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Making Departure Management Weather Impact Models Airspace-Adaptable: Adapting the New York Route Availability Planning Tool (RAPT) to Chicago Departure Airspace

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16. Abstract

The Route Availability Planning Tool (RAPT) operational prototype was deployed to Chicago in the summer of 2010, the first RAPT deployment outside of the New York departure airspace for which it was originally developed. The goal of the deployment was to evaluate the adaptability of RAPT's airspace definition, departure management and weather impact models to different terminal areas throughout the National Airspace System (NAS). This report presents the results of a summer-long evaluation of the Chicago RAPT operational prototype, in which the performance of RAPT algorithms and the effectiveness of the RAPT Concept of Operations were assessed. The evaluation included observations made by researchers simultaneously stationed at O'Hare terminal (ORD), the Chicago TRACON (C90), and the Chicago Air Route Traffic Control Center (ZAU) during several days of convective weather impact and post-event analysis of air traffic data from the Enhanced Traffic Management System (ETMS) and RAPT weather impact predictions and departure management guidance. The study found that significant departure delay reduction could be achieved through the use of RAPT in Chicago, and that RAPT effectiveness in 'typical' corner post airspaces like Chicago could be further increased with some modifications to the Concept of Operations, user training, and site adaptation.

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1. INTRODUCTION

The Route Availability Planning Tool (RAPT) operational prototype was deployed to Chicago in the summer of 2010, the first RAPT deployment outside of the New York departure airspace for which it was originally developed. In addition to the routine aspects of site adaptation (e.g., defining site-specific algorithm inputs such as departure route trajectories), the deployment offered an opportunity to test several more fundamental elements of RAPT: weather impact estimation algorithms, models for departure operations, and concept of operations. Since Chicago airspace, departure management practices, and prevailing convective weather patterns differ markedly from those in New York, the Chicago RAPT deployment provided an opportunity to evaluate the adaptability of RAPT's departure management and weather impact models to different terminal areas throughout the NAS.

This report presents the results of a summer-long evaluation of the Chicago RAPT operational prototype. The evaluation included observations made by researchers simultaneously stationed at O'Hare terminal (ORD), the Chicago TRACON (C90), and the Chicago Air Route Traffic Control Center (ZAU) during several days of convective weather impact. Air traffic data from the Enhanced Traffic Management System (ETMS) were analyzed and compared to RAPT blockage status forecasts to determine the suitability of RAPT guidance to Chicago departure operations. Forecast RAPT route status was compared to 'true' RAPT route status (blockage based on actual, not forecast weather) to determine the accuracy of the RAPT blockage forecast. RAPT performance in Chicago was analyzed to identify issues in the weather forecast inputs, the RAPT blockage and operational models, and the concept of operations that must be addressed in order to ensure that RAPT can provide consistent and effective departure management guidance in a wide variety of terminal areas. Finally, a summary of observed operational RAPT use is presented.

The evaluation is presented in five sections: description of the evaluation methodology, description of departure management in Chicago, evaluation of the performance of RAPT algorithms, discussion of the adaptation of the RAPT concept of operations, and observed operational use of RAPT during the evaluation, and conclusions and future work. Where applicable, comparisons are made to New York operations and RAPT use.

1.1 RAPT EVALUATION METHODOLOGY

The RAPT evaluation included field observations of traffic management operations during SWAP events and qualitative post-event data analysis. Observers were placed at ORD tower, C90 TRACON, and ZAU TMU for three different SWAP events (Table 1). The events included a wide range of weather impact severity, duration, and locations (Figure 1).

TABLE 1
Chicago RAPT Field Evaluation Days

Date	Start (Z)	Finish (Z)	Facilities
06 July	1100	0100	C90, ZAU
07 July	1130	0100	C90, ZAU
28 July	1400	0100	C90, ZAU
01 Sept	1100	2300	ORD, C90, ZAU
02 Sept	1130	2300 (1600 in ZAU)	ORD, C90, ZAU

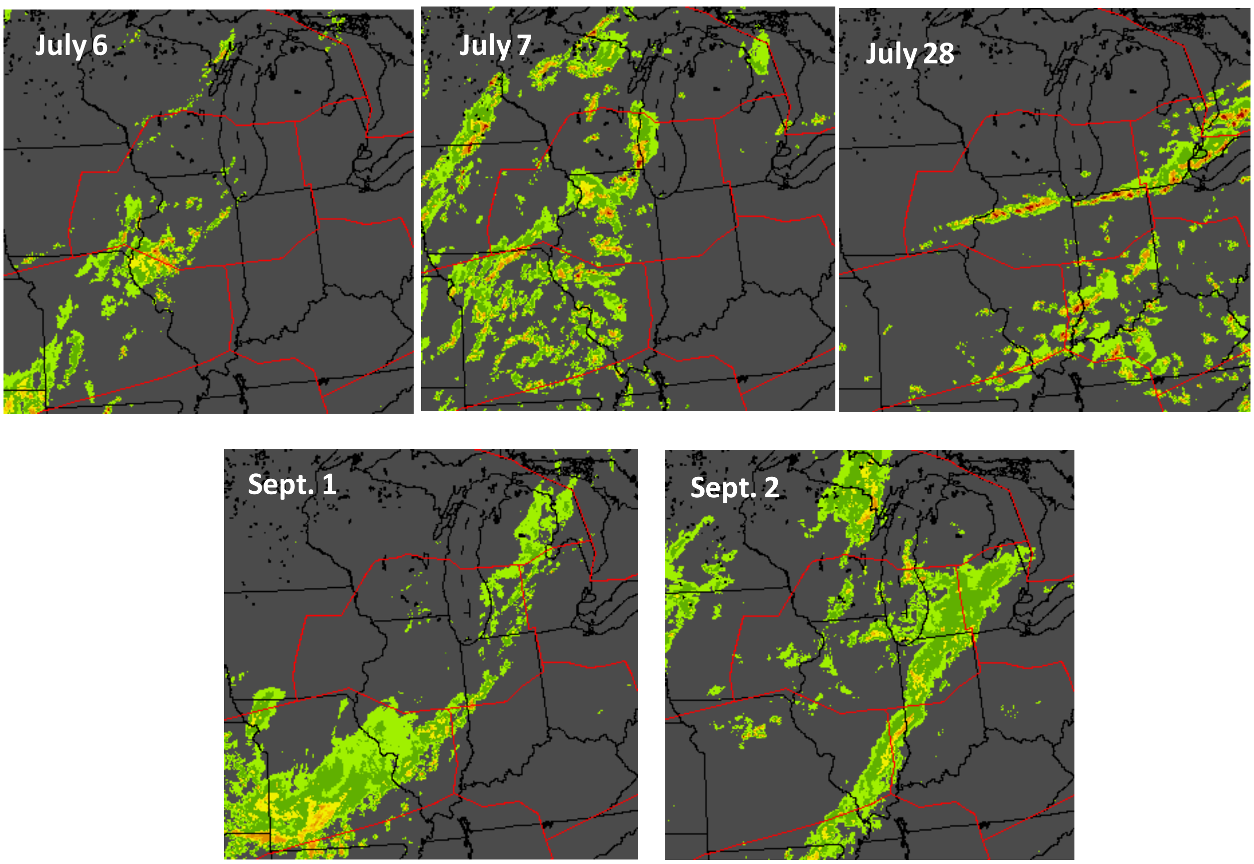


Figure 1. RAPT field evaluation case days.

1.2 DEPARTURE MANAGEMENT DURING CONVECTIVE WEATHER SEVERE WEATHER AVOIDANCE PROGRAMS (SWAP)

The Chicago terminal area is cornerpost airspace, and operations are dominated by O'Hare International Airport (ORD) traffic. Key departure fixes and routes—referred to as 'tracks' in Chicago operations—are illustrated in Figure 2. Departure demand is greatest out the east and south gates, and departure demand peaks in the morning and late afternoon/early evening. Figure 3 illustrates typical, fair weather terminal area traffic flows and contrasts them to operations in New York.

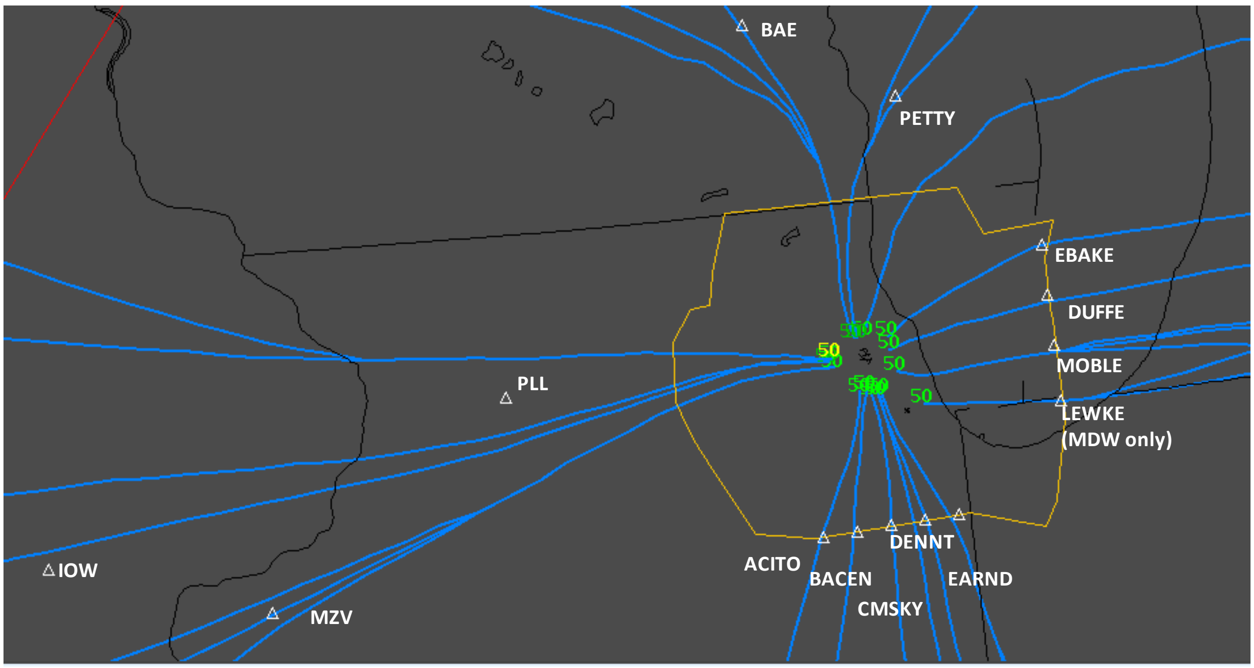


Figure 2. Major Chicago tracks and fixes.

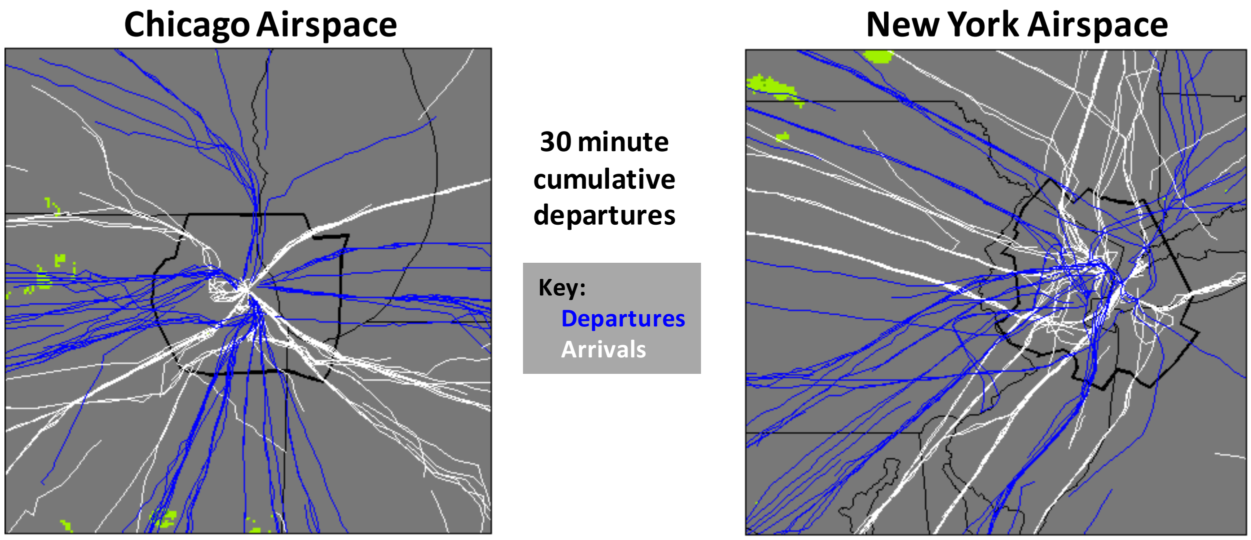


Figure 3. Fair weather traffic in Chicago and New York.

Most departure management decisions during SWAP are made at the en route center (ZAU). The ZAU traffic management unit (TMU) is staffed during SWAP with a Supervisory Traffic Management Controller (STMC), and several traffic management controllers (TMC) (departure coordinator, SWAP coordinator, arrival coordinator, and two en route coordinator positions). All positions are in close physical proximity, and traffic managers can communicate and move around easily. The SWAP coordinator handles tactical problems, taking calls from other facilities and rerouting them to the TMU position who can handle the query. The SWAP coordinator and departure coordinator, with input from the area supervisors, collaborate on route status, restrictions, and reroute strategy decisions, keeping the ORD/C90/ZAU IDS4 display up to date with local restrictions, ordered by gate and airport (ORD/satellites). The arrival coordinator handles incoming (mostly ORD) traffic. En route coordinators collaborate constantly with the arrival coordinator to handle over-flights, and manage the most pressing cross-facility issue: coordination with Detroit airport (DTW). ZAU also does adjacent center Traffic Management Advisor (TMA) metering for DTW, but this was not a factor during the RAPT observations. The STMC generally concentrates on more strategic planning, and is not heavily involved in tactical departure management. Confusion about the status of routes is relatively rare (compared to New York), since the SWAP coordinators consistently maintain the IDS4 status display.

In response to convective weather impacts, traffic managers in ZAU may apply a combination of three different strategies: route closure, mile-in-trail (MIT) restrictions on individual routes, and 'gate management,' where several departure tracks out a particular gate may be merged into one or two departure streams that are vectored around weather and then split back onto the original filed routes. For instance, departures through the five south gate fixes may be merged into two streams, each with 10 MIT restrictions (south gate '2 × 10'), to avoid convective weather impacts, and then split back onto their normal routing after the impacts have been passed (Figure 4). Individual route closures also occur, particularly when the impacted route is directly adjacent to an arrival stream and traffic managers are concerned that departures will deviate into arrival airspace to avoid weather, or when weather impacts are relatively limited in scope (Figure 5). Gate management and traffic merging is more common in Chicago than in New York, because it is better suited to the cornerpost structure. As a result of the use of gate management strategies, Chicago departure gates are rarely completely closed. It is almost always possible to maintain a single departure stream, albeit with severe restrictions—in effect, the departure gate is constantly probed by pathfinders. By comparison, in New York's more complex, highly constrained airspace, individual route management strategies (closure, restriction, and/or vectoring to avoid weather) are more common. Table 2 summarizes key similarities and differences in departure management in Chicago and New York.

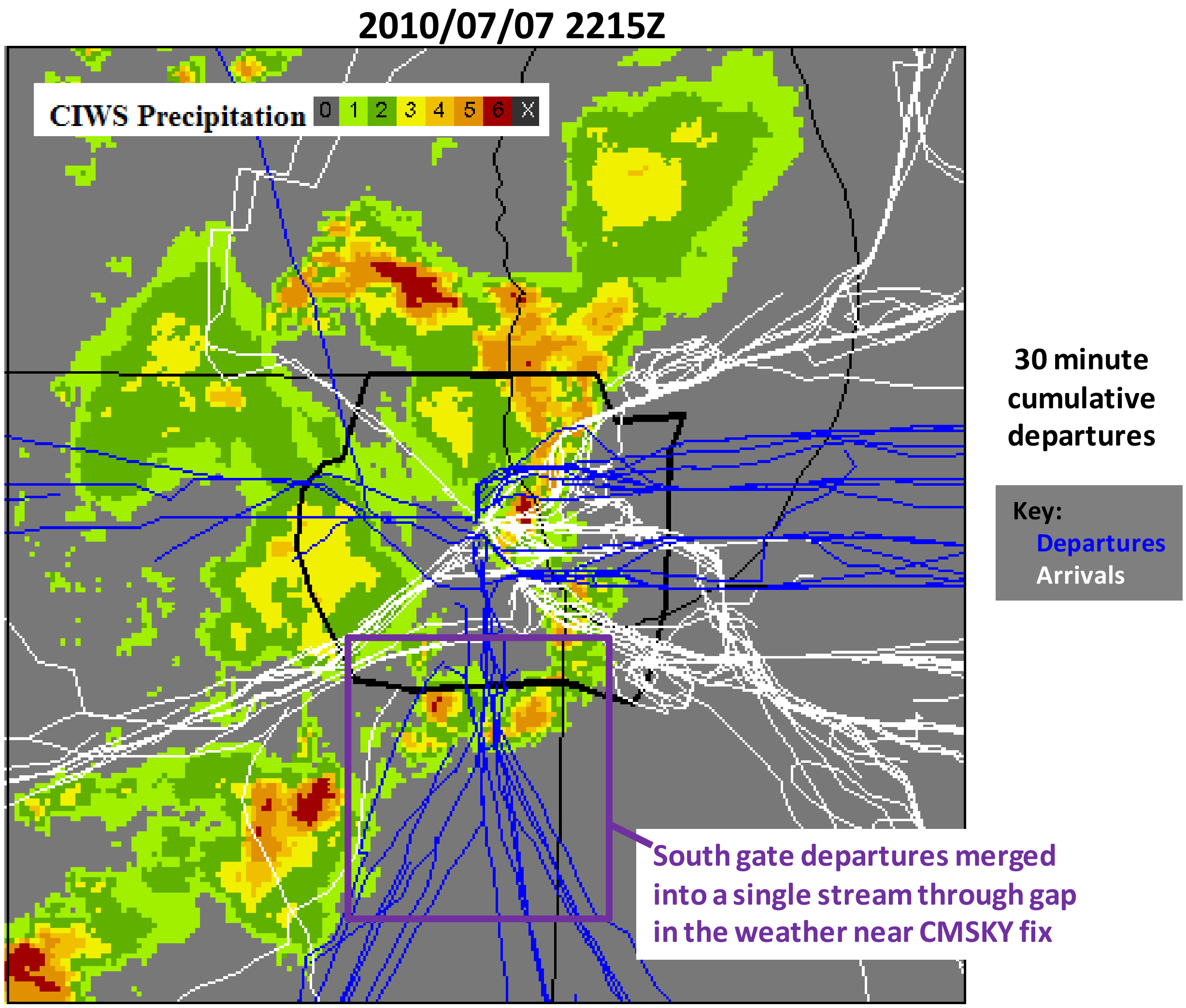


Figure 4. 'Gate management' departure merging and splitting.

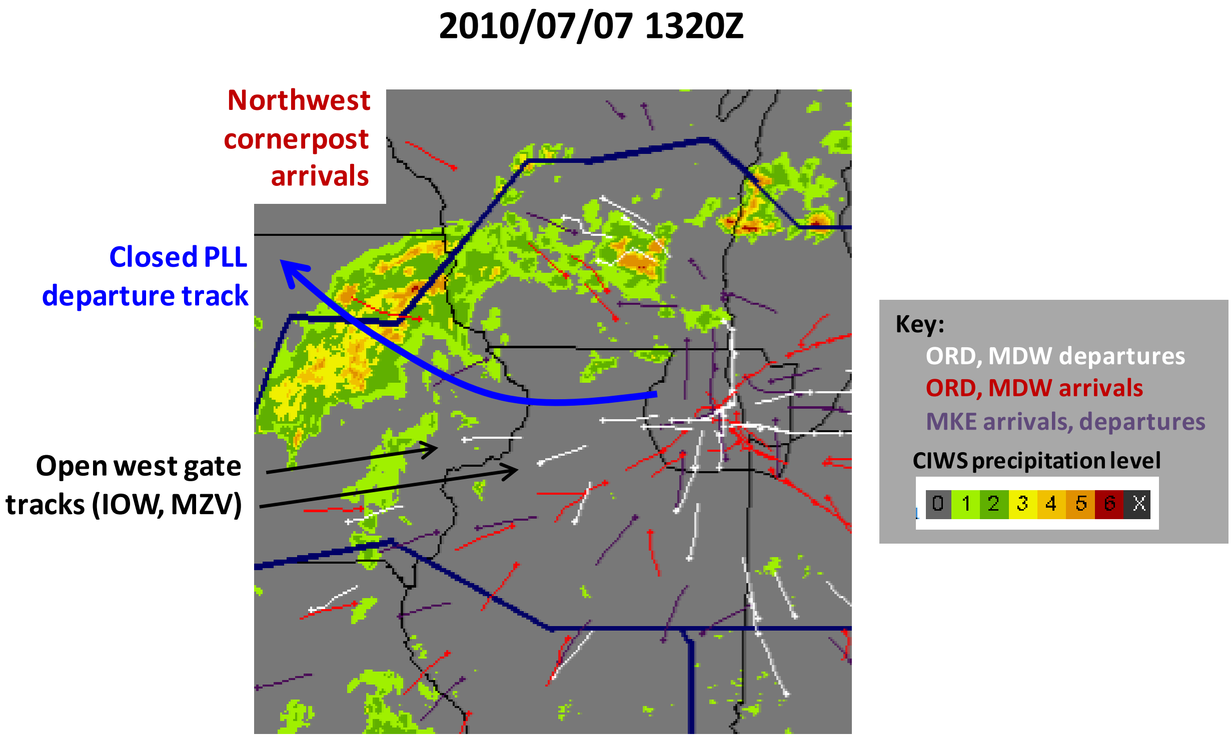


Figure 5. Managing individual route impacts near arrival airspace.

TABLE 2
Comparison of New York and Chicago Departure Traffic Management

	New York	Chicago
Total operations (departures + arrivals) from major airports (>10% of operations) 10/2009–09/2010 **Source: FAA OPSNET**	1.5×10^6	1.3×10^6
Major airports, % of operations (*denotes RAPT airport)	EWR*(27%), JFK*(27%), LGA*(24%), HPN(11%), TEB*(10%)	ORD*(67%), MDW*(19%), MKE(15%)
Airspace structure	Interleaved departure, arrival airspace; horizontally separated in ZNY, vertically separated in N90	Standard cornerpost
Locus of departure management decision making	ZNY TMU, areas (N90 when weather impacts are within N90)	ZAU TMU, areas (C90 when weather impacts are within C90)
Common weather mitigation strategies	Individual route closure, opening, restriction; vectoring/route merging to avoid weather	Individual route closure, opening, restriction; vectoring/route merging to avoid weather, 'gate management'
Reroute procedures	ZNY TMU plans reroute strategy, ZNY PIT implements (limited rerouting performed in N90)	ZAU TMU plans reroute strategy, implements all satellite reroutes and ORD non-SWAP/CDR reroutes, delegates SWAP/CDR reroutes to ORD tower

SWAP reroutes are rarely applied to move a flight from its filed route onto another departure track within a gate; they are generally used only when a departure gate is completely closed or severely restricted, and flights must be rerouted out a different departure gate. Several TMU personnel suggested that early (1–2 hours in advance) airline filing of proactive reroutes to avoid weather impacts is often counterproductive. The weather and ATC response is very dynamic, and more often than not, premature proactive rerouting results in additional reroutes to undo the original reroute—only now, with aircraft that may have additional fuel unnecessarily loaded.

When reroutes are required, ZAU will often delegate the implementation of CDR reroutes for flights departing from ORD to ORD tower. Non-CDR reroutes of ORD departures and reroutes of departures from satellite airports are implemented by the departure coordinator in the ZAU TMU. One STMC requested the inclusion of commonly used SWAP reroutes in RAPT, and suggested that the choice and implementation of SWAP routes would best be planned with input from the TMCs who staff the SWAP and departure coordinator positions.

The TRACON and towers have relatively limited roles in SWAP departure management. TRACON may impose restrictions on ORD and/or MDW departures when weather impacts are inside the TRACON; otherwise, C90 'does what is necessary' to implement the current plan. ORD implements CDR reroutes when they are in effect. Both ORD and MDW may also push ZAU for reductions in departure restrictions when long departure queues threaten to gridlock surface operations.

1.3 RAPT ALGORITHM PERFORMANCE

Overall, RAPT performance was very good. REDs and GREENs on individual routes were generally in agreement with observed operations (Figure 6). The EBAKE departure track was closed by thunderstorms with level 4–5 precipitation and echo tops up to 45 kft; RAPT correctly forecast the impacts (YELLOW transitioning to RED status with high echo tops. EBAKE traffic was merged with departure traffic on the adjacent DUFFE track, where RAPT impacts were relatively light (DARK GREEN transitioning to YELLOW). RAPT YELLOWs routes were usually open, with some restriction; Figure 7 illustrates an instance where operations continue with little or no restrictions through moderate impacts (a combination of DARK GREEN and YELLOW with echo tops below 30 kft). RAPT typically matched operations when merging strategies were employed with multiple YELLOW/RED, all YELLOW, or YELLOW/GREEN route timeline combinations (Figure 8). In such circumstances, adjacent departure tracks often showed patterns of higher impacts (YELLOW/RED) next to lower impacts (GREEN/YELLOW), or YELLOW impacts spread across several adjacent tracks. This RAPT 'signal' could often be correlated to operational decisions to merge traffic flows on the adjacent tracks, directed along the less impacted track to avoid the weather before splitting the traffic back onto the originally filed route.

The most significant RAPT status problem observed was over-warning when weather impacts were inside the TRACON, particularly as weather passed over the airport (Figure 9). The problem appears to be more common in Chicago than in New York, where storms that impact the TRACON often dissipate quickly as they move toward the nearby ocean. TRACON impacts in Chicago can linger for a long time as the storm moves from one departure gate to the next (Figure 10), and, as a result, RAPT errors in the Chicago TRACON may be more consequential than in New York. The observed over-warning may be due to a combination of factors: a tendency of the CIWS echo top forecast to decay echo tops too slowly, errors in the convective weather avoidance model (CWAM) for departure airspace near the airport, and/or route widths in the TRACON that do not reflect operations accurately, particularly when the gate management tactics described in the previous section are in use. Nonetheless, on several occasions when RAPT showed gate impacts that were 'dead RED' (all tracks departing out the gate were RED), the gate was either completely closed or severely restricted (a single departure stream with at least 10 MIT—a tactic described operationally as '1 × 10') (Figure 11). TRACON over-warning may be partially addressed by adjusting RAPT site adaptation parameters, particularly the deviation sensitivity field that is used to map RAPT route blockage to route status color, although such an approach could result in an increase in under-warning.

In the TRACON and near en route airspace, RAPT occasionally underestimated weather impacts. On occasion, deviations around low intensity (level 2), low-topped storms in the TRACON required closure of departure gates because TRACON could not thread traffic through the weather to the fix

(Figure 12). Uncertainty in predicting pilot behavior, lack of sufficient information on low altitude storm structure, and the complexity of operational constraints on the ability of air traffic control to vector traffic around weather (e.g., the relationship between arrival/demand balance, runway configuration, and airspace availability for departure traffic) make cornerpost TRACON operations exceedingly difficult to model at the fine spatial scale required for accurate RAPT blockage calculation.

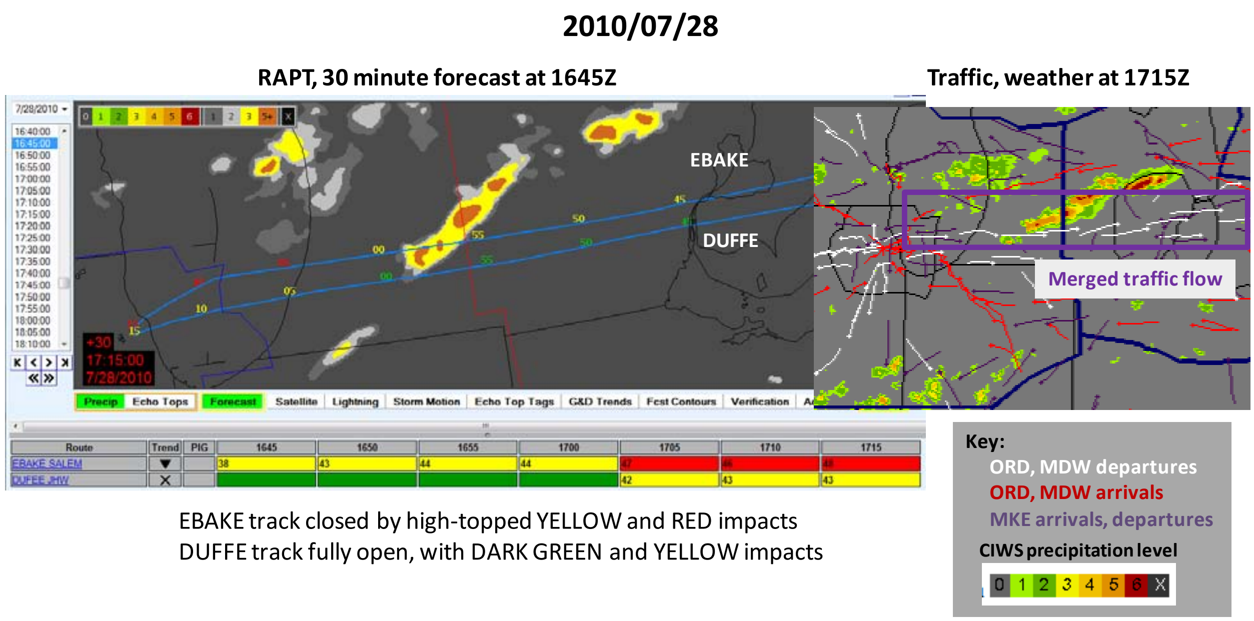


Figure 6. Illustration of RAPT individual RED and GREEN route guidance that matches well with operations.

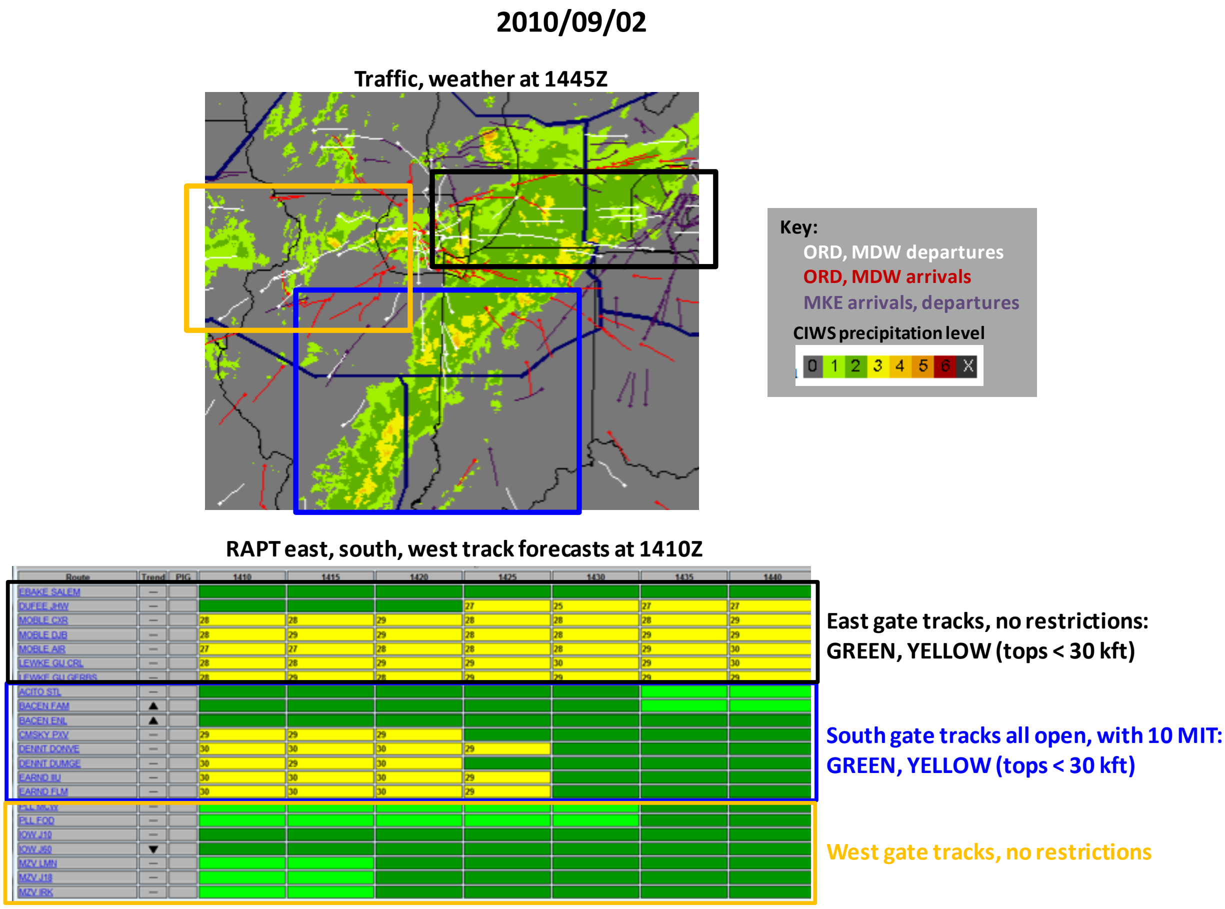


Figure 7. Illustration of restrictions in place on RAPT YELLOW routes.

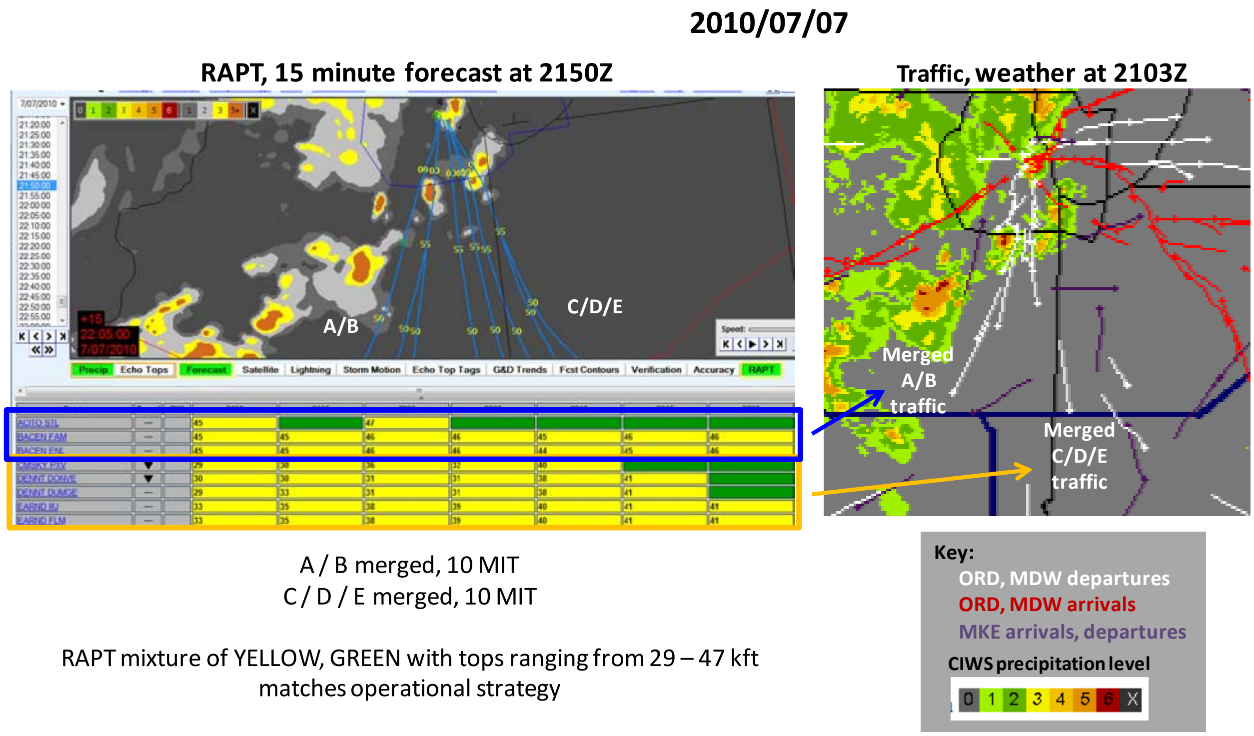


Figure 8. Illustration of RAPT gate guidance that matches well with operations.

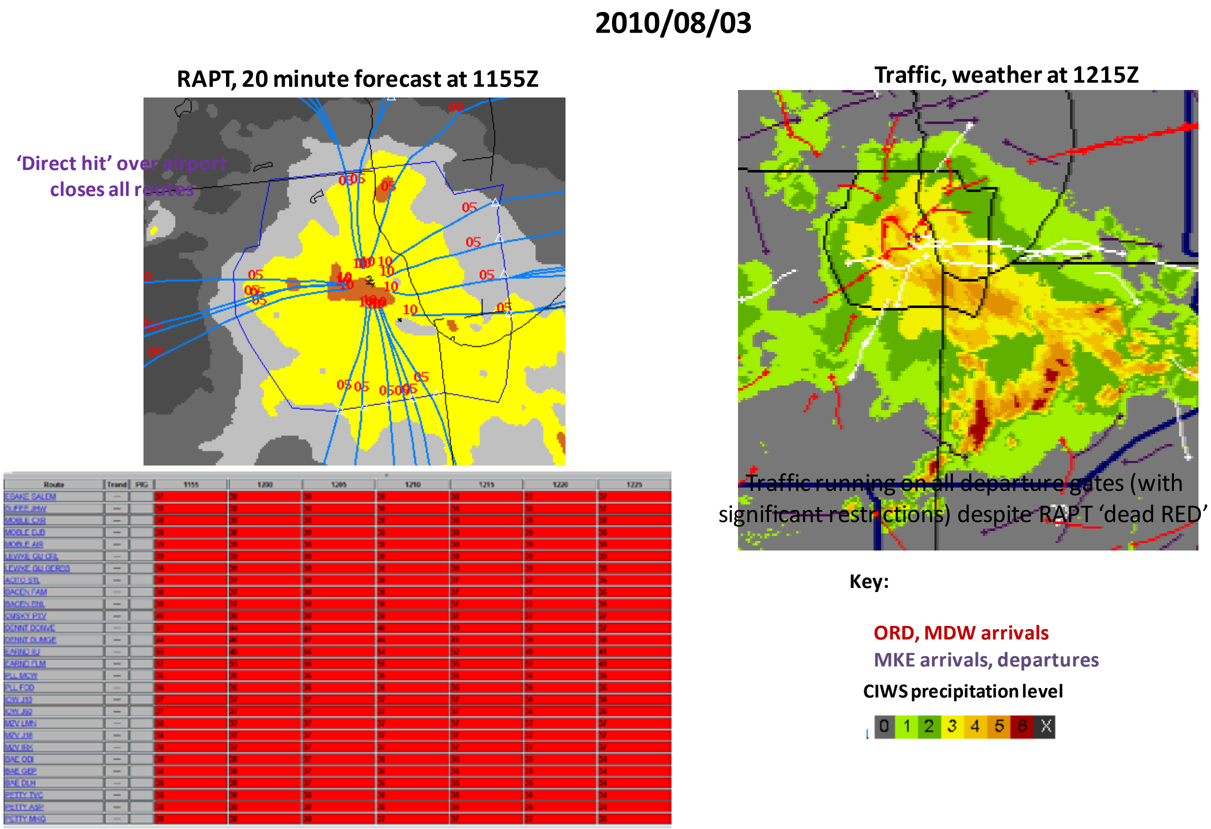


Figure 9. Illustration of RAPT over-warning in the TRACON as weather impacts pass over ORD.

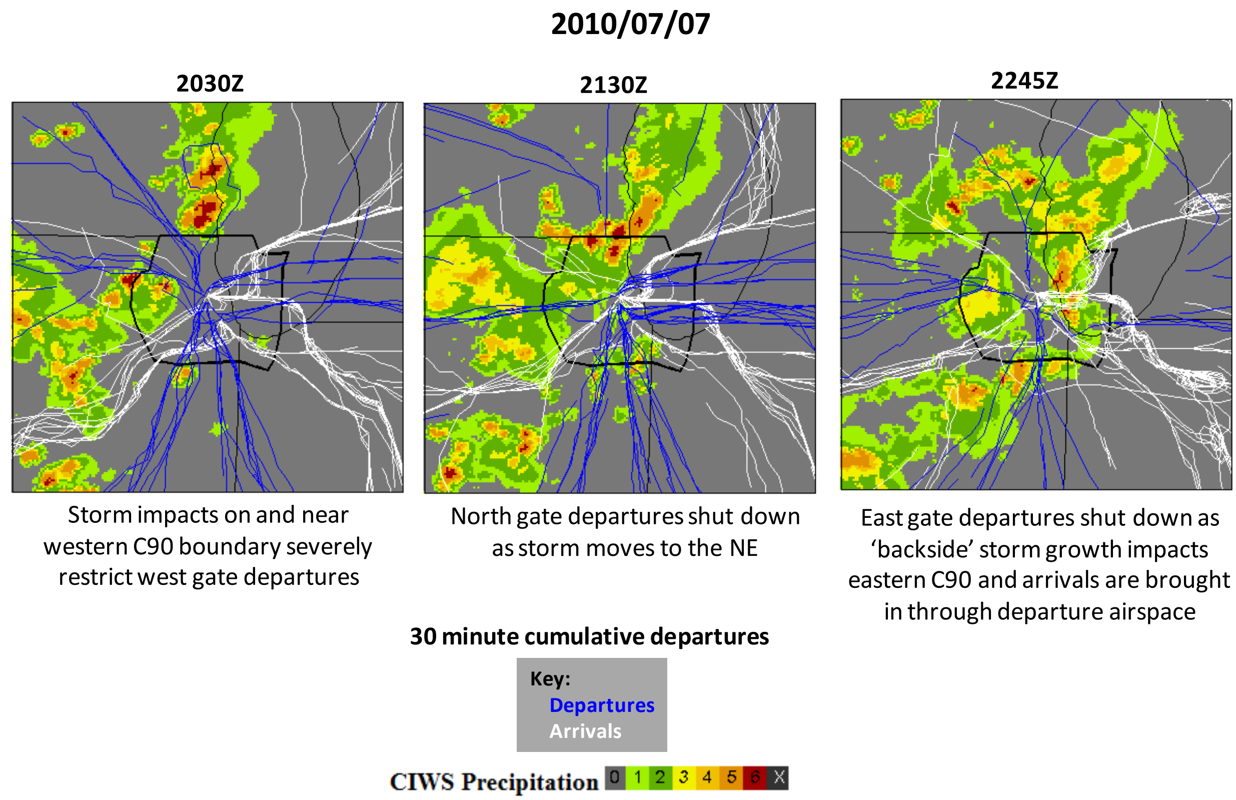


Figure 10. Long-lived weather impacts crossing the TRACON.

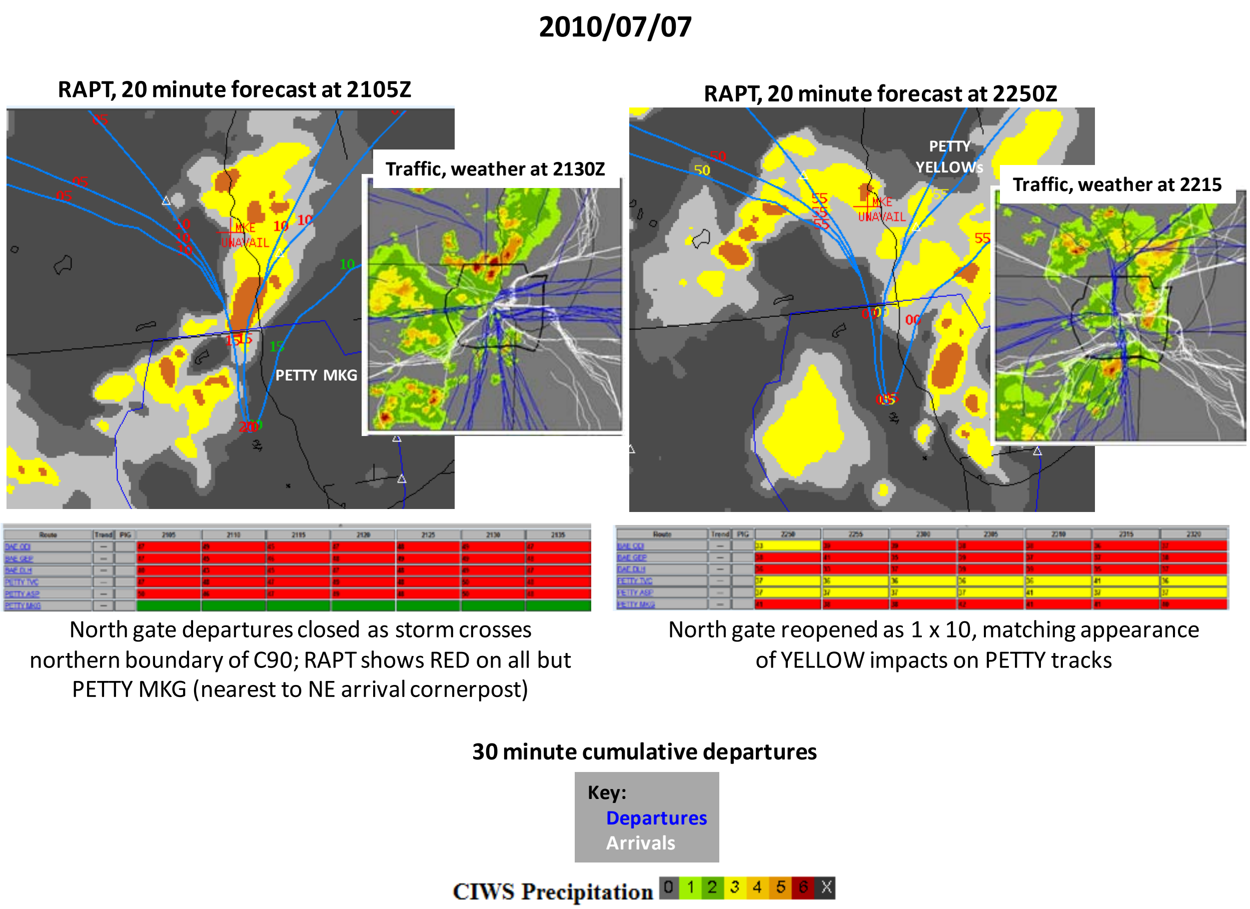
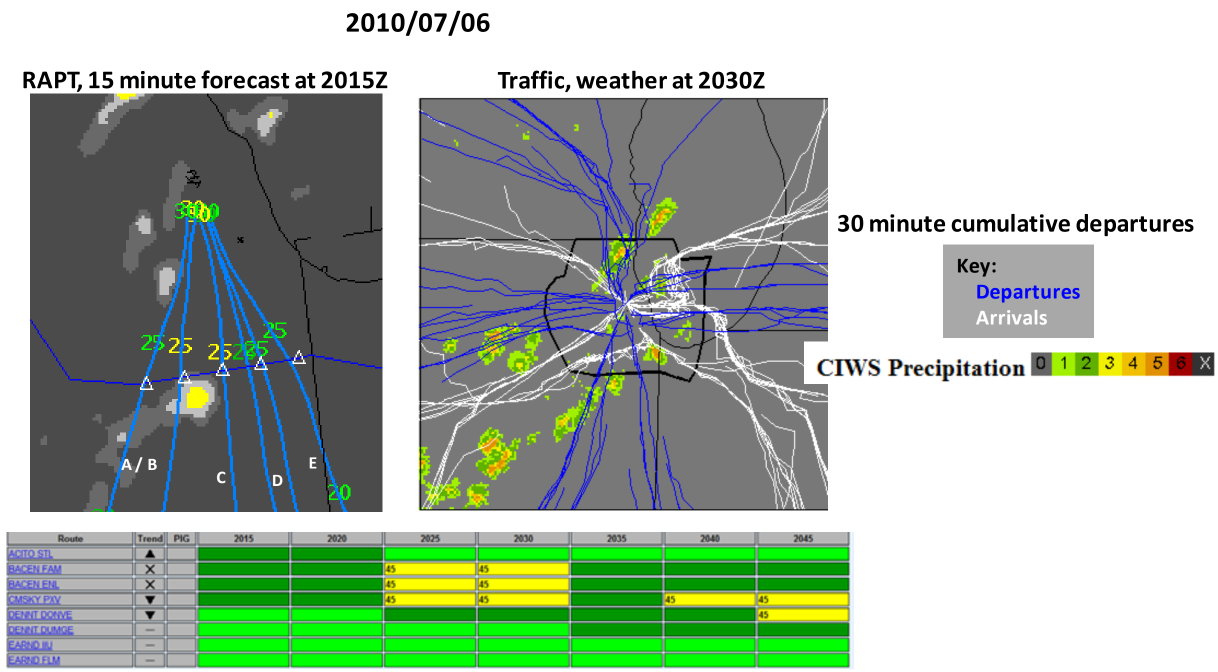


Figure 11. Perception of RAPT over-warning.



South gate departures running under heavy restrictions (A/B 1x10, C,D,E 10 MIT), despite RAPT mix of GREEN and YELLOW

Figure 12. RAPT under-warning on TRACON weather impacts.

The accuracy of RAPT route blockage forecasts, based on a comparison of route status color calculated from forecast weather (operational RAPT) with route status calculated from observed ('true') weather, was scored for six days of operations (8/12, 8/13, 8/14, 9/10, 9/18, and 9/21). Figure 13 shows the results of the comparison for RAPT 15 and 30 minute forecasts. RAPT 30 minute forecasts of GREEN were accurate over 95% of the time, YELLOWs were accurate roughly 70% of the time, and RED forecasts were accurate approximately 60% of the time. RAPT forecasts showed a slight bias toward over-warning.

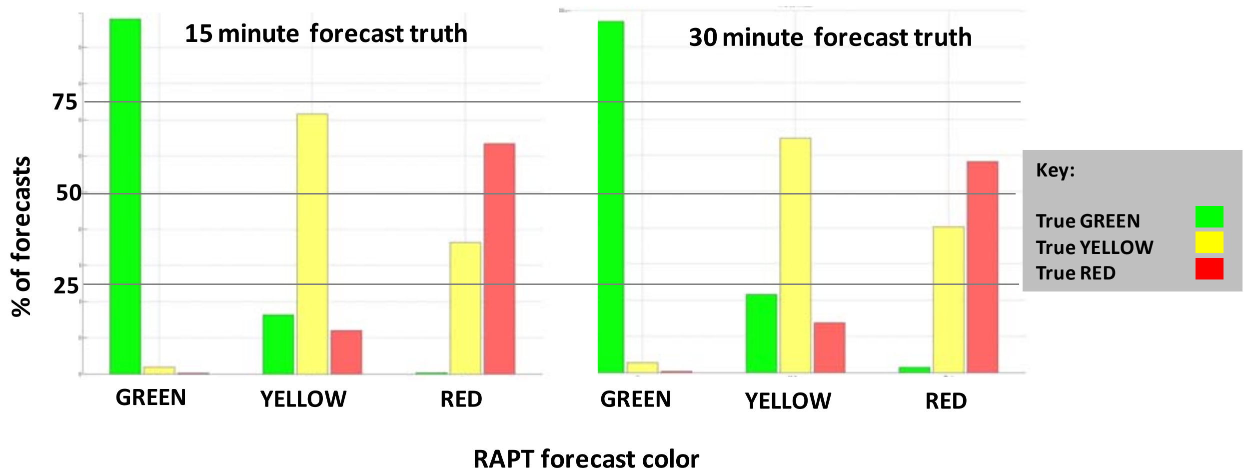


Figure 13. RAPT route status forecast accuracy.

Algorithms that automatically assign departures to RAPT departure routes based on observed (ETMS) flight trajectories and filed flight plans were developed for post-event analysis in the New York departure airspace. Based on these route assignment algorithms, objective measures of departure throughput are calculated for New York operations. These metrics include the statistical distribution of departure counts on routes as a function of RAPT status color, and the time to first departure and departure rates after the appearance of a post-impact GREEN (PIG) [1][2]. Unfortunately, the accuracy of the route assignment algorithm was poor in Chicago airspace, due to the use of gate management tactics to vector aircraft around weather without changing flight plans. The automated algorithms that assign flights to RAPT routes and identify PIGs must be refined to improve their accuracy in Chicago airspace. Further work is needed to develop automated algorithms (e.g., automated detection and characterization of merged departure streams) and additional performance metrics appropriate to the analysis of gate management performance.

1.4 RAPT CONCEPT OF OPERATIONS AND OBSERVED USE

The RAPT concept of operations, illustrated in Figure 14, can be summarized as follows:

GREEN means GO! After weather impacts have cleared a route and the RAPT forecast timeline has turned all GREEN (or some combination of GREEN and DARK GREEN—the appearance of a PIG), reopen the route without restrictions (unless other concerns—for example, arrivals deviating into the departure airspace—merit further constraint).

RED means PLAN REROUTE. When the RAPT forecast timeline turns all or substantially RED, plan to reroute departure traffic off the route.

YELLOW means use judgment to manage restrictions. YELLOW status indicates partial blockage, and/or uncertainty in the forecast. When routes are substantially YELLOW, traffic managers should consult additional information (the RAPT route trend box, echo top heights and trends, weather forecast animation) to decide whether restrictions should be increased, decreased, or maintained at the current level. For instance, experienced RAPT users in New York commonly reopen routes closed by RED impacts when RAPT routes begin to show post-impact YELLOW status with decreasing or stable echo tops. This practice has resulted in significant increases in post-impact departure throughput.

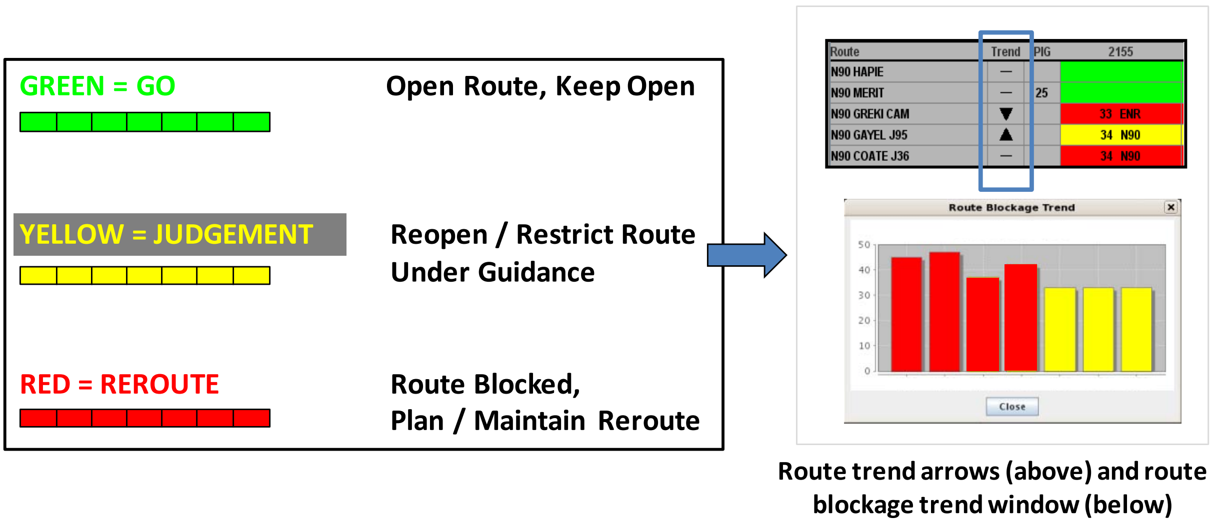


Figure 14. RAPT concept of operations.

The RAPT concept of operations was readily applied in circumstances where departure management was focused in individual route impacts. Several applications of RAPT to reopen closed routes or to reduce restrictions on already open routes were observed. Table 3 and Figures 15–18 present a list of observed RAPT applications, some of which were assisted by the observer.

TABLE 3
Observed RAPT Uses during the Evaluation

Date	Time (Z)	Facility	Use	Figure
06 July	2039	C90	Situational awareness: managing restrictions on W gate departures	--
06 July	2215–2235	C90	Situational awareness: managing restrictions on E gate departures	--
06 July	1910	ZAU	Situational awareness: confirmation of area request for restrictions on W gate departures in response to deviations	--
06 July	2020	ZAU	Situational awareness: RAPT blockage trends on W gate departures, S gate track A (westernmost of S gate departures)	--
07 July	1415	ZAU	Avoided restrictions: assessment of area warning (also based on RAPT) that restrictions may be needed on N gates; SWAP TMC used RAPT GREEN forecasts to keep N gates running without restriction	--
07 July	1430	ZAU	Route reopening: SWAP TMC used RAPT to convince area to reopen W PLL tracks as 1 × 20	15
07 July	1903	ZAU	Proactive reroute: planned weather avoiding reroutes of W gate departures (MZV) to S gate track A	16
28 July	2006–2038	C90	Situational awareness: plan restrictions as severe impacts hit the S gate; look to reopen W gate departures over MZV to relieve S gate demand	--
28 July	1929	ZAU	Situational awareness: plan to reduce restrictions on E gate (DUFFE, EBAKE)	--
28 July	2020	ZAU	Route reopening: reopen W gate (MZV) to westbound, rerouted southbound departures in 10 minutes (also a missed opportunity—could have been done sooner)	--
01 Sept	1120	ZAU	Route reopening: S gate tracks D, E reopened, restrictions on C reduced to 7 MIT	17
02 Sept	1952	ORD	Situational awareness: ‘push from the bottom’ as ORD calls ZAU to requested reduction of restrictions on E gate departures based on RAPT guidance	18

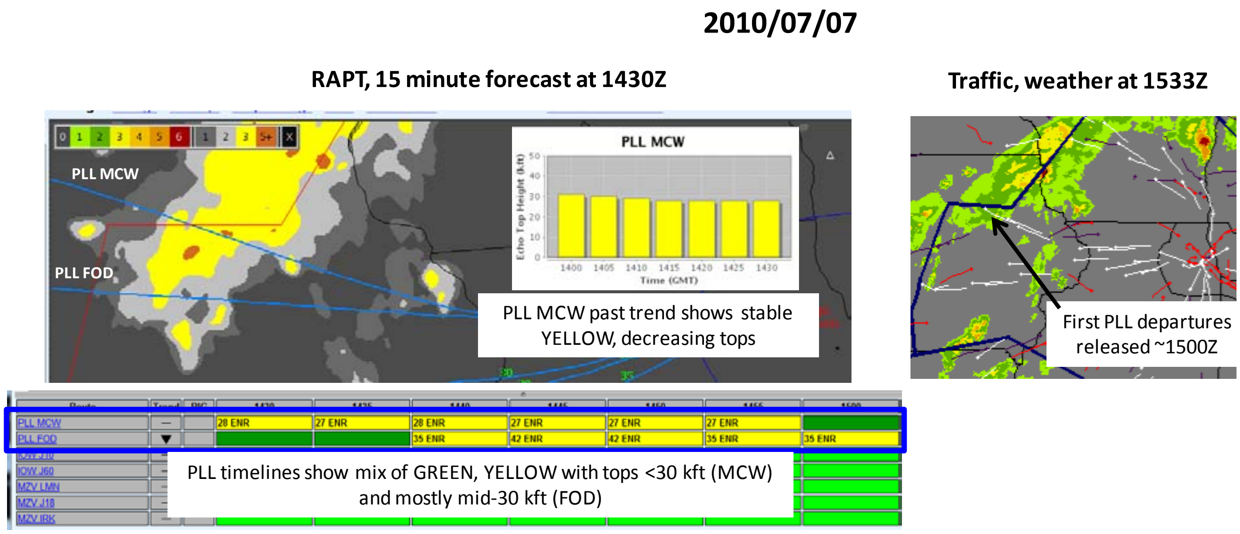


Figure 15. Use of RAPT to reopen west gate (PLL tracks) departures.

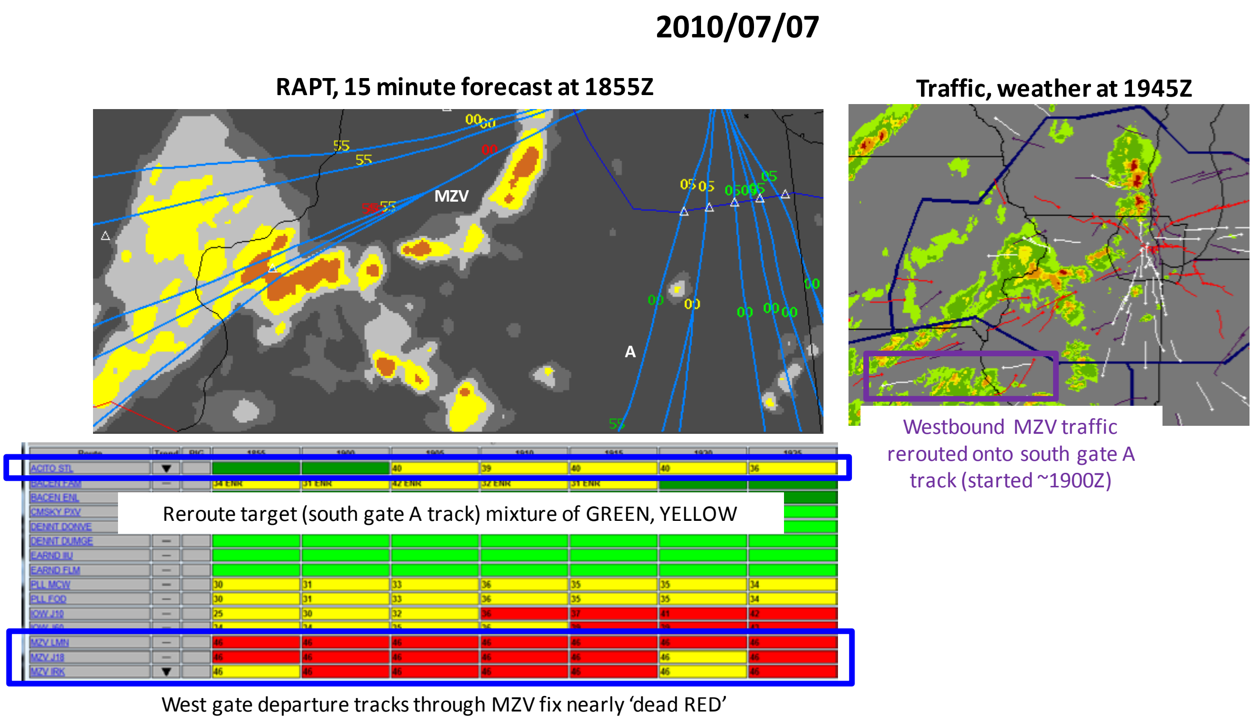


Figure 16. Use of RAPT to plan proactive weather-avoiding reroutes from west gate to south gate.

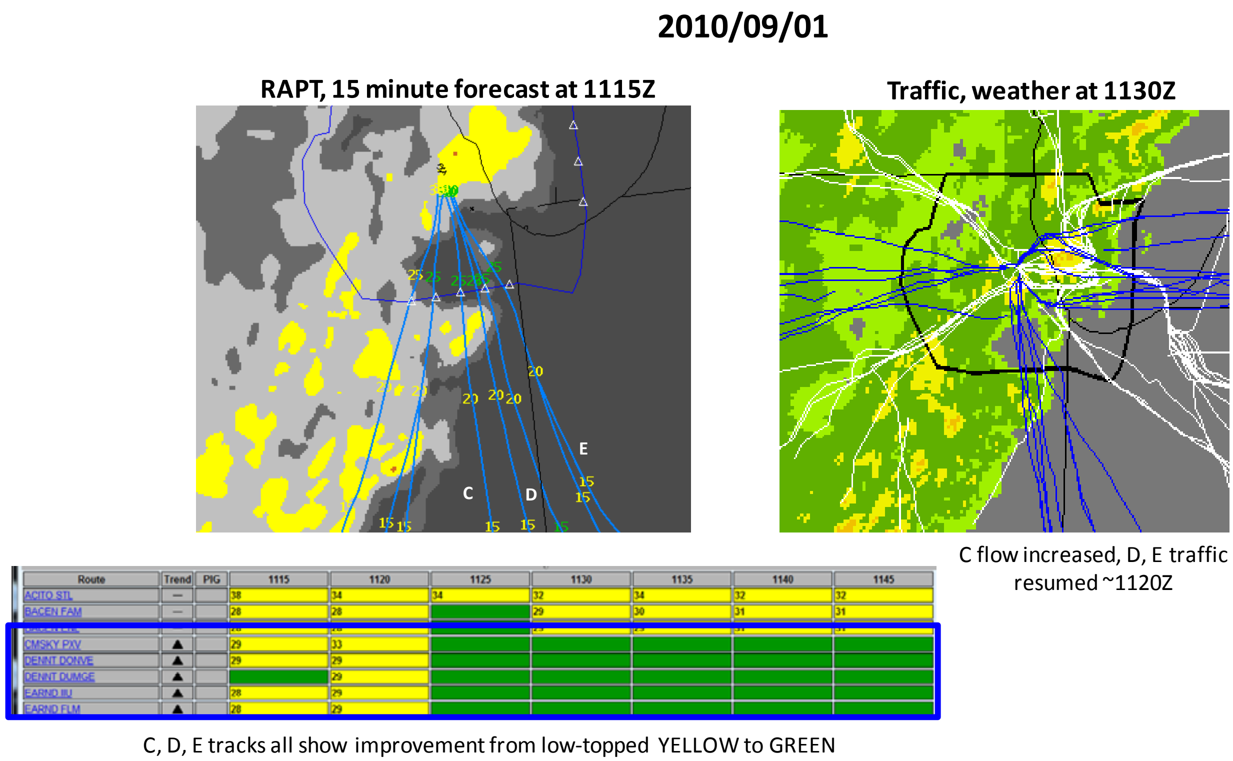


Figure 17. Use of RAPT to reopen south gate departure tracks.

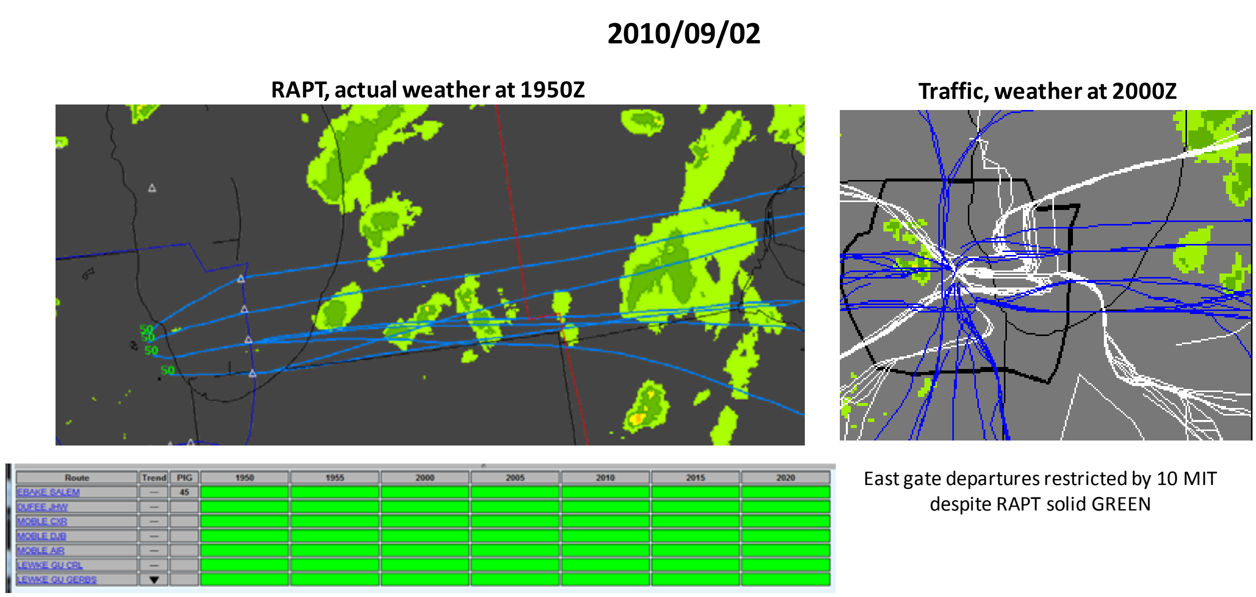


Figure 18. ORD use of RAPT to request reduction of restrictions on east gate departures to relieve surface congestion.

Missed opportunities to reduce restrictions on routes as RAPT status progressed from RED to YELLOW GREEN to PIG were observed. RAPT guidance also provided information that could have improved gate management and restriction reduction decisions, such as the number of departure streams that could have been opened and the appropriate level of restriction that should have been applied to traffic on those streams. Since the RAPT route status timelines are arranged geographically on the display, experienced RAPT users can readily identify opportunities for merged operations on adjacent, heavily impacted routes by using a sort of timeline pattern recognition. Recognizing changes in patterns can alert traffic managers to opportunities to reduce restrictions, or the need to increase them. Table 4 and Figures 19–21 present a partial list of observed missed opportunities, in the opinion of the observer.

TABLE 4
Observed Missed Opportunities for RAPT Use

Date	Time (Z)	Missed Opportunity	Figure
07 July	1345–1512	Route reopening: W gate departures out PLL stopped, reopened with 20 MIT at 1507, fully reopened at 1512. Missed opportunities: reopen on RAPT solid YELLOW with 30–32 kft tops at 1345, mix of YELLOW, GREEN from 1350; PIG on PLL MCW route starting at 1440	15, 19
07 July	2135–2338	Reduction in restrictions: W gate reopened after impacts as 1 × 20 at 2100, 1 × 15 at 2214, restrictions removed at 2338. Missed opportunities: open second stream on RAPT solid YELLOW, 30–35 kft tops starting at 2135	--
28 July	1940–2055	Reduction in restrictions, route reopening: IOW/PLL 1 × 15, starting 1930, MZV closed; IOW, PLL, MZV all opened 10 MIT at 2055. Missed opportunities: reopen PLL on all GREEN at 1940, IOW PIG begins 1945; reopen MZV YELLOW/GREEN at 2015	20
28 July	2006–2015	Proactive reroute planning: S gate departures closed at 2015 after deviations force closure of BEARZ arrival fix; C90 TMU noted potential for closure at 2006. Missed opportunity: start planning reroutes on RAPT at 2000 showing S gate 'dead RED' starting at 2015; RAPT at 2005 shows S gate 'dead RED' starting at 2010	20
28 July	2110–2320	Reduction in restrictions: E gate to 2 × 20. Missed opportunities: EBAKE all GREEN, DUFFE all YELLOW, MOBLE mixed; EBAKE, DUFFE all GREEN, MOBLE all YELLOW/GREEN (2250)	--
02 Sept	1714–1814	Reduction in restrictions, route reopening: W gate 1 × 10, restriction removed at 1814. Missed opportunities: RAPT shows W gate GREEN through 1730, GREEN, YELLOW (tops • 32 kft) to 1805, all GREEN at 1810	--
02 Sept	1750–1954	Reduction in restrictions, route reopening: E gate, EBAKE/DUFFY 1 × 7, MOBLE 15 MIT (10 MIT at 1827); E 3 × 10 at 1954. Missed opportunities: MOBLE, DUFFE all GREEN starting at 1850, EBAKE all GREEN, PIG at 1905	21

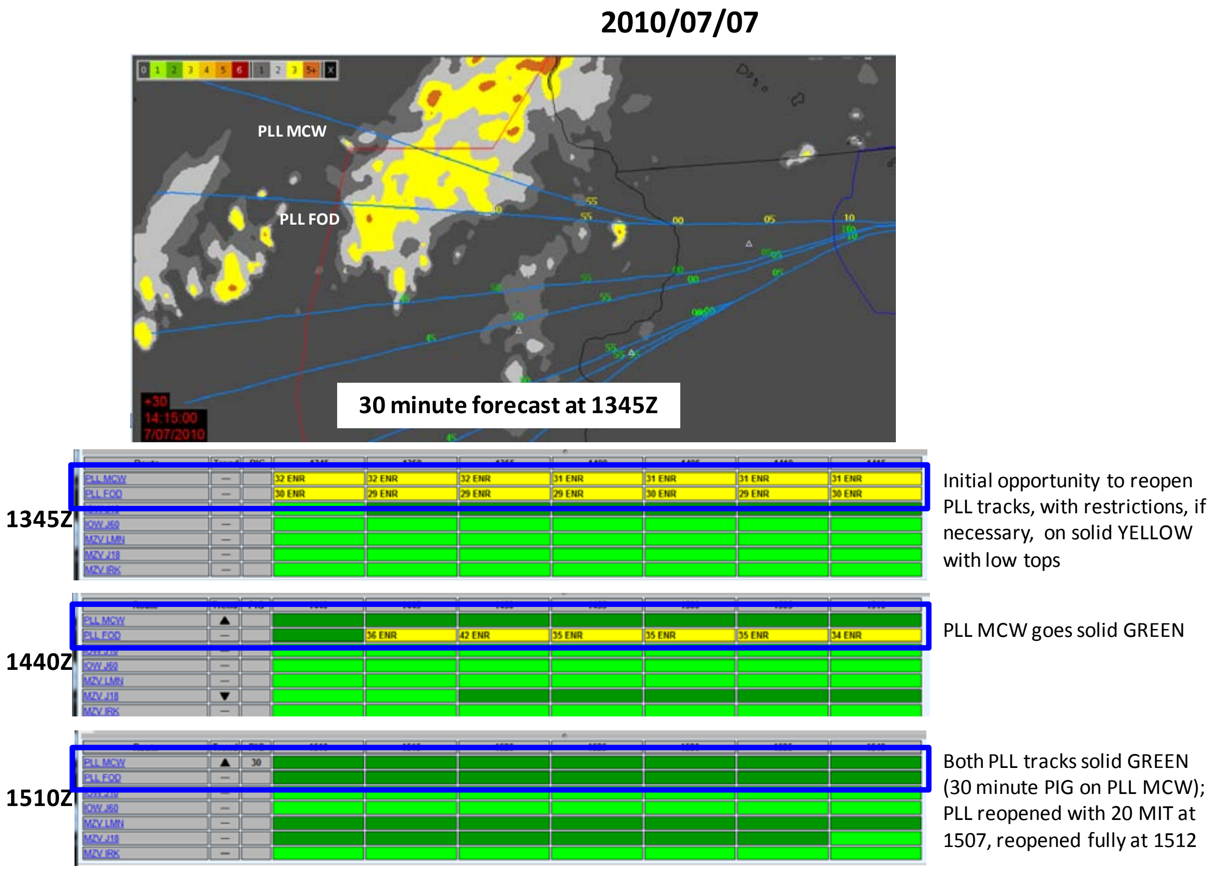
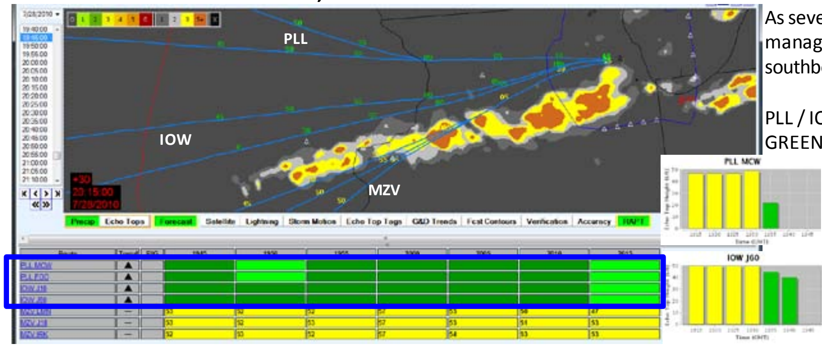


Figure 19. Missed opportunity to reopen departure routes through the PLL fix.

2010/07/28

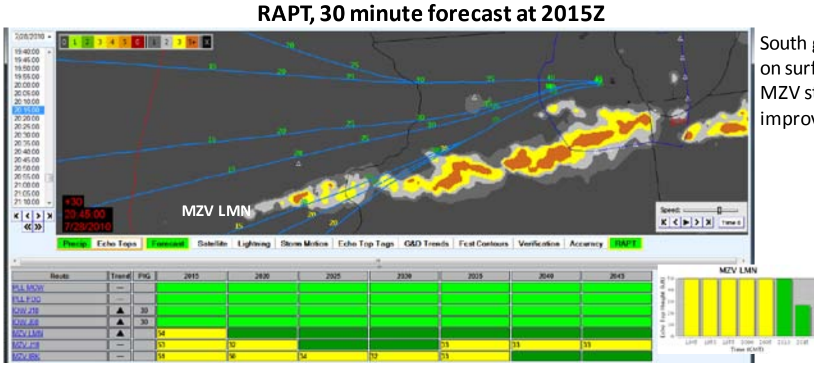
RAPT, 30 minute forecast at 1945Z



As severe impacts move over south gate, traffic management is looking for opportunities to reroute southbound departures to west gate tracks

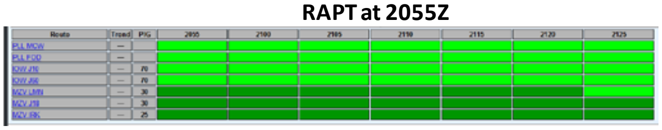
PLL / IOW 1x15 restriction too severe, given solid RAPT GREEN and rapidly improving trends; MZV closed

RAPT, 30 minute forecast at 2015Z



South gate closed, southbound demand building up on surface. PLL / IOW restrictions remain in place; MZV still closed despite RAPT GREEN / YELLOW mix, improving trend on MZV LMN track

RAPT at 2055Z



PLL, IOW, MZV restrictions all reduced to 10 MIT, using RAPT (solid GREEN, PIGs on IOW, MZV)

Reroutes of south gate departures via MZV begun

Figure 20. Missed opportunity to reduce restrictions on and reopen west gate routes, proactively plan reroutes off south gates to avoid severe weather impacts.

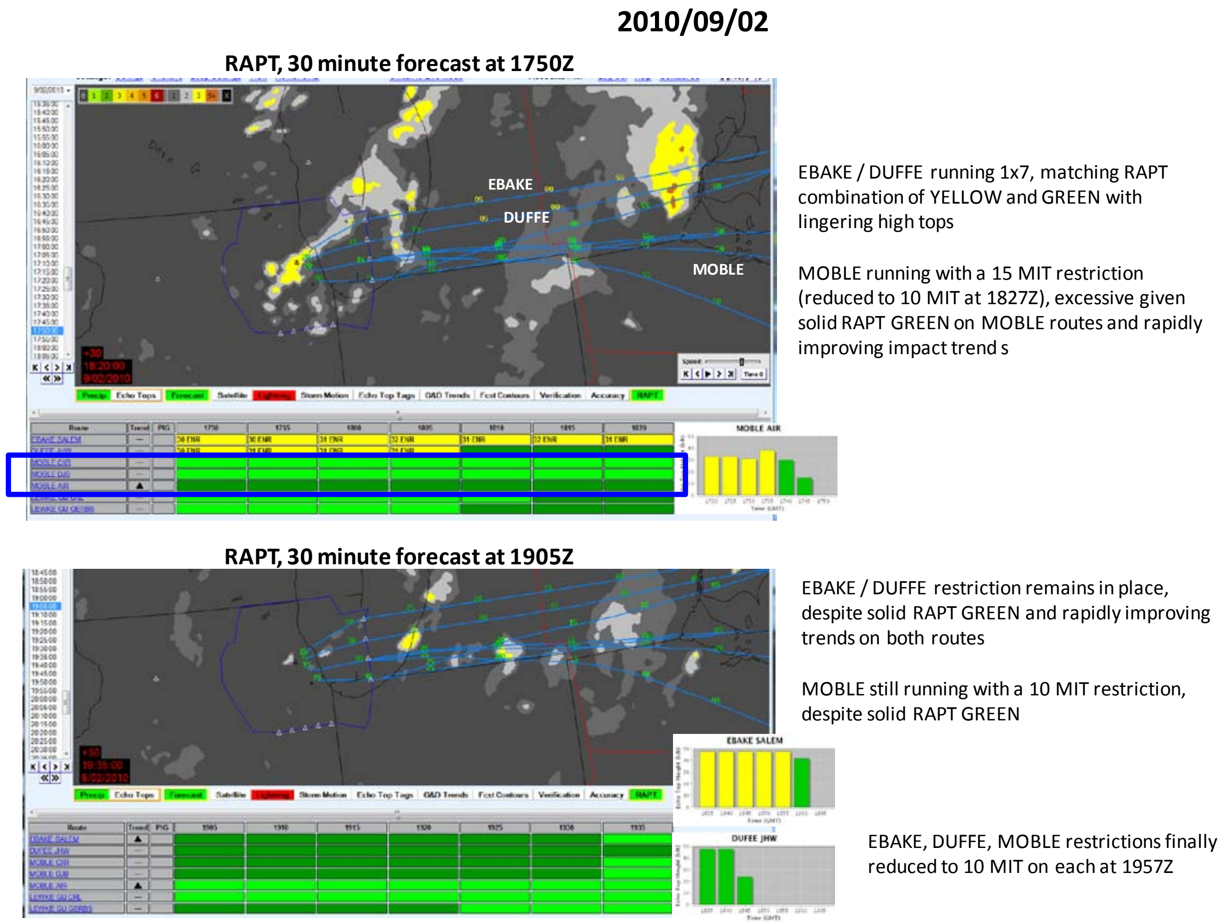


Figure 21. Missed opportunity to reduce restrictions and reopen departure routes on east gate.

The use of RAPT in making gate management decisions requires sufficient experience with RAPT to match timeline patterns to complex gate management operations that involve merging and vectoring traffic flows. While this is possible (traffic managers are masters of complex pattern recognition!) and has been observed among experienced users in New York, this mode of use makes significant cognitive demands on the user, particularly if one tries to consider trends in timeline patterns. These cognitive demands could be greatly reduced by the provision of 'gate blockage' forecast and trend information (Figure 22) based on a combination of automated trajectory identification algorithms [3], adapted to the specific departure airspace and the RAPT route blockage algorithm [4].

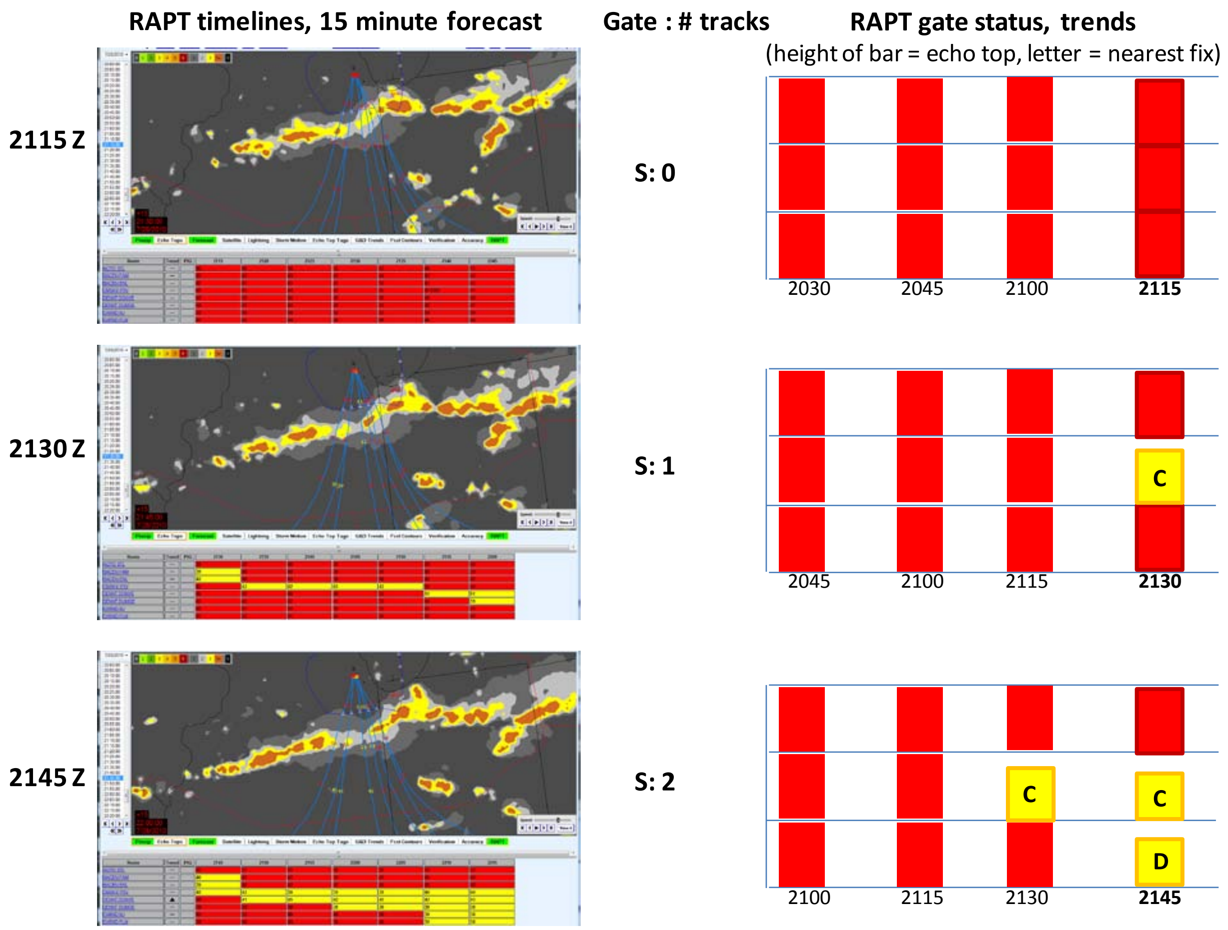


Figure 22. Proposed RAPT gate management status function. The traffic manager can select the departure gate to examine (the South gate has been selected in the example). The guidance forecasts the number of separate passable traffic flows through the gate (up to three). The past trend and forecast RAPT blockage status and maximum echo top height is provided for each flow (columns at right). For non-RED flows, the display also suggests the departure fix nearest the passable flow. For example, at 2145Z (bottom row), the past trend has changed from no open flows (2100, 2115Z), to a single open flow (2130Z), to a prediction for the next 30 minutes of two open flows (two YELLOW status blocks in the right hand column). The open flows pass nearest to the C and D departure tracks.

Users regarded RAPT with a level of professional skepticism appropriate for the introduction of a brand new tool. Traffic managers generally took note of RAPT status (or were willing to do so when asked by observers) when decisions were being considered or made, occasionally made decisions based on RAPT guidance at the suggestion of the observer, and eventually used RAPT in a few decisions without suggestion from the observer. No RAPT-based decisions were rescinded, perhaps an indication that users were applying RAPT in low risk situations, where there appeared to be a high probability of success (again, perfectly appropriate behavior often observed in New York field evaluations). Users in C90 and ORD tower tended to view RAPT less as an active decision support tool and more as enhanced situational awareness; however, as ORD tower is already accustomed to making specific requests for reduced restrictions to ZAU, it is a reasonable expectation that ORD tower will use RAPT guidance to become more proactive in making their requests. Given the high degree of coordination among Chicago facilities, the ability to formulate and implement plans quickly, and the strong focus on ORD, the potential for proactive decision making and departure delay reduction using RAPT is great and can readily be realized if users are given the follow-up training needed to develop confidence and experience with RAPT. Finally, it is clear that traffic managers would benefit from follow on training that highlights observed and potential opportunities for RAPT use, and the positive outcomes that result from RAPT-based decisions.

2. CONCLUSIONS AND FUTURE WORK

A RAPT prototype was deployed to Chicago in the summer of 2010. A field study was carried out to evaluate the applicability of the RAPT concept of operations and the ability to site-adapt RAPT to a typical cornerpost airspace very different from the New York airspace for which RAPT was developed. Observers were deployed to ZAU, C90, and ORD tower for three SWAP events (over five days of operations), characterized by a wide variety of weather impacts. The study included an analysis of departure management operations, a qualitative analysis of the operational accuracy of RAPT guidance, forecasts and site adaptation, RAPT use, and the applicability of the RAPT concept of operations to Chicago departure management.

The Chicago airspace differs markedly from New York's, and departure management operations reflect that difference. The majority of route management decisions are made in ZAU and focused primarily on the needs of ORD, and coordination between departure management facilities is common and effective. The influence of a single dominant airport and the flexibility of the cornerpost structure enables a flexible departure 'gate management' strategy, in which departure flows out a single gate may be merged into one or more traffic streams that are vectored to avoid weather, and then returned to their planned routes once the weather is cleared. (Traffic flow merging is also employed in New York, but less frequently and on a smaller scale.) RAPT guidance can be readily adapted to this mode of use by experienced users, but the potential benefits from RAPT use in gate management operations could be increased significantly with the addition of a gate blockage forecast enhancement that is specifically focused on gate management decision making. This enhancement could be based on the adaptation of automated trajectory identification algorithms already developed to the Chicago airspace, combined with the existing RAPT blockage algorithm.

Individual route management, similar to that employed in New York, is also widely employed in Chicago departure management operations, and the RAPT concept of operation applies readily, with no further adaptation. The site adaptation and RAPT algorithm were well suited to operations and RAPT guidance should be as applicable to decision making in Chicago as it was in New York. The tendency of RAPT to over-warn during weather impacts in the TRACON should be addressed through training and adjustments to the site adaption. However, given difficulties observed in both New York and Chicago when weather impacts are primarily in the TRACON, further research is needed to improve RAPT models of TRACON operations.

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3. GLOSSARY

C90	Chicago TRACON
CIWS	Corridor Integrated Weather System
CWAM	Convective Weather Avoidance Model
DTW	Detroit Metropolitan Wayne County airport
ETMS	Enhanced Traffic Management System
NAS	National Airspace System
ORD	O’Hare International Airport
RAPT	Route Availability Planning Tool
STMC	Supervisory Traffic Management Controller
TMA	Traffic Management Advisor
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TRACON	Terminal Radar Control
ZAU	En route center

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4. REFERENCES

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