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The Route Availability Planning Tool (RAPT): Evaluation of Departure Management Decision Support in New York during the 2008 Convective Weather Season*

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***Abstract*— Severe weather avoidance programs (SWAP) due to convective weather are common in many of the busiest terminal areas in the US National Airspace System (NAS). In order to make efficient use of available airspace in rapidly evolving convective weather, it is necessary to predict the impacts of the weather on key resources (e.g., departure and arrival routes and fixes), with frequent updates as the weather changes. Currently, this prediction is a mental process that imposes a significant cognitive burden on air traffic managers. As a result, air traffic management in SWAP is often inconsistent and decisions result in less than optimal performance.**

The Route Availability Planning Tool (RAPT) is a prototype automated decision support tool, intended to help air traffic managers in convective weather SWAP, by predicting the impacts of convective weather on departure routes. Originally deployed in New York in August, 2002, RAPT has recently undergone two field evaluations (2007 and 2008) in order to test and refine its concept of operations, evaluate the accuracy and usefulness of its guidance, and estimate observed and potential delay reduction benefits that may be achieved as a result of its use. This paper presents the results of the 2008 performance evaluation, including the concept of operations, quality of decision support guidance, and analysis of delay reduction benefits and the operational decision making environment in which RAPT is deployed.

Keywords – Decision support, departure management, Route Availability Planning Tool (RAPT), weather impact, convective weather

I. INTRODUCTION

There is a critical need for improved departure management during convective weather events in the highly congested airspace in the Northeast and upper Midwest United States. An early study of the New York Integrated Terminal Weather System (ITWS) prototype [1] identified the need for improved departure management in New York, and suggested that small increases in airport departure rates during SWAP could result in significant delay reduction. Departure delays continue to be a major problem at New York airports, and their effects cascade across the National Airspace System (NAS), as the need to clear departure backlogs necessitates airborne holding, ground delays, and ground stops of inbound traffic [2].

The ability to predict impacts of convective weather on future departures is a fundamental need in departure management that is extremely difficult to do without automated support. It requires projection into the future of three-dimensional thunderstorms and flight trajectories to determine the nature and severity of the weather that departing flights will encounter. Once the intersection of weather and flight trajectory is determined, it is necessary to estimate the likelihood and amount of deviation that may be required to avoid weather encountered along the route. Without automated decision support, this prediction is done mentally, imposing a significant cognitive burden on air traffic managers. As a result, departure management during SWAP is often inconsistent and inefficient. Detailed studies of New York operations in 2007 [3] found that there were often missed departure opportunities during SWAP.

The Route Availability Planning Tool (RAPT) [4] is an automated decision support tool (DST) intended to help air traffic managers and airline dispatchers determine the specific departure routes and times that will be affected by operationally significant convective weather. RAPT assigns a blockage status color - RED (blocked), YELLOW (partial or uncertain blockage), DARK GREEN (insignificant weather encountered) or GREEN (clear) - to each route for departure times up to 30 minutes into the future. Based on RAPT guidance, air traffic managers can quickly determine if and when specific routes are free of significant convective weather impacts and available for use. To our knowledge, it is the only tool of its kind currently in operational use.

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In the summer of 2007, a comprehensive field evaluation of RAPT performance found that RAPT guidance provided a generally accurate assessment of route availability [5], and that significant delay reduction benefits could be achieved as a result of RAPT use [3]. These studies also found that over-sensitivity to small-scale features of the input weather forecasts occasionally resulted in poor or unstable RAPT guidance, which, in turn, reduced user confidence and realization of potential benefits. In order to improve the robustness of RAPT guidance, the RAPT route blockage algorithm was significantly redesigned, and a new version was deployed operationally in July, 2008.

A second field study was performed in 2008 to evaluate the RAPT concept of operations, the quality of RAPT guidance, and the observed and potential delay reductions achievable as a result of RAPT use. This paper describes RAPT and its operational concept, and presents a brief evaluation of the quality of RAPT guidance and its ability to support the concept of operations. An analysis of observed benefits, missed opportunities, the operational decision making environment, and the challenges of deploying automated decision support follows. Finally, enhancements planned for deployment in 2009 are presented.

II. RAPT DESCRIPTION

RAPT determines departure route availability by calculating route blockage along departure routes that are defined by four-dimensional, modeled flight trajectories that extend out to 60 minutes flight time. Trajectory points are spaced at one minute intervals.

Flight trajectories have four phases – climb, transition, near en route and en route – that reflect flight altitude and airspace complexity. Routes are defined by 'blockage boxes' centered on the trajectory points, and box length and width are functions of the flight phase. The lengths are set to approximately two minutes flight distance, and the widths reflect the route density and the ability of air traffic control to maneuver flights around convective weather in the region traversed during the flight phase. Typically, routes are wide during the climb and transition phases (inside the TRACON), become narrower in the near en route phase where departure and arrival routes are densely packed [NY (ZNY) and northern Washington (ZDC) Air Route Traffic Control Centers (ARTCC)], and widen again in the en route phase where routes are not so densely packed (Cleveland (ZOB) and southern ZDC ARTCCs). Figure 1 illustrates the RAPT departure routes from 2008.

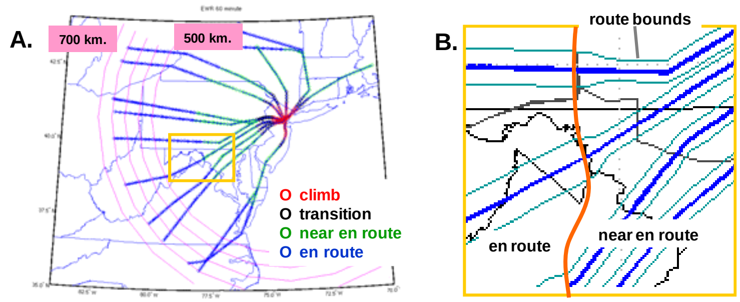


Figure 1. RAPT departure routes (A) and inset (B) showing different route widths in near en route and en route airspace.

Figure 2 illustrates the RAPT algorithm. Vertically integrated liquid (VIL) and echo tops forecasts from the Corridor Integrated Weather System (CIWS) [5] are input to a Weather Avoidance Field (WAF) generator that estimates the probability of pilot deviation at each pixel in the RAPT domain. VIL provides a measure of precipitation intensity and echo tops give an estimate of storm height, both of which are important indicators of the severity of convective weather. The WAF in the Terminal Radar Control (TRACON) region is based on a heuristic convective weather avoidance model (CWAM), in which VIL intensity is the dominant factor. In en route airspace, the WAF is based on an en route CWAM [6], in which echo top height is dominant. Transition between TRACON and en route WAF occurs over a 20 km range (between 80 and 100 km from Newark International airport), in which WAF deviation probabilities are a range-weighted average between TRACON and en route WAF. WAF predictions are generated at five minute intervals, in synchronization with CIWS forecast updates.

The route blockage algorithm [7][8] calculates route blockage at each trajectory point as a function of WAF deviation probabilities inside the blockage box for the point. The route blockage, a number between 0 and 1, is converted to a blockage status - RED (blocked), YELLOW (partial or uncertain blockage), DARK GREEN (insignificant weather encountered) and GREEN (clear) - using thresholds from a two dimensional 'deviation sensitivity field'. The deviation sensitivity field reflects the disruption to air traffic in different regions of the RAPT domain that could result from an unexpected pilot deviation outside the blockage box. It provides a rudimentary estimate of decision risk. Deviation sensitivity is highest (i.e., blockage thresholds are lowest) near highly congested regions of the RAPT domain (e.g., near departure fixes) and lowest in far en route space where airspace is less congested.

The departure status assigned to a particular route and departure time is the worst blockage status encountered along the departure trajectory. The blockage location is the trajectory phase where the worst blockage status first occurs (the 'first worst' blockage encountered). The departure status timeline for a route (the 'RAPT timeline') is the sequence of status triplets [route blockage status, blockage location, echo top height at the blockage location] for each departure time from T0 (the current time) to T0 + 30 minutes, in one minute intervals. RAPT combines departure statuses into 5 minute bins for the operational display.

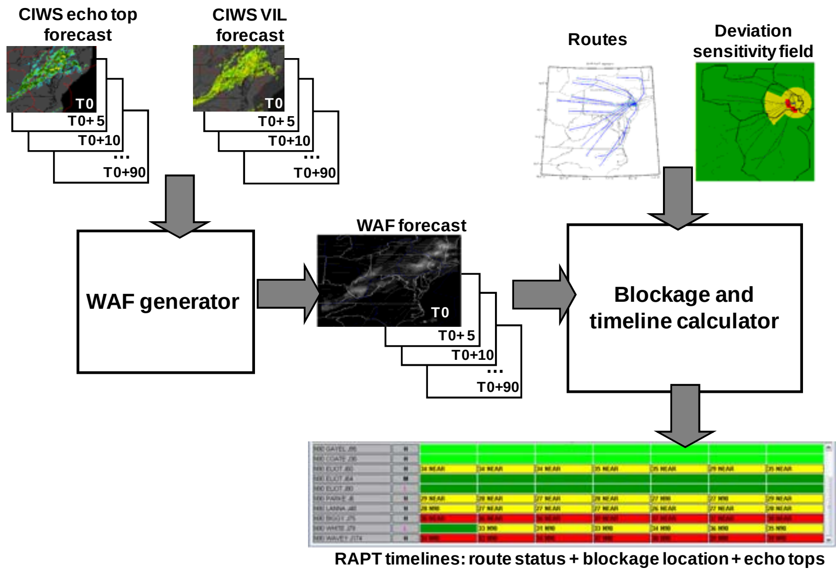


Figure 2. RAPT algorithm overview.

The RAPT user interface (Figure 3) displays RAPT timelines and a weather animation window. Each row of the timeline display corresponds to a departure route. Each column corresponds to a future departure time, starting at the current time and extending out to 30 minutes into the future in five minute intervals. The color of each timeline bin represents the departure status. YELLOW and RED bins have text annotations giving the trajectory phase and the echo top height at the blockage location. The animation window overlays predicted locations of departing aircraft on forecasts of VIL or echo tops. Other CIWS products can also be displayed.

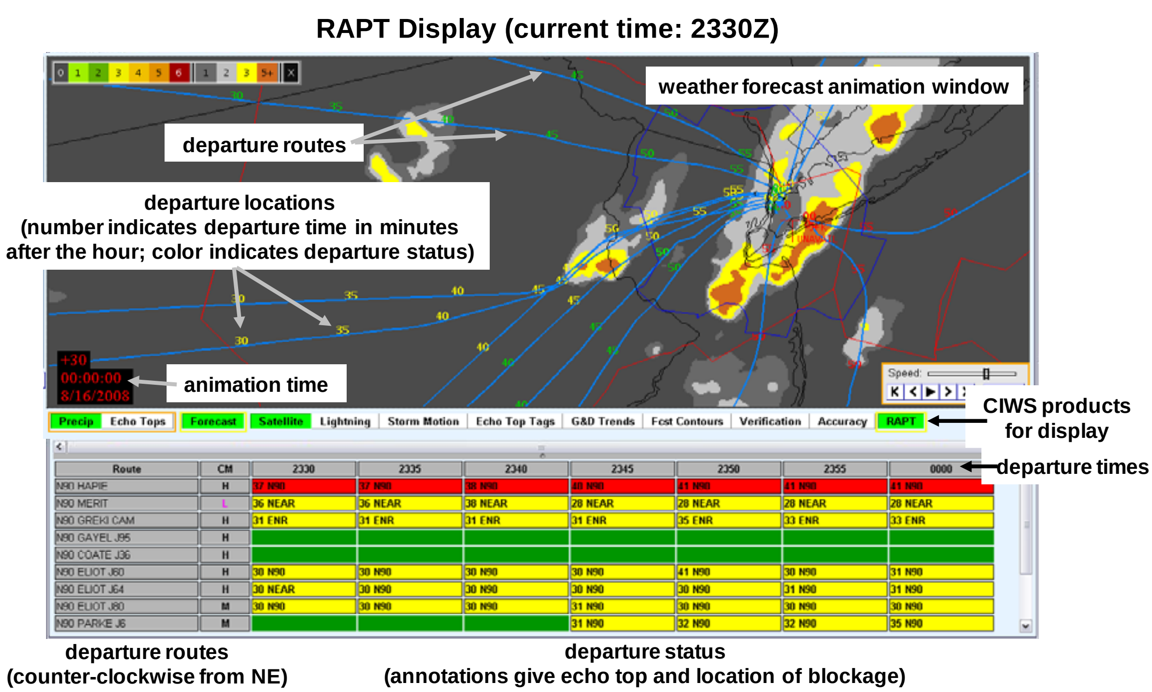


Figure 3. RAPT user interface.

RAPT is distributed to all participants in the departure management process to reduce the effort needed to coordinate departure management decisions, and enable initiation of proactive decisions by any participant in the decision making chain. The RAPT concept of operations can be summarized as follows:

- GREEN means GO! When weather impacts clear and RAPT departure status turns GREEN ('post impact GREEN' or PIG), reopen the route with no weather-related restrictions. For DARK GREEN PIGs, users may elect to reopen with some restrictions until the weather clears completely.
- RED means REROUTE. When departure status turns RED, severely restrict the route and begin planning reroutes for the affected departures.
- YELLOW with improving trend or low echo tops means RELEASE UNDER GUIDANCE. If the route is already open, consider increasing flow. If the route is currently closed, consider reopening with restrictions.
- YELLOW with high echo tops or deteriorating trend means INCREASE RESTRICTIONS. If traffic is flowing, consider imposing restrictions and begin to plan reroutes.

In order to implement the RAPT concept of operations, traffic managers must be confident that RAPT guidance accurately reflects operational reality. RAPT must reliably identify PIGs and REDs. RAPT should identify trends needed to support decision making under YELLOW conditions, particularly when weather is evolving. A comparison of observed traffic to RAPT departure status confirmed the accuracy of the RAPT blockage model in most circumstances. (An analysis of departure traffic statistics for EWR, LGA and JFK from four SWAP days in 2008 also showed good agreement between RAPT route status and departure throughput. Figure 4 shows the distribution of departures per half-hour as a function of RAPT status. The lower departure rates for PIGs relative non-PIG GREENs indicates lost opportunities for departure delay reduction (see Section V below).

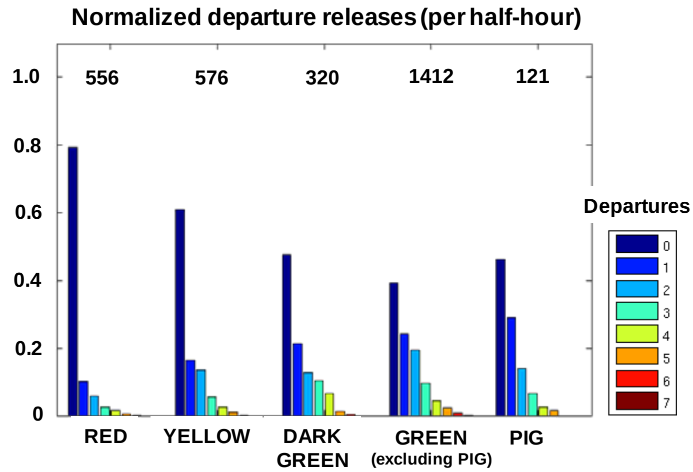


Figure 4. Normalized histogram of departures per half-hour by RAPT status

RAPT guidance was least reliable in two circumstances: presence of small, scattered thunderstorms in far en route airspace, and intense, low-topped thunderstorms in the TRACON. In the former case, RAPT tended to overwarn because it does not sufficiently capture the operational flexibility to implement tactical weather avoidance in less-congested airspace. In the latter, RAPT tended to underwarn due to its overweighting echo tops in the TRACON WAF and overly-wide route widths during the climb phase.

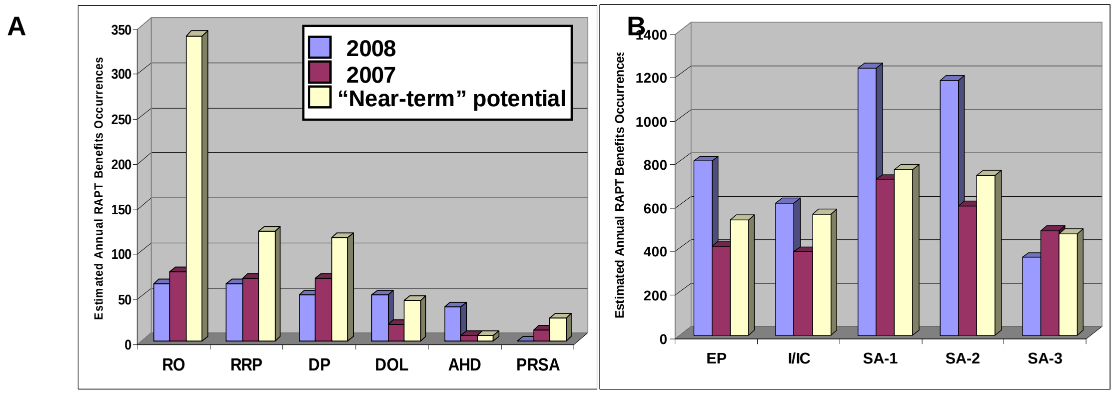
III. EVALUATION OF 2008 RAPT BENEFITS

The 2008 RAPT operational benefits study was modeled after the Corridor Integrated Weather System (CIWS) delay reduction studies conducted in 2003 and 2005 [9][10]. Knowledgeable observers were dispatched to air traffic management facilities during four convective weather events, (39 hours of air traffic operations) to observe the operational uses of RAPT in real-time. Simultaneous observation of several facilities was necessary in order to understand the coordination and collaboration efforts associated with departure flow management.

Observation teams from Massachusetts Institute of Technology Lincoln Laboratory (MIT LL) and the FAA Aviation Weather Office were dispatched to the four airport control towers [Newark (EWR), LaGuardia (LGA), John F. Kennedy (JFK), and Teterboro (TEB)], the NY TRACON facility, several ARTCCs [ZNY, ZDC, ZOB and Boston (ZBW)], the Air Traffic Control System Command Center (ATCSCC), and the airline operations centers for Continental (at EWR). The observations of RAPT-derived departure management decisions at each facility were used to determine ways that RAPT was used to improve operational decisions, and to estimate the frequency and magnitude of delay savings attributable to RAPT use [3].

RAPT benefits were partitioned into 11 categories. The benefits categories and annual frequency of observed occurrences in 2008, 2007, and near-term potential estimates

[3], is presented in Figure 5. Annual RAPT delay reduction benefits for the four primary categories (RO, RRP, DP, and DOL) were determined by multiplying the annual RAPT frequency of use (Figure 6A) with the mean/median delay savings per RAPT use for each of these individual categories, as done in Robinson et al. [3]. The annual estimate of RAPT benefits in 2008 totaled 2,600 hours of delay saved, an increase of 10% compared to 2007.



RO	**Route Reopenings; Eased Restrictions**
RRP	**More Timely Reroute Planning/Implementation**
DP	**Directing Pathfinders**
DOL	**Departure Routes Open Longer**
AHD	**Proactively Resuming Arrival Flows Decreased Airborne Holding**
PRSA	**Proactive Runway Sequencing Assistance**

EP	**Enhanced Productivity; Reduced Workload**
I/IC	**Enhanced Inter/Intra-Facility Coordination**
SA-1	**Enhanced Common Situational Awareness**
SA-2	**Improved Awareness of Evolving Impacts**
SA-3	**Decision/Information Confirmation/Evaluation**

Figure 5. RAPT benefits categories, extrapolated annual frequency of occurrence for 2008, 2007, and estimated "near-term" (2008-2010) potential

IV. DECISION MAKING ENVIRONMENT

The issues most relevant to RAPT use, and the observed limitations in expected delay reduction in 2008 include:

1. Route status uncertainty
2. ZNY TMU vs. Area route-use decisions
3. Arrival traffic affecting NY departure operations
4. Pathfinder procedures for reopening closed routes

A. Route Status Uncertainty

Operational traffic managers across all RAPT-equipped facilities in the Northeast were collectively uncertain about the availability (open, closed, or restricted) of specific departure routes or fixes an estimated **960** times over the 2008 SWAP season. At times, confusion and workload associated with trying to track and correct airspace status information became a SWAP impact more significant than convective weather or volume congestion. RAPT cannot be used to reopen closed routes if traffic managers are unaware that the route is closed.

B. ZNY TMU vs. Area Route-Use Decisions

In ZNY, Area Supervisors and controllers are key SWAP decision-makers who often coordinate on tactical ATM decisions. Area Supervisors have significant influence over the final decision regarding NY departure route use, often making the final decision on whether a specific departure route or fix will be used.

Field observations suggest that the ZNY TMU and Areas have different interpretations of the risks associated with managing departure traffic during SWAP events. Area Supervisors managing en route air traffic controllers are particularly sensitive to the risk of deviating traffic since the resulting increase in air traffic control (ATC) complexity increases the possibility for operational errors by controllers. Conversely, TMU traffic managers, removed from direct controller workload concerns, are responsible for optimizing the use of ZNY airspace to minimize delay.

In 2008, the ZNY TMU used RAPT often to identify improving departure route conditions and opportunities to proactively reopen closed departure routes. RAPT use by ZNY Area Supervisors increased in 2008 but was still very low compared to the TMU. Areas were often not aware of RAPT-derived opportunities evident to the TMU. The inability of the TMU and Areas to collaborate on plans to proactively reopen blocked departure routes resulted in several missed opportunities to increase departure capacity. When a ZNY traffic manager was asked how often a TMU decision to reopen a route is halted by the Areas, the response was "more often than not".

C. Arrival Traffic Affecting NY Departure Operations

During both the 2007 and 2008 storm seasons, airborne arrival demand often dictated NY departure route use. This was especially true when arrival traffic deviated into departure airspace to avoid convective weather. In these instances, arrival flows were given priority, and the impacted departure routes were either restricted or closed. A preliminary assessment suggests that departure route restrictions related to arrival demand occurred on approximately *80% of NY SWAP days* in 2007 and 2008.

In these scenarios, the departure route would be closed, even though RAPT showed it as unblocked, which eroded user confidence in RAPT. Continued training and real-time RAPT support will improve user understanding of these scenarios and associated RAPT interpretations. Preliminary research is underway to expand the RAPT concept of operations to improve RAPT guidance in these circumstances.

D. Pathfinder Procedures for Reopening Closed Routes

The common approach for reopening a departure route closed due to convective weather is to probe the route with a pathfinder. Unfortunately, the pathfinder process requires a considerable amount of time and coordination, resulting in delayed reopening of routes and missed opportunities to increase departure capacity. Identifying a pathfinder often took upwards of 30 minutes, and on occasion, a pathfinder was never identified (and the departure route remained closed). Pathfinders were often buried in airport taxi queues, resulting in additional delays of 20 minutes or more before the pathfinder could depart. When a pathfinder finally did depart, traffic managers had to wait for the pilot to report back on weather conditions before the route could be reopened. The delay between the decision to release a pathfinder and eventual route reopening often exceeded 60 minutes.

The RAPT concept of operations replaces pathfinders with proactive route reopening based on RAPT route status timelines. To support this procedural transition, RAPT enhancements are planned for 2009 to ensure that the GREEN status is highly reliable, and that opportunities to reopen closed routes are clearly identified. RAPT training will focus on identifying low-risk opportunities to use RAPT proactively and reduce reliance on pathfinders.

V. RAPT MISSED OPPORTUNITIES

Field observations in 2008, coupled with post-event analyses, revealed numerous instances where traffic managers failed to take advantage of RAPT guidance that, if acted upon, would have reduced departure delay. A preliminary examination suggests that between 4 and 8 opportunities to use RAPT to increase departure throughput were missed per SWAP event in 2008.

The causes of these missed opportunities noted by the field observers include:

1. User was unaware of potential opportunity
2. Coordination workload limited realized benefits
3. Route status uncertainty (was the route open or closed)
4. Risk management differences between decision makers resulting in decisions not being executed
5. Impacts of arrival traffic on departure operations
6. Inefficient pathfinder process

The most commonly observed RAPT missed opportunity was not taking advantage of an accurate RAPT forecast of unimpeded route conditions in a timely fashion. Such missed opportunities occurred frequently, even when RAPT consistently (and accurately) predicted GREEN. These "all clear" route blockage forecasts, referred to in Section II as "Post-Impact Green" (PIG) opportunities, are considered the most reliable and operationally usable type of RAPT guidance.

An analysis was performed to quantify the frequency and duration of RAPT "Post-Impact Green" missed opportunities. A RAPT PIG event was defined as one for which the entire RAPT timeline for a specific route (all 6 bins in the 30 min forecast period) was GREEN for three hours or more. This conservative time window was chosen to ensure that a weather impact had ended and an opportunity to reopen a closed departure route definitely existed.

Within this window, a RAPT PIG missed opportunity was identified if the first departing flight on the route in question was released 15 minutes or more after RAPT first correctly identified the PIG. For each PIG missed opportunity, the total time between the first RAPT "ALL GREEN" prediction and the first departing flight on that route was noted. An example of a RAPT PIG missed opportunity is shown in Figure 6. At 2340 UTC, the RBV – J6 departure route is all DARK GREEN (bottom row of the RAPT timeline display in Figure 6A). Starting at 2340, departures can readily fly over echo tops predicted to be less than 30 kft (white circle on RAPT weather display). The traffic plot (inset), illustrating 30-minute cumulative departures (blue) and arrivals (white), shows no departures on RBV – J6. Figure 6B shows the sequence of RAPT timelines for RBV – J6 for the full day (top half of the figure) and the observed departure counts per 5-minute bin (bottom half). The first departure after the PIG was released at 0105 UTC, an 85 minute missed-opportunity.

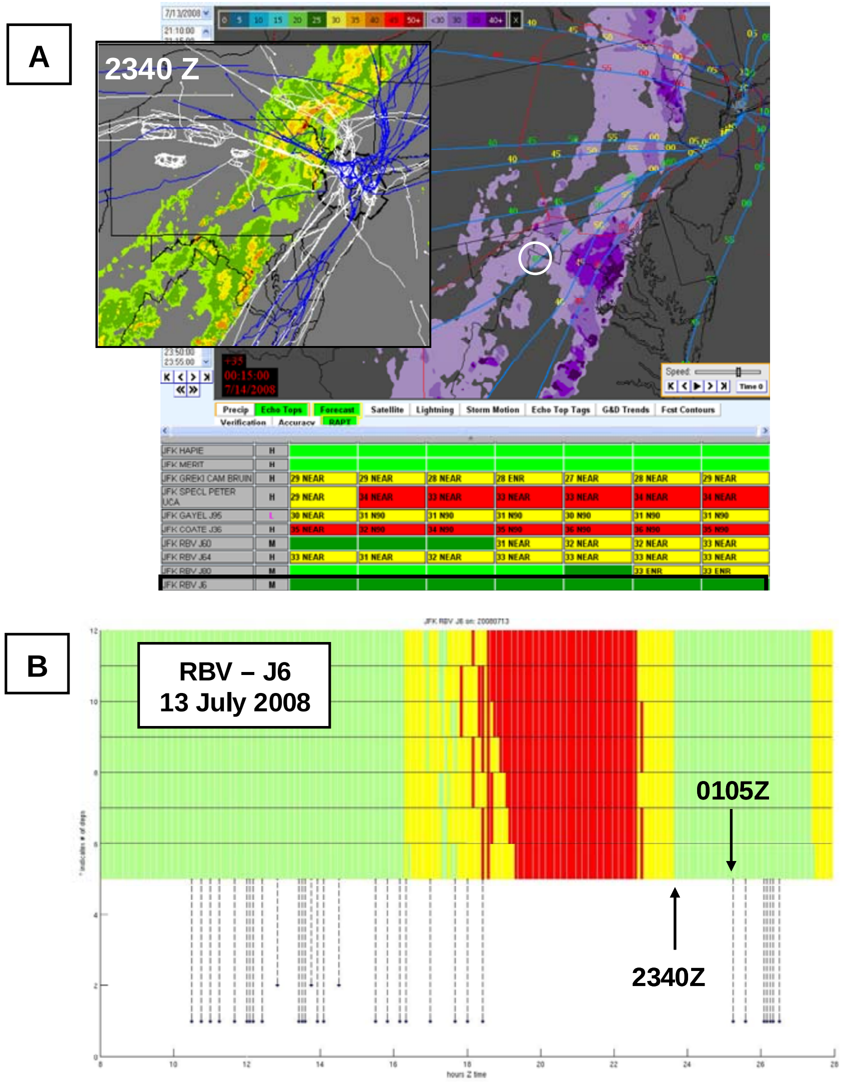


Figure 6. Illustration of a RAPT PIG missed opportunity.

In an attempt to ensure the results were conservative, all potential RAPT PIG missed opportunities were cross-checked against air traffic management logs, high-resolution weather/traffic movies, and fair-weather air traffic demand statistics for confirmation. In addition, a PIG missed opportunity was discounted if the validity of the RAPT "ALL GREEN" route blockage forecast was in doubt

During 11 SWAP case days in 2008, 113 RAPT PIG events occurred on the seven departure route groupings analyzed. A missed opportunity to reopen a closed departure route was identified in 40 of them (35%) (Figure 7). These results show that the frequency of PIG missed opportunities was highly variable depending on which group of departure routes was considered. Such operational tendencies – which were not clearly apparent to users – are valuable information that can be presented to air traffic managers during operational reviews and training. Identification of such specific tendencies is helpful both to focus RAPT development, and to identify opportunities to accelerate changes in operational procedures.

The frequency of RAPT PIGs and missed opportunities per SWAP day is presented in Figure 8. On average, approximately 10 PIGs occurred per SWAP day, of which almost 4 had missed opportunities. The average duration – or the delayed departure route reopening – of each RAPT PIG missed opportunity ranged from approximately 30 – 60 min (Figure 9A). The average duration of missed opportunities was similar for all departure route groupings. However, when accounting for the relative frequency per route of PIG missed opportunities, the average total delayed route reopening per SWAP day was significantly higher for RBV – J60/J64 departures (Figure 9B).

The total delay per SWAP day associated with RAPT PIG missed opportunities in 2008 was 2.6 hours. If traffic managers used RAPT to eliminate all PIG missed opportunities, RAPT RO (route opening) primary delay reduction (including reduced queuing delays) would increase from 2.7 hours to 25.2 hours per SWAP day. The resulting estimated annual RO delay reduction benefits for 2008 would have increased from 225 hours to 1,500 hours.

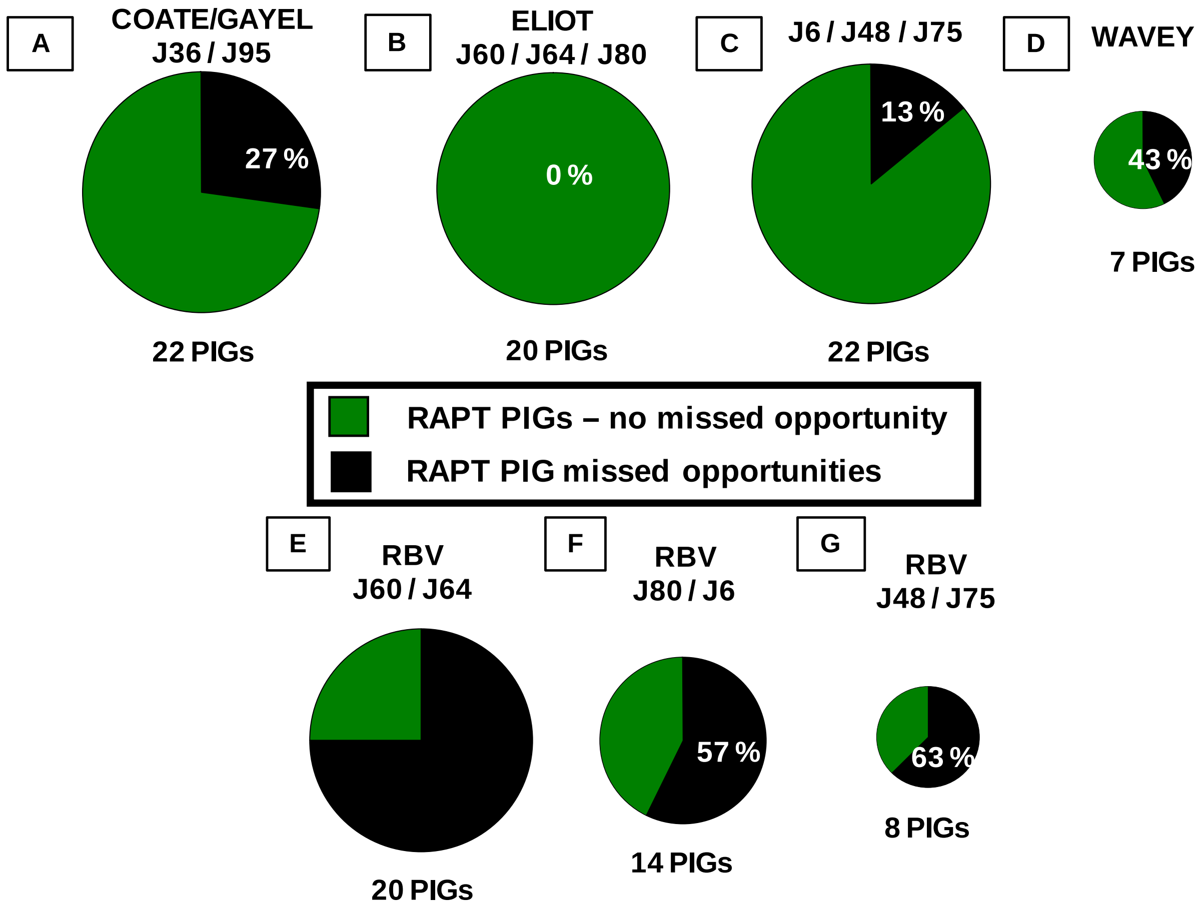


Figure 7. Frequency of RAPT PIG events and PIG missed opportunities per individual departure route groupings for all 11 SWAP case days. The size of each pie chart represents the relative frequency of total post-impact events per route.

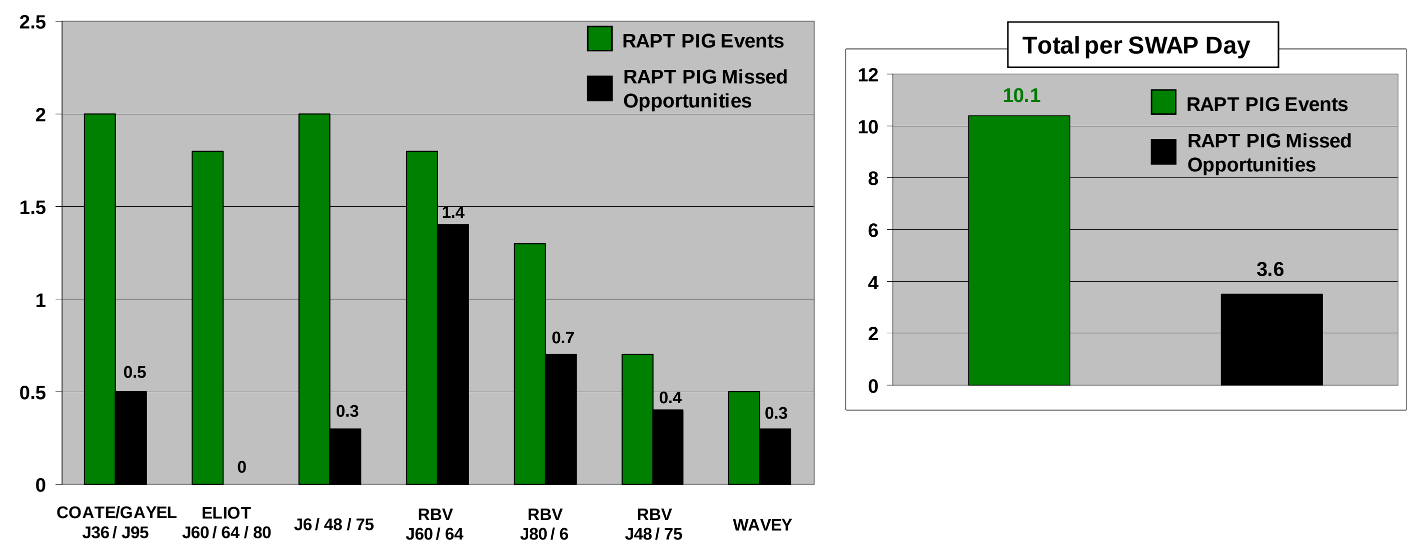


Figure 8. Frequency of RAPT PIG missed opportunities per SWAP day for (A) individual departure route groupings and (B) all departure routes considered in this study.

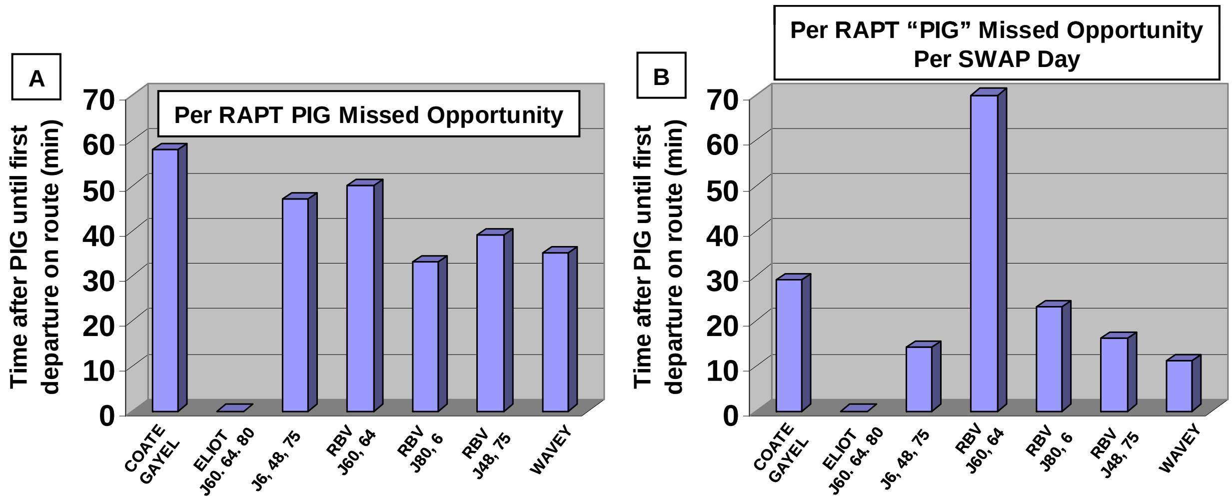


Figure 9. Average duration of RAPT PIG missed opportunities (A) and per SWAP day (B). In Fig. 9B, the large spike for the RBV – J60/J64 routes is the result of the high frequency of missed opportunities for these routes (see Figure 9A).

VI. Planned Enhancements

Post-event analysis of RAPT performance has demonstrated that RAPT guidance correlates well with operational reality. RAPT predictions of the onset and clearing of weather impacts [REDs, GREENs and Post-impact GREENS (PIGs)] provide useful information to air traffic managers that can support more proactive and consistent decision making. However, discussions with operational users suggest that RAPT usage would improve if RAPT provided explicit information about weather impact trends (particularly during YELLOW periods), real time RAPT forecast scores, and more clarity in the operational display.

Figure 10 illustrates these enhancements on the planned 2009 user interface. Impact trends for each departure route, calculated over the previous half-hour, are identified as 'improving' (upward arrow), 'deteriorating' (downward arrow) or 'stable' (right-pointing arrow). A 'PIG timer' gives the time, in minutes, since weather impacts cleared previously blocked routes. Users can click on the trend arrows to see detailed trend information. The trend information includes the previous 30 minute history of RAPT status and echo top heights, and a text message reminding the user of the action suggested by the concept of operations under the current conditions. An improved route timeline display filter enables users to display only the departure routes that are of interest. RAPT forecast scores, based on the route blockage scoring algorithm presented in [8], are calculated for each of the regions that include the major departure routes in the RAPT domain. The score accounts for the spatial scale and orientation of the routes and their relationship to the weather.

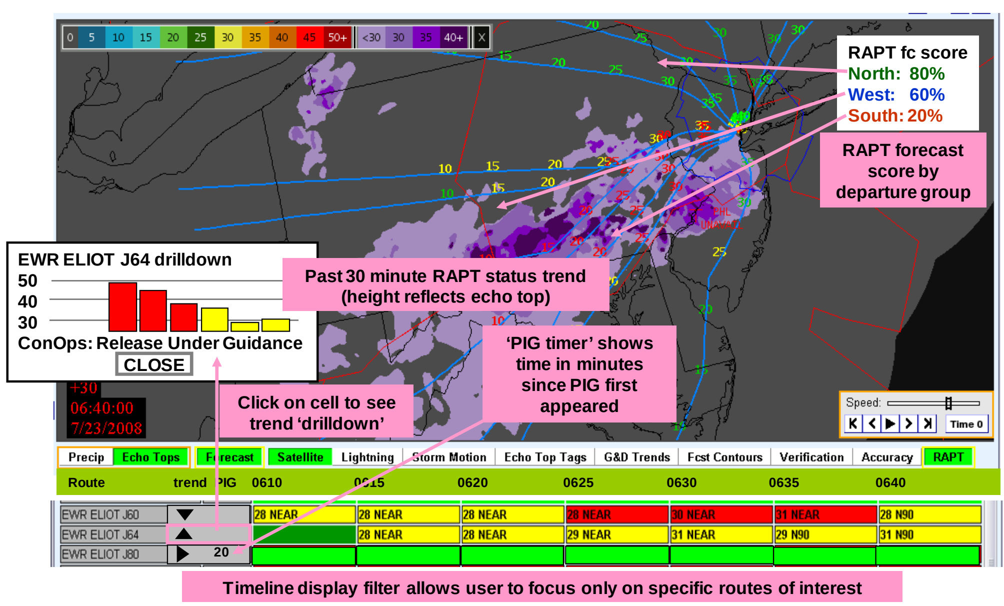


Figure 10. Proposed RAPT user interface for 2009.

VII. CONCLUSIONS

The Route Availability Planning Tool (RAPT) is a prototype automated decision support tool that has been deployed in the New York area to help air traffic managers make departure decisions in convective weather SWAP. It predicts the impacts of convective weather on departure routes, providing a departure status (RED is blocked, GREEN is clear, DARK GREEN is insignificant impact and YELLOW is partially blocked or uncertain) for future departure times (up to 30 minutes) on specific departure routes. The RAPT concept of operations is to support proactive departure management decision making: plan reroutes for departure routes that are turning RED, reopen closed departure routes that are turning GREEN after weather impacts, and use trend information to support planning when impacts are YELLOW.

An operational evaluation of RAPT performance was carried out over the summer of 2008. Observers recorded detailed, simultaneous observations from several FAA facilities and one airline operations center involved in New York departure management. Observations were correlated with post-event analysis of air traffic data. The evaluation focused on the ability of RAPT to support its concept of operations, estimation of delay savings achieved as a result of RAPT use, and identification of opportunities to improve RAPT effectiveness.

During the evaluation, RAPT guidance frequently correlated well with observed departure traffic, suggesting that RAPT route status is sufficiently accurate to support the concept of operations. Departure delay savings due to RAPT use increased by 10% over 2007, to approximately 2600 hours. Several operational factors that reduced the realization of RAPT benefits were observed. Some factors, such as the uncertainty of route status or the impacts of arrivals deviating into departure airspace, were beyond the currentscope of RAPT. However, several delay-reducing opportunities were lost because air traffic managers failed to identify and act to reopen closed departure routes after weather impacts cleared and RAPT status turned GREEN. Post-event analysis of these Post-impact GREENs (PIGs) found that departure routes remained closed more than 15 minutes after weather impacts cleared in 40 of 113 (35%) of PIGs observed on 11 SWAP days in 2008. The average time to first departure ranged between 30 and 60 minutes for different departure routes. Eliminating these missed opportunities would have resulted in an estimated sixfold increase in departure delay reduction derived from RAPT use, from 225 to 1500 hours.

Several enhancements will be deployed in 2009 to improve the effectiveness of RAPT. Explicit identification of PIGs and their duration will focus attention on specific opportunities to reopen previously blocked routes. Weather impact trends will provide additional guidance to help air traffic managers plan initiatives when RAPT guidance is uncertain. Improved RAPT timeline display filtering will allow users to focus only on the specific routes of interest at any given time. Finally, an explicit RAPT forecast score will enable traffic managers to evaluate the quality of RAPT guidance and manage risks associated with RAPT-based decisions.

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AUTHOR BIOGRAPHY

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