A Historical Perspective on the Integration of Weather Information into Air Traffic Management Decision Support Tools

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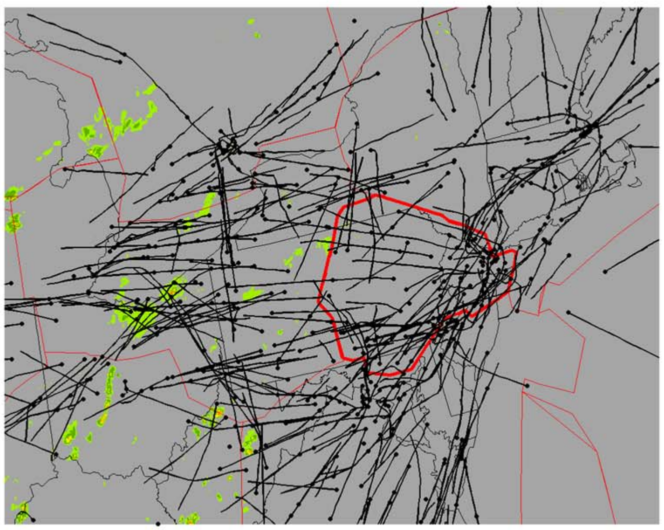
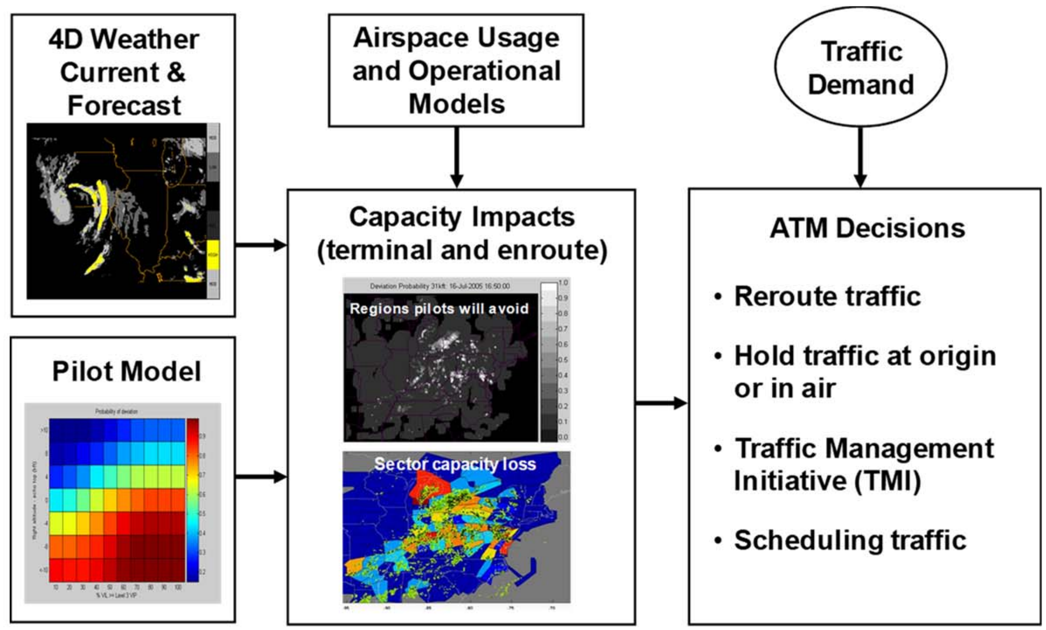
Introduction

- **Improving the decision support to achieve safe and efficient aviation operations under adverse weather conditions has been a major objective for decades**
- **Explicit consideration of air traffic management (ATM) in decision support design and use is critical for improving operational outcomes**





Operationally Tested Weather-ATM Systems 1980-2019

Weather Impact

Weather Information

	Convection	Final approach visibility	Winds on wake vortices	Final approach winds
Separate weather display	✓ ITWS, CIWS, WARP			
Weather & traffic on same display	✓ ARTS, CIWS, WARP			
Weather translated into ATC impacts	✓ CWAM	✓ MSFS		
Weather translated into ATM decisions	✓ RAPT/IDRP	✓ GPSM/MSFS	✓ WTMD	✓ TBFM

ATM-weather systems have been developed with a variety of different options for conveying weather information and impacts

ARTS-Automated Radar Terminal System CIWS- Corridor Integrated Weather System CWAM Convective Weather Avoidance Model
ITWS Integrated Terminal Weather System GPSM GDP Parameters Selection Model IDRP-Integrated Departure Route Planning
MSFS –Marine Stratus Forecast System RAPT-Route Availability Planning Tool TBFM-Time Based Flow Management WARP-Weather and Radar Processor

Outline

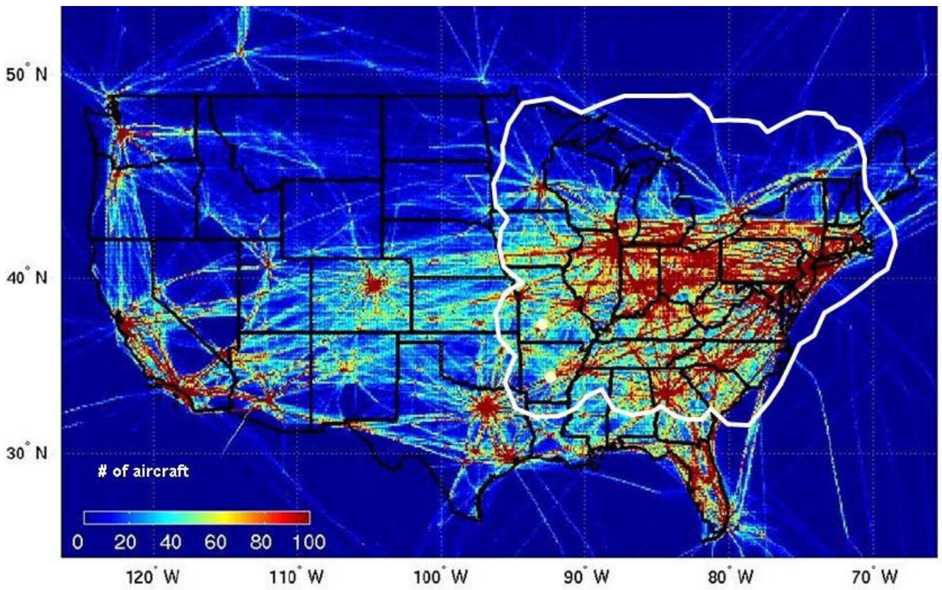
1. Examples of weather/ATM decision support systems
   – Successful (after six years of prototype operational use): Corridor Integrated Weather System (CIWS)
   – Mixed success: Route Availability Planning Tool (RAPT)

2. How have various ATM-weather integration options worked out in practice?

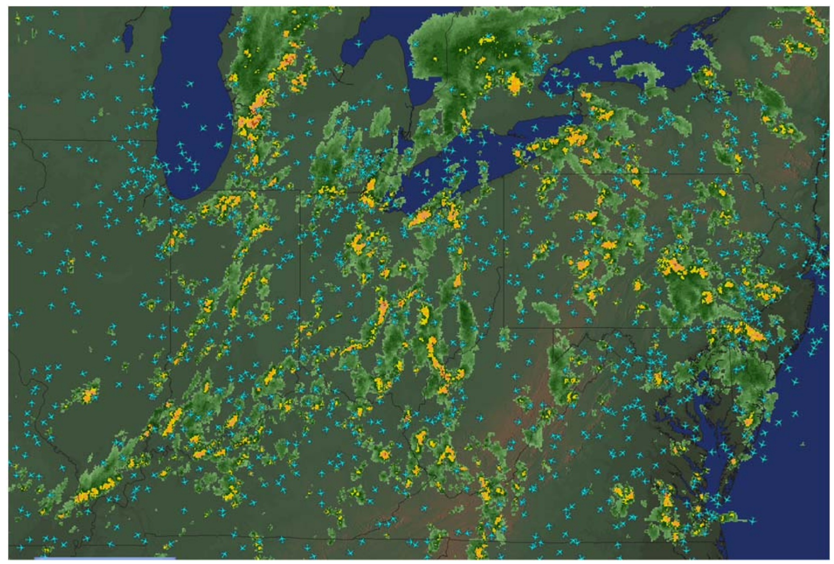
3. Thoughts on how to improve the operational effectiveness of ATM-weather integration going forward

Motivation for Corridor Integrated Weather System (CIWS)

Congestion + Convection = Trouble



Density of traffic for a 24 hour period in Sept. 2002 with CIWS 2005 coverage region



Convective weather and aircraft on a day in summer 2005

CIWS provides 0-2 hour forecast of Vertically Integrated Liquid (VIL), Echo Tops (ET) & precipitation phase

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Understanding of Weather-ATM Issues at Start of CIWS Development

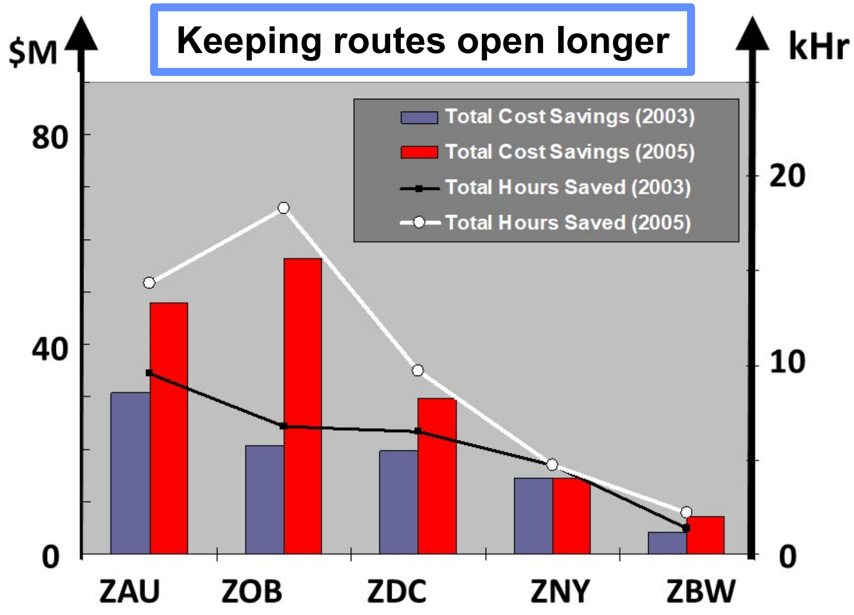
- What was understood from Integrated Terminal Weather System (ITWS) operations
  - Importance of interacting with operational users
  - Current/forecast precipitation products
  - Initial understanding of pilot storm avoidance decision making
    - Echo tops in relationship to flight altitude a key factor

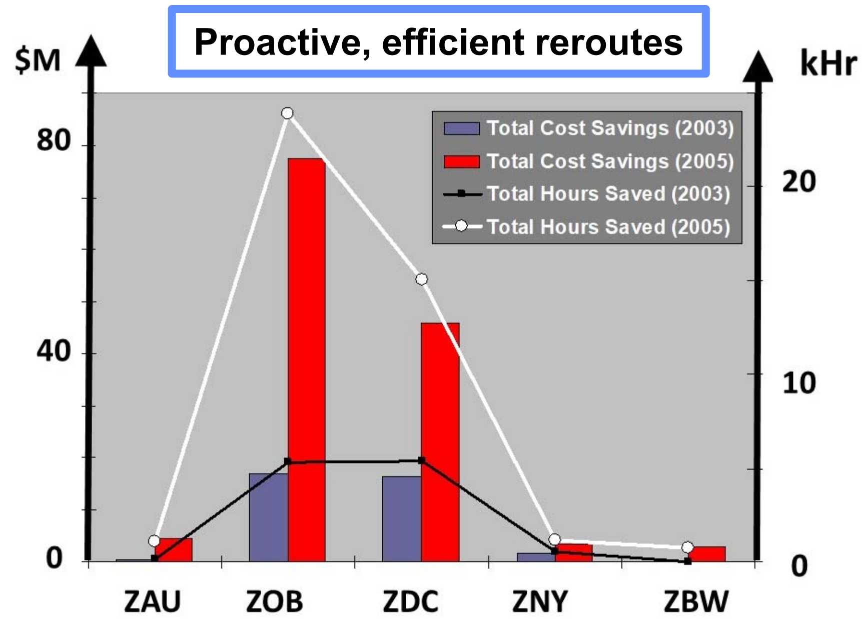
- What was <u>not</u> understood for en route congested airspace ATM
  - Frequency of relatively low topped high VIL storms
  - ATM decision making in an ARTCC
    - Key users
    - Communication/collaboration
  - Impact of how operational personnel make ATM decisions on
    - Training
    - Data for post event ATM decision analyses

VIL = Vertically Integrated Liquid

2005 CIWS Benefits Assessment Insights

- Approach: Simultaneous intensive observations during widespread events followed by facility-specific quantitative analyses
  - Interaction Benefits ⟺ Key decisions
    Products
  - Importance of identifying and supporting key decision makers
- Area supervisor experiment at ZOB 2003 and 2005
  - ZDC had area displays both years; ZOB did not in 2003, but did in 2005





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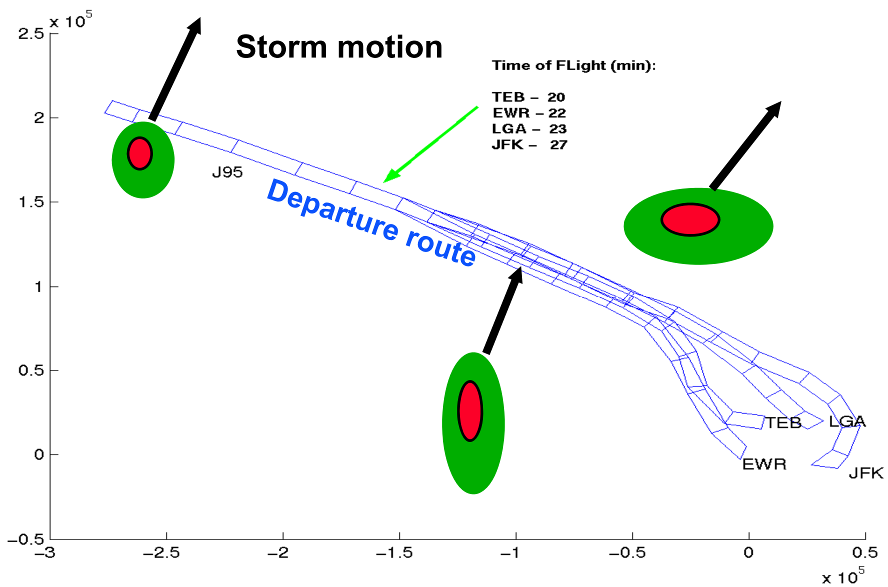
Route Availability Planning Tool (RAPT) at New York

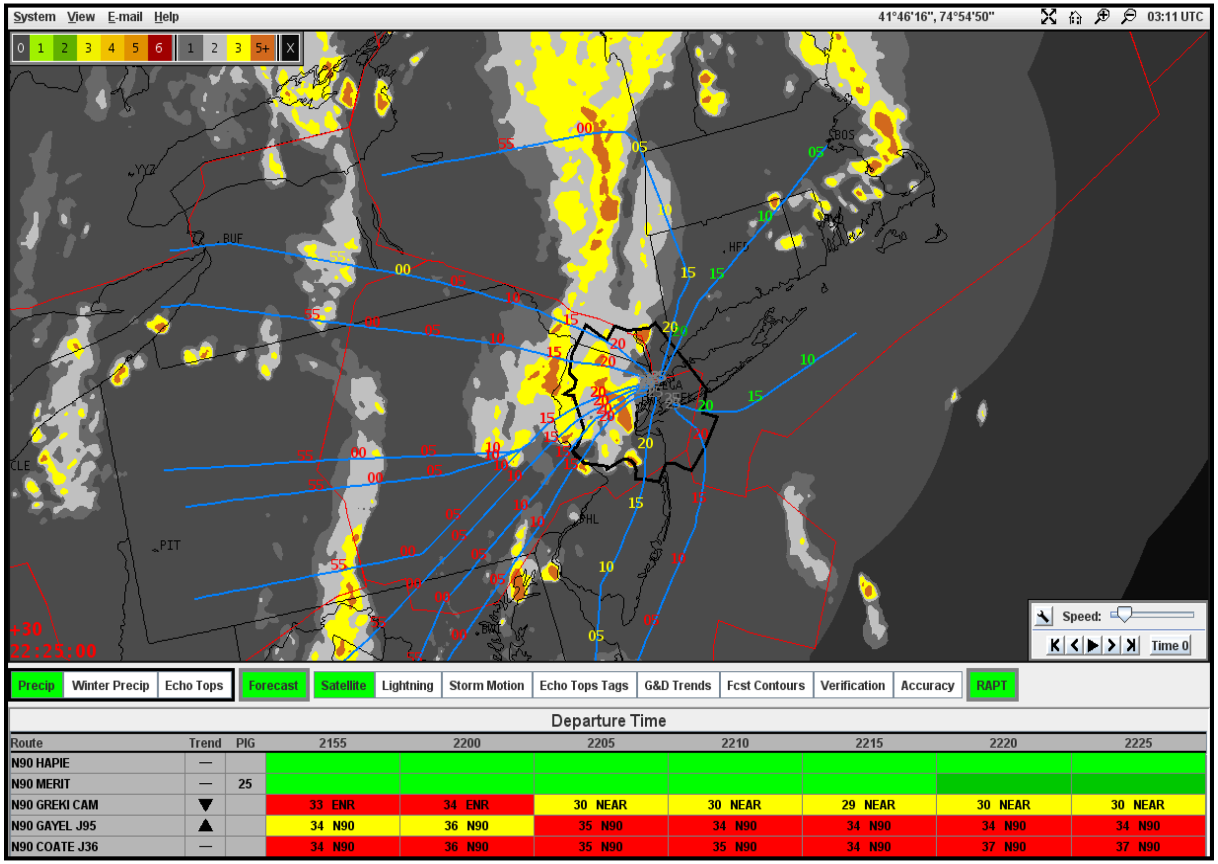
- **Route structures and traffic density at NY make rerouting very difficult – need to focus on keeping departure routes open**



Key operational question addressed by RAPT: If at this time an aircraft is released on this route, will it encounter hazardous weather?

- **ATM challenge: it was difficult to assess departure route availability**
  - **Need to account for both aircraft trajectories and storm movement**
  - **Many facilities and ATC areas involved in departure route decisions: manual assessment by many different people takes too long**

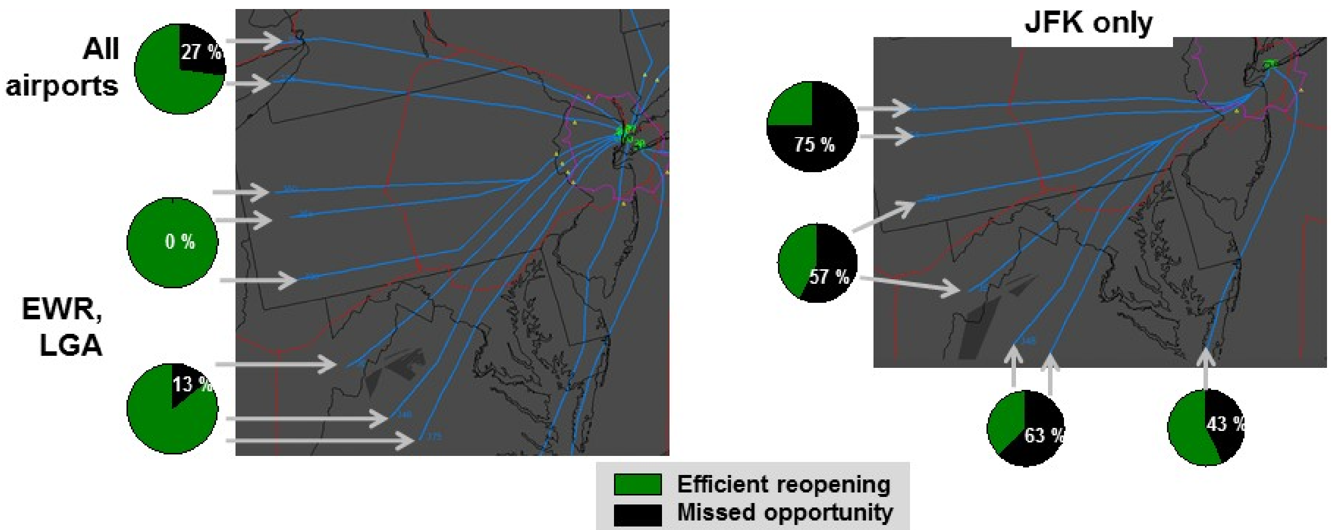
Route Availability Planning Tool (RAPT)



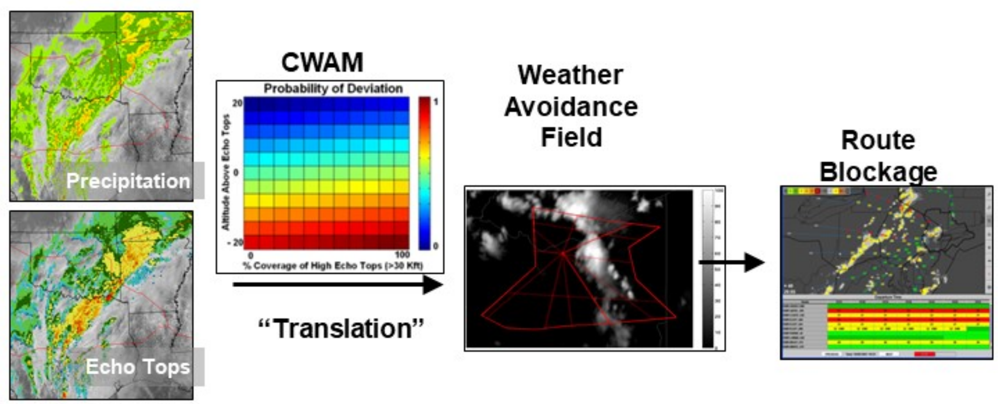
- **Funded initially by PA NY/NJ**
- **Used operationally starting in August 2002**
- **Uses CIWS forecasts (VIL and echo tops)**
- **Helps get departures out of airports during SWAP**
- **Annual delay savings ≈ $ 17 M (in 2009)**
- **Operational users**
  - **EWR, LGA, JFK, TEB**
  - **NY TRACON**
  - **ZNY, ZDC, ZOB**
  - **Airlines**

Outgrowths of RAPT Development/Usage

1. **CIWS-like observations to refine ATM model combined with training focused on observed usage more than doubled operational benefits**



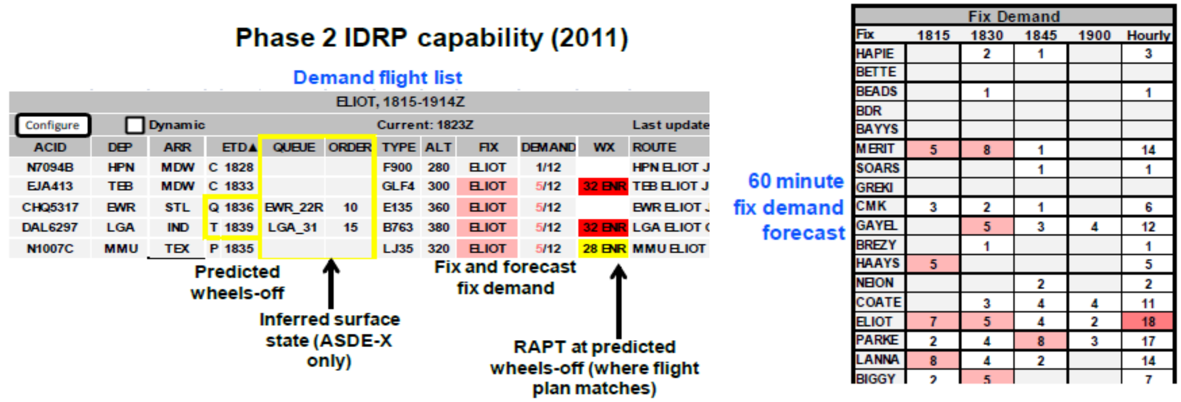
2. **Convective weather avoidance model (CWAM) use in other ATM-weather systems such as rerouting of departures at DFW**



Integrated Departure Route Planning (IDRP)- RAPT Testing 2010-2011

- **Objective: Quickly find flights to use a route that is reopening and, reroute flights whose route will be closed for a lengthy period**

IDRP provided departure traffic forecasts for departure fixes and specific flights whose route is closed



ACID	DEP	ARR	ETD▲	QUEUE	ORDER	TYPE	ALT	FIX	DEMAND	WX	ROUTE
N7094B	HPN	MDW	C 1828			F900	280	ELIOT	1/12		HPN ELIOT J
EJA413	TEB	MDW	C 1833			GLF4	300	ELIOT	5/12	32 ENR	TEB ELIOT J
CHQ5317	EWR	STL	Q 1836	EWR_22R	10	E135	360	ELIOT	5/12		EWR ELIOT J
DAL6297	LGA	IND	T 1839	LGA_31	15	B763	380	ELIOT	5/12	32 ENR	LGA ELIOT (
N1007C	MMU	TEX	P 1835			LJ35	320	ELIOT	5/12	28 ENR	MMU ELIOT

Fix	1815	1830	1845	1900	Hourly
HAPIE		2	1		3
BETTE					
BEADS		1			1
BDR					
BAYYS					
MERIT	5	8	1		14
SOARS			1		1
GREKI					
CMK	3	2	1		6
GAYEL		5	3	4	12
BREZY		1			1
HAAYS	5				5
NEION			2		2
COATE		3	4	4	11
ELIOT	7	5	4	2	18
PARKE	2	4	8	3	17
LANNA	8	4	2		14
BIGGY	2	5			7

Results of 2011 RAPT/IDRP evaluation (DeLaura, et. al., 2012)

1. **Forecasting flight availability for departures and, forecasting fix demand provided difficult**
2. **Routes with no weather blockage ("green") were at times unusable due to arrival deviations into departure airspace**
3. **Departures operated on "red" RAPT routes because ATC had merged adjacent departure routes to obtain more space for deviations around cells**

In retrospect:

1. **Test period (1 year) was far too short given the complex ATM situation**
2. **RAPT could not be the only source of information on route availability**

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How has ATM-Weather Integration Worked Out in Practice?

- Some successes (TDWR, ITWS, CIWS, CWAM)
- Many current problems with the advanced weather-ATM systems
  – Production RAPT installed at NY, ORD, PHL, DC but current operational benefits unclear
  – SFO marine stratus dissipation decision support is facing many challenges to forecast system operation. The GDP planning backend was turned off in 2013 due to lack of funding.
  – SFO wake vortex departure system turned off due to multiple issues (procedure reviews, RAP access for "safety critical" operations)
- Institutional (NWS, FAA) problems dealing with "special NAS cases" such as SFO and New York: R & D responsibility, training that considers operational usage, updating system (with user engagement) as weather and ATM changes occur
- Developing and validating ATM models for airspace usage in convective weather has proven a difficult challenge

TDWR = Terminal Doppler Weather Radar
ITWS = Integrated Terminal Weather System
CIWS = Corridor Integrated Weather System
CWAM = Convective Weather Avoidance Model
GDP = Ground Delay Program

Why the Differences in Current Operational Effectiveness of RAPT versus CIWS

Factor	CIWS	RAPT Prototypes	RAPT Production
Tailored to Generic Decision Making	Yes	NA	NA
Develop ATM model for specific facility decisions	No	NY, ORD-partial	NY, ORD-partial PHL, PCT-no
Training in use of display	Yes	Yes	Yes
Annual facility specific scenario training	Yes	Yes	No
Full complement of product reliability information	Yes	Yes	No
Post event online archive	Yes	Yes	No
Operational use metrics to drive training and refinement	Only initially	Yes	No
Airline real time access	Yes	Yes	Limited
Airline access to post event archive and, annual training	Yes	Yes	No

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How Might ATM-Weather be in a Better Place by 2050?

- **Improving coupling to the key operational decision makers**
  - **Highly successful developments had close coupling to the operational decision makers over several years using prototypes**
  - **Arriving at adequate ATM models critical for highly integrated systems**
- **Handling weather forecast uncertainty and, complicated (e.g., AI) algorithms**
  - **A major problem for convective weather ATM for the foreseeable future**
  - **The success of CWSU located within the TMU at ZTL in helping ATC make ATM decisions suggests providing a tailored parallel weather/ATM information stream to CWSU staff located in the TMU area**
- **Training driven by post event assessment of operational decisions**
  - **FAA PERTI (Plan, Execute, Review, Train, Improve) program**
- **Ongoing assessment and updating of the decision support systems**
- **Improve management for ATM-weather decision systems of R & D, ongoing maintenance/refinement and operational usage driven training**

AI = Artificial Intelligence
CWSU = Center Weather Service Unit

ZTL = Atlanta Air Route Traffic Control Center
TMU = Traffic Management Unit