on an Internet-ready PC in the tower cab, but the PCs were either poorly placed or hosted additional applications used for critical administrative tasks. This effectively reduced access to the RAPT products at the ATC towers, which in turn reduced the overall RAPT operational effectiveness there. Options are being explored for providing RAPT in the NY towers via dedicated displays (similar to how RAPT is accessed at the ARTCCs). This would greatly increase

RAPT usage at the metro NY towers, leading to improved coordination and enhanced collaborative decision-making for departure flow management.

Adding a dedicated RAPT display at the Teterboro airport (TEB) tower would also likely increase RAPT usage and the operational effectiveness of departure routing decisions for this airport. TEB departure delays during NY SWAP events can be severe. Route blockage forecasts for all nominal TEB departure routes are already available in RAPT, and with a RAPT display and training, controllers at TEB tower would have the same awareness of near-term departure route impacts derived from RAPT as those at all other NY ATC facilities.

RAPT product access should also be improved at the FAA Command Center (ATCSCC). Here, RAPT is available on the dedicated CIWS display provided in the National System Strategy Team (NSST) Unit. However in 2007, the CIWS/RAPT display was located on the other side of the Unit from the NY-desk. Therefore, an NSST traffic management specialist working the NY-desk would have to leave his / her position, walk across the Unit to review RAPT information, and then return to the NY position, attempting to coordinate NY departure decisions with the RAPT data now committed to memory. This was obviously not an ideal setup for RAPT usage within the ATCSCC. Redesign plans for the NSST in 2008 should significantly improve RAPT data access and tool usage at the FAA Command Center.

D. Interactive user training and real-time in situ support continues

RAPT will continue to be supported by a multi-faceted RAPT training program. As in 2007, RAPT training in 2008 will include small-classroom training and demonstration sessions for all FAA and airline dispatch personnel who may use RAPT. Real-time in situ RAPT training will also be provided at all RAPT-equipped facilities during the storm season, with particular focus on real-time RAPT training for ZNY Area Supervisors.

An important addition to the 2008 RAPT training plans will be the introduction of RAPT Operational Scenario Training (ROST). After each significant NY SWAP event where observers are in the field to study RAPT performance and usage, instances of potential missed opportunities to increase NY departure capacity or mitigate airspace complexity will be documented and presented to operational traffic managers for discussion.

E. Recommendations for Post-2008 RAPT Capabilities

(i) Route status information

Improved route status information is critical for achieving usage of the available departure capacity during severe weather. Work is underway to improve the real time acquisition of route status information. Displaying that information graphically (e.g., via the RAPT display) would significantly improve the overall situational awareness. The expected benefits of readily-accessible route status information for improved common situational awareness would be significant, not only in terms of RAPT effectiveness in particular but for improved convective weather TFM in general.

(ii) Management of arrival route blockages

The RAPT route blockage algorithms could readily be adapted to provide a forecast of arrival route blockages in space and time. By combining that information with information on the arrival aircraft, it should be possible to provide forecasts of situations in which arrivals are likely to deviate into departure airspace.

(iii) Improved decision support for blocked departures

A particularly difficult departure management decision is determining a suitable alternative departure route when the filed route for an aircraft is blocked. The RAPT capability should be extended to include the presentation of decision support information on the utility of alternative routes [e.g., coded departure routes (CDRs and CDM playbook routes)] for the filed destination including:

- Takeoff times that would avoid severe weather encounters for each of the alternative routes,
- Additional flight time associated with use of each of the alternative routes, and
- Expected future congestion on each of the alternative routes (including congestion on departure fixes and in en route airspace).

It should be noted that this particular decision support needs to be aircraft specific. The near-term availability of high quality airport surface traffic information at the NY airport (from ASDE-X) makes providing this type of decision support potentially feasible (using prototype TFM systems) as soon as 2009.

The full report on the Operational Usage of RAPT During the 2007 Convective Weather Season (MIT LL Project Report ATC-339) can be retrieved from the following web site:

http://www.ll.mit.edu/mission/aviation/publications/faa-atc-reports_300-399.html

A copy of the full report may also be obtained by calling the Lincoln Laboratory Weather Sensing Group at: (781) 981-7430.