Decision Support Capabilities for Effective Application of Collaborative Trajectory Options Programs (CTOP)

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participation from Ohio State (Phil Smith), UC Berkeley (Mark Hansen)
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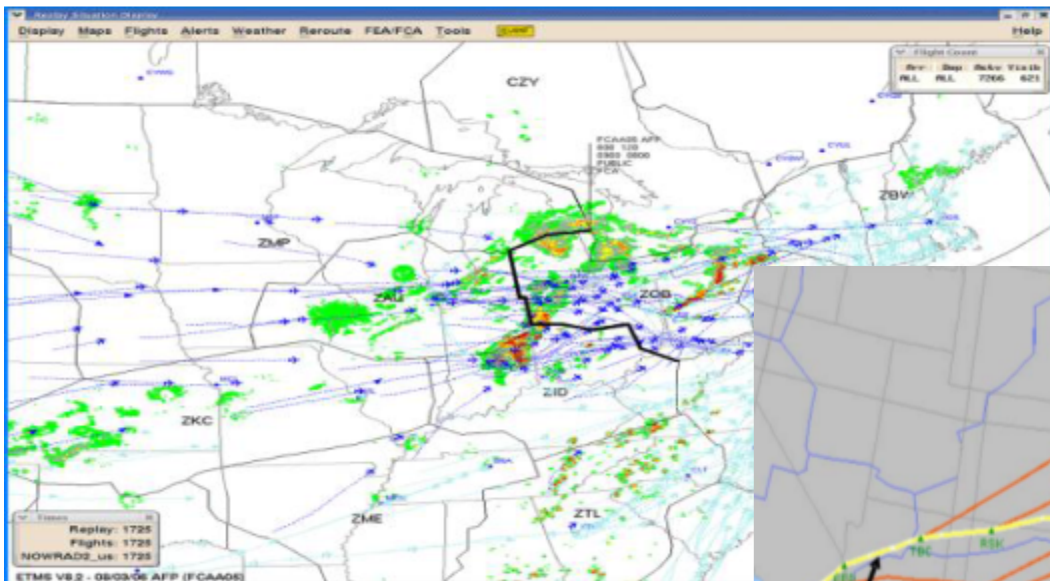
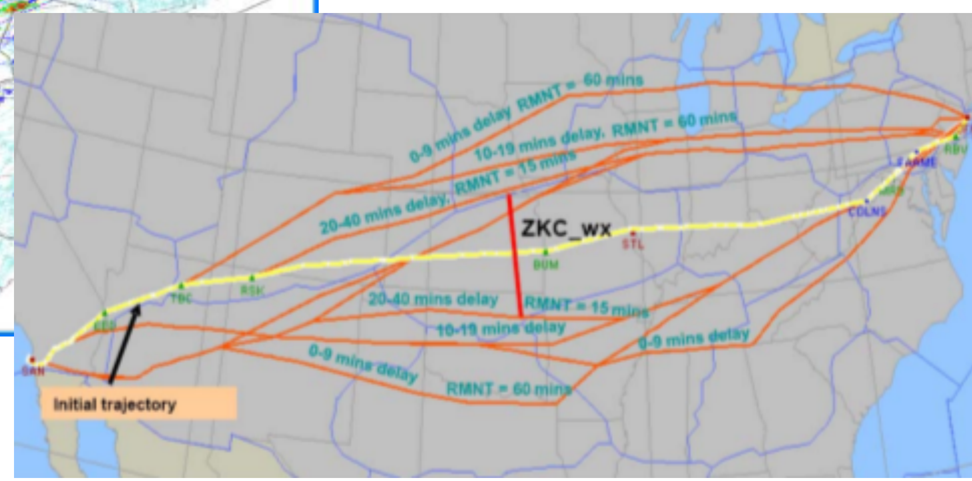
What is CTOP?

CTOP is a new traffic management initiative for controlling traffic through ground delays and rerouting

Traffic managers can create multiple flow constrained areas (FCAs)



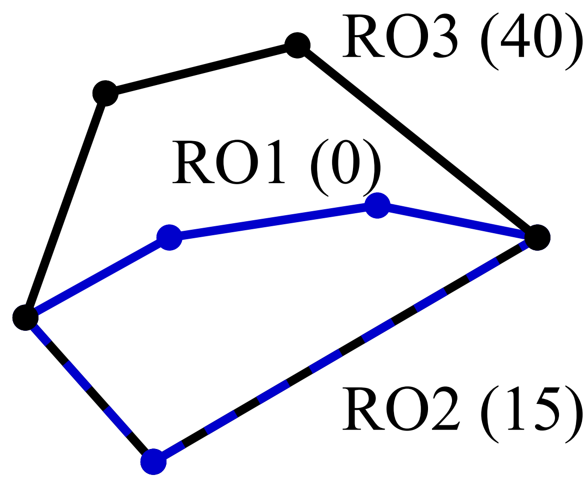
Flight operators to express and exercise preferred routing options



Key to CTOP:
Trajectory Options Set (TOS)

In a CTOP, flight operators express operational priorities for a given flight via a TOS

RO = route option
RTC = Relative trajectory cost
RMNT = required min notification time
TVST/ET = trajectory valid start/end time



ERTD	RO	RTC	RMNT	TVST	TVET	delay required	Adj Cost
15:00	RO1	0	-	-	-	30	0+30 = 30
15:00	RO2	15	-	-	-	10	15+10 = 25
15:00	RO3	40	-	-	-	0	40+0 = 40

CTOP Timeline and Project Goals

2006-2010: Initial concept development by CDM group as SEVEN (System Enhancements for Versatile Electronic Negotiation)

2010-2013: Development & Deployment of Initial CTOP capability

2014: Deployment under TFMS

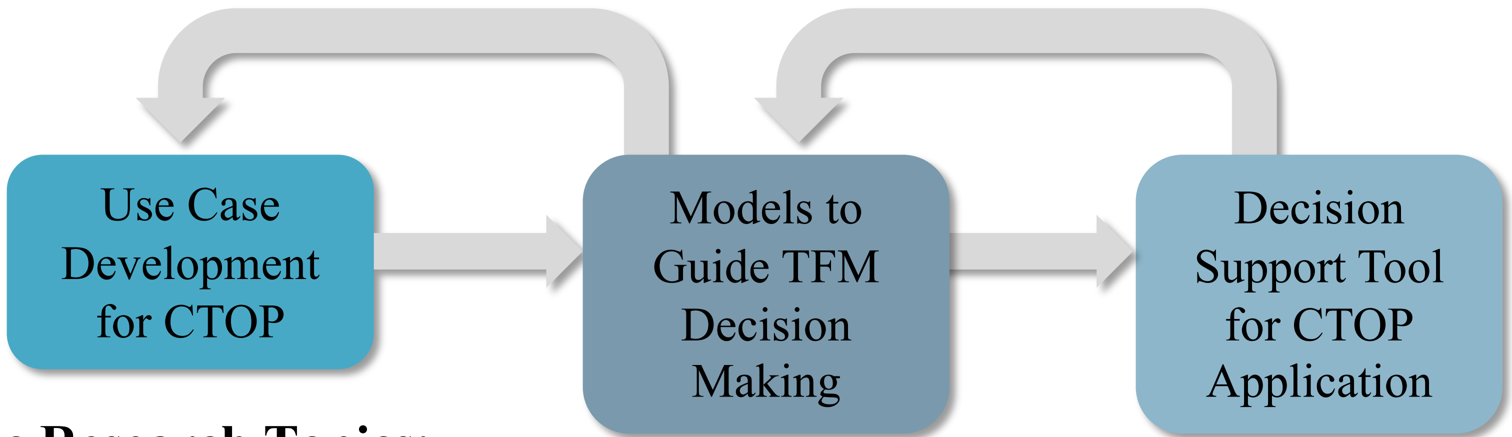
- Regular and widespread use has been slow

CTOP is a very flexible and complex tool

It can (potentially) do a lot of things

It is difficult to understand and use

Project Overview



Specific Research Topics:

- ***A: Use case development***
- Support for FCA definition and location
- Models for FCA rate setting
- ***B: Support for setting CTOP start time and revision decisions***
- ***C: Understanding airline RTC values from historical (AFP) data***
- Modeling and supporting RTC decisions
- ***D: Identification of improved CTOP resource allocation mechanisms***

A: Use Case List

- **Departure management**
- **Single-center en route airspace management**
- **Multi-center en route airspace management**
- **Demand overage**
- **Airport corner post arrival management**
- **Integration with TBFM**
- **Integration of TMIs**
- **Concurrent CTOPs**
- **New York airport through-flow**
- **Oceanic transition airspace**
- **Contingency planning for facility outages**
- **Special Use Airspace management**

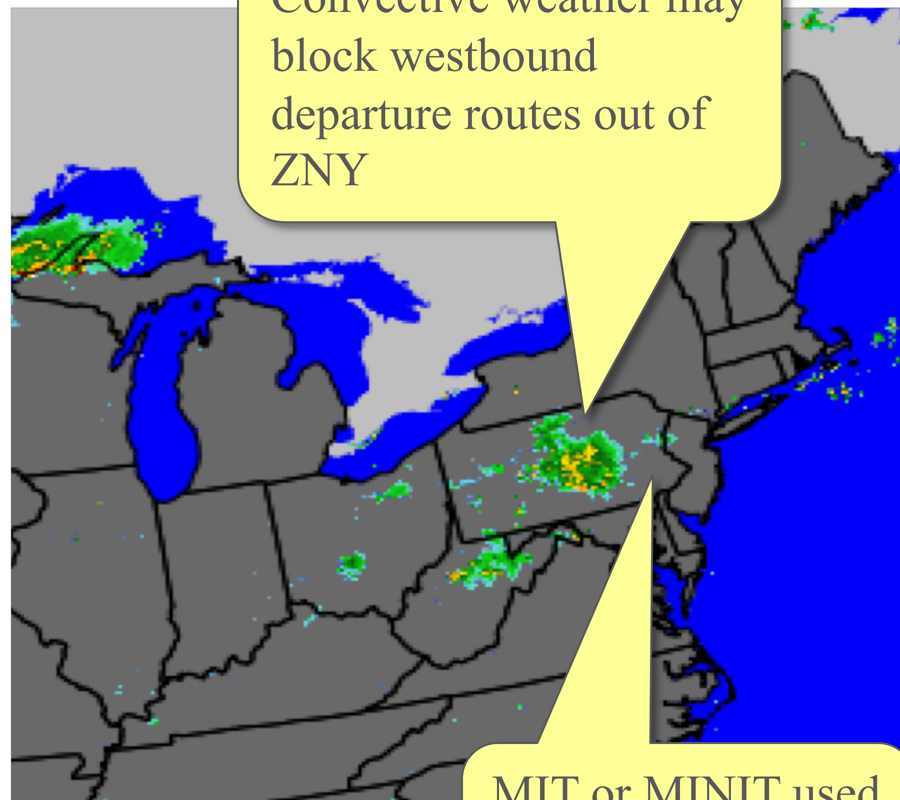
Departure Management (CLT and N90) Use Cases

These two use cases apply CTOP to control:

- flow out of departure fixes at a single airport
- weather is moving across one or more departure fixes

This would be a replacement for

- Miles/minutes-in-trail (MIT/MINIT)
- Mandatory reroutes
- Manual departure reroutes due to route closures



Convective weather may block westbound departure routes out of ZNY

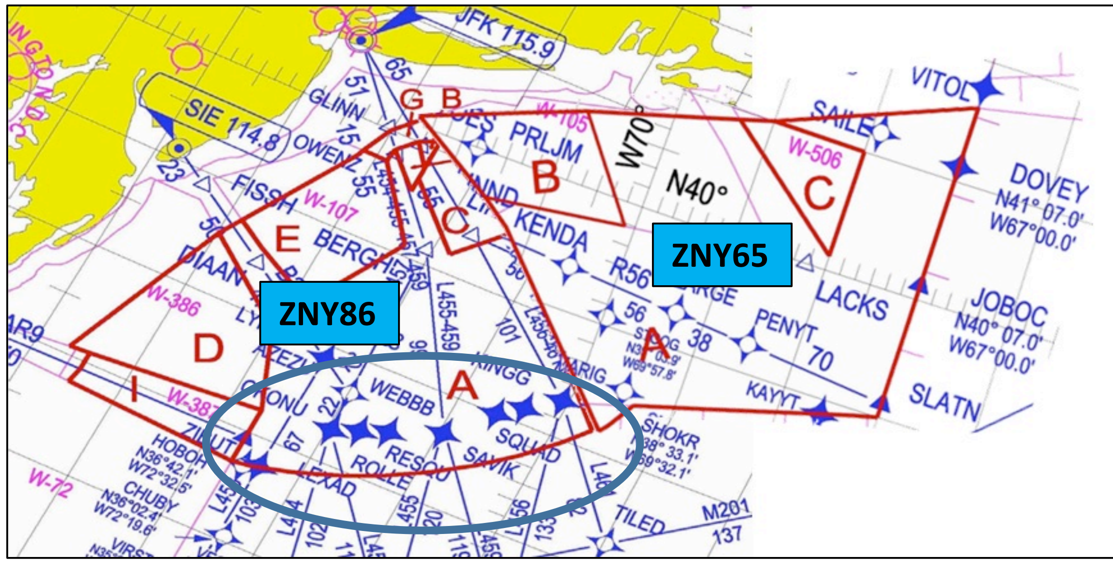
MIT or MINIT used as primary control measure now

Oceanic Transition Airspace Use Case

- Use CTOP to curtail and smooth the flow of traffic into oceanic transition airspace.

- Today, there is inefficiency in sequencing aircraft for procedural separation limits just prior to entering oceanic airspace.

- CTOP can smooth out the flow of aircraft just before departing the CONUS for oceanic airspace.



NASA Use Only

B: Statistical Inference of RTC submissions

UCB developed statistical models to infer airline preferences for rerouting versus ground delay based on AFP data

– Random Utility Models applied to historical data on TMIs

– Compute tradeoff between additional flight time and ground delay (marginal RTC)

Also, used probabilistic clustering to predict TOS routing options

Conclusions

- Assumptions about airline behavior are sound, but marginal RTC much higher than we expected

What we think is going on with airline behavior in AFPs

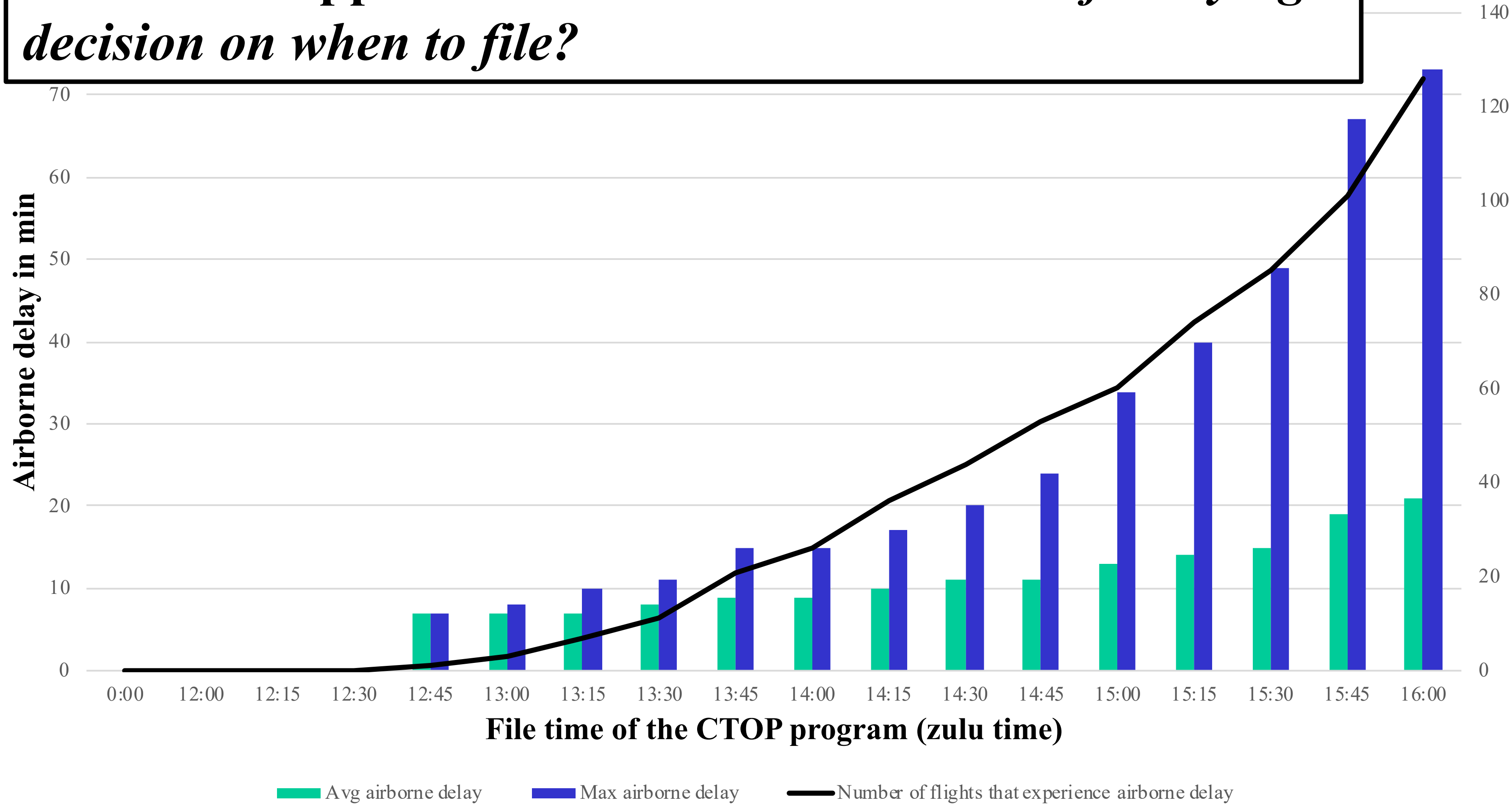
- Airlines may be holding out with high levels of assigned ground delays
- Gambling that their delay will be reduced, as other flights (or theirs) route out
- Since AFP is an unpredictable situation, they may “wait and see” what happens

	Mean Initial	Stdev Initial	Mean Final	Stdev Final
Stay in AFP	65	41	33	51
Route Out	17	15	25	45

- AFP data represents an imperfect sample so further investigation is warranted

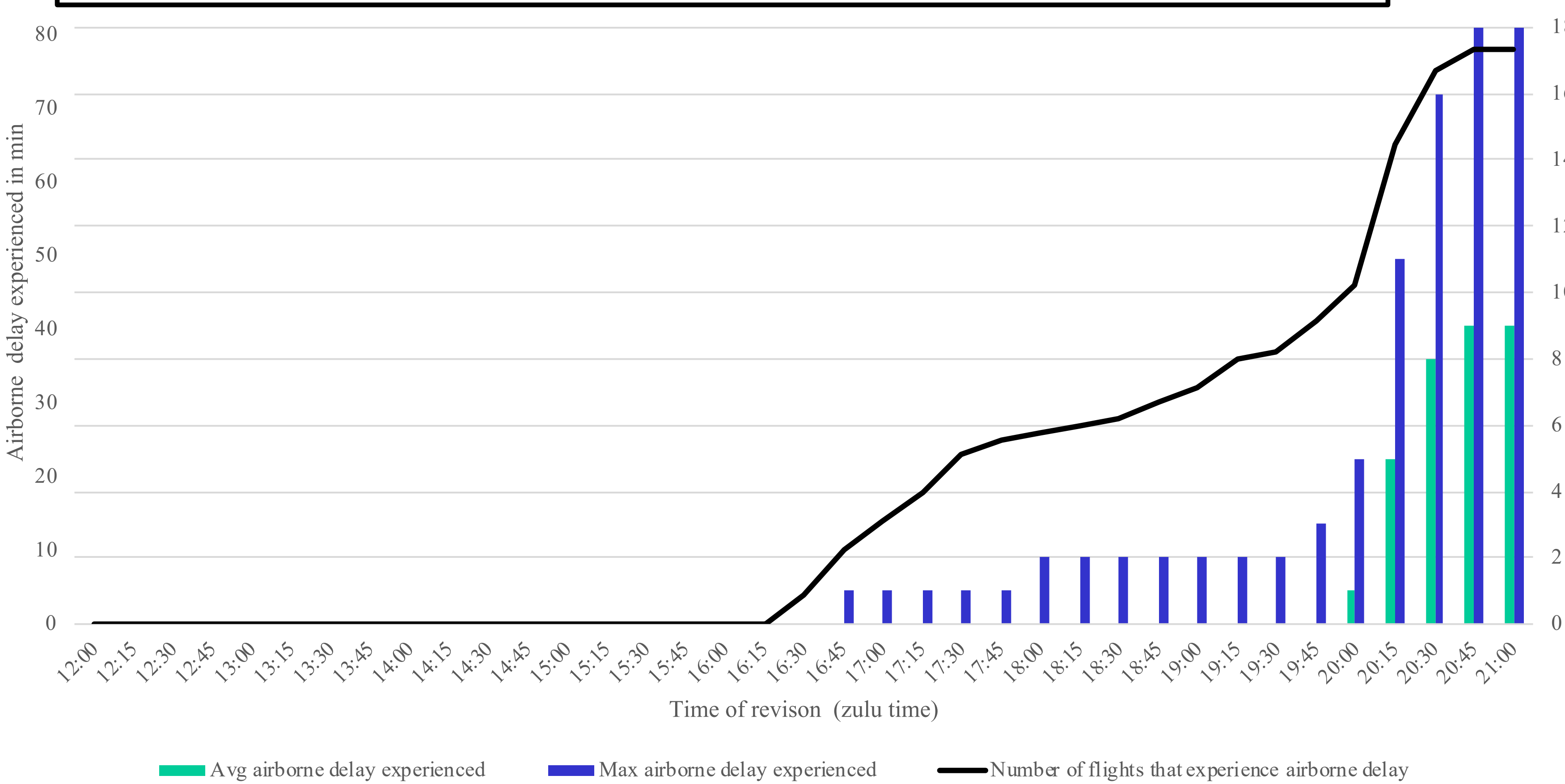
C: Support for CTOP File Time Decision

Risk-based approach: ***What is downside risk of delaying decision on when to file?***



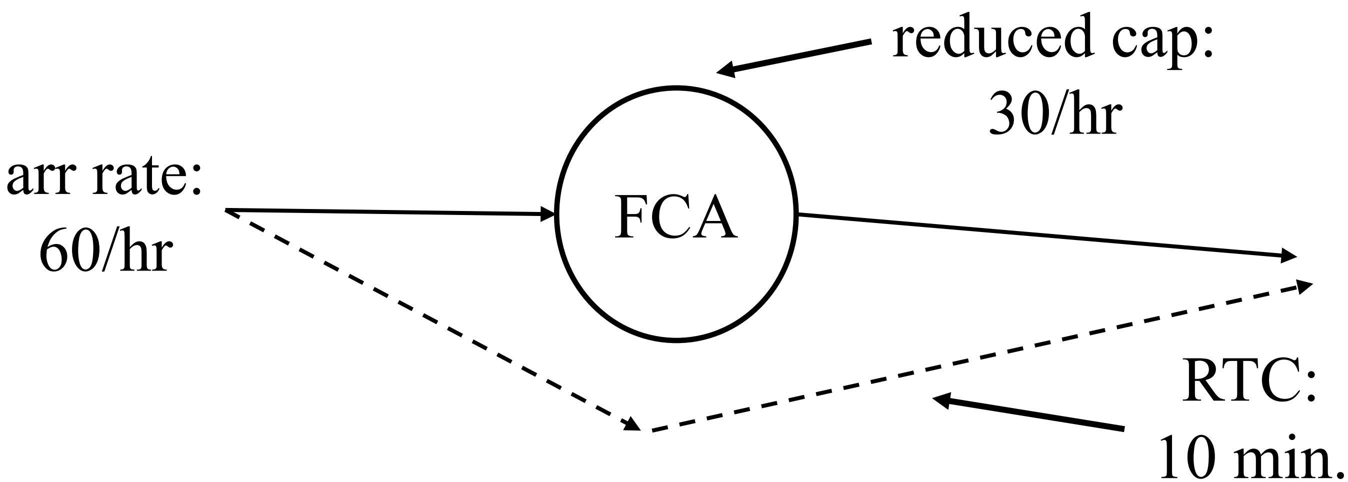
Support for CTOP Revision Decisions

What is downside risk of delaying decision on when to revise?



D: Identified of Improved Resource Allocation Mechanisms

Motivating example: analysis of most basic CTOP Case: single FCA + common TOS



- Single FCA
- Steady flow of more or less identical flights

Identified of Improved Resource Allocation Mechanisms

Original Schedule: 1 flight / min:

SCHED TIME	Flight #	SCHED SLOT
1600	1	1
1601	2	2
1602	3	3
1603	4	4
1604	5	5
1605	6	6
1606	7	7
1607	8	8
1608	9	9
1609	10	10
1610	11	11
1611	12	12
1612	13	13
1613	14	14
1614	15	15
1615	16	16
1616	17	17
1617	18	18

Slot avail w capacity reduced fr 60/hr to 30/hr:

SCHED TIME	Flight #	SCHED SLOT
1600	1	1
1601	2	2
1602	3	3
1603	4	4
1604	5	5
1605	6	6
1606	7	7
1607	8	8
1608	9	9
1609	10	10
1610	11	11
1611	12	12
1612	13	13
1613	14	14
1614	15	15
1615	16	16
1616	17	17
1617	18	18

SLOT AVAIL	TIME
1	1600
	1601
3	1602
	1603
5	1604
	1605
7	1606
	1607
9	1608
	1609
11	1610
	1611
13	1612
	1613
15	1614
	1615
17	1616
	1617

CTOP slot allocation:

SCHED TIME	Flight #
1600	1
1601	2
1602	3
1603	4
1604	5
1605	6
1606	7
1607	8
1608	9
1609	10
1610	11
1611	12
1612	13
1613	14
1614	15
1615	16
1616	17
1617	18

SLOT AVAIL	TIME	DELAY
1	1600	0
	1601	
3	1602	1
	1603	
5	1604	2
	1605	
7	1606	3
	1607	
9	1608	4
	1609	
11	1610	5
	1611	
13	1612	6
	1613	
15	1614	7
	1615	
17	1616	8
	1617	

Note w each RTC = 10, all flights (so far) will take ground delay rather than reroute

CTOP slot allocation:

Flight 12 would incur an 11 min delay > RTC=10 ➔ reroute

TIME	Flight #
1609	10
1610	11
1611	12
1612	13
1613	14
1614	15
1615	16
1616	17
1617	18
1618	19
1619	20
1620	21
1621	22
1622	23
1623	24

SLOT AVAIL	TIME	DELAY
19	1618	9
	1619	
21	1620	10
	1621	
23	1622	10
	1623	
25	1624	10

CTOP slot allocation:

Reroute

"cost" = RTC = 10

Reroute

"cost" = RTC = 10

TIME	Flight #
1609	10
1610	11
1611	12
1612	13
1613	14
1614	15
1615	16
1616	17
1617	18
1618	19
1619	20
1620	21
1621	22
1622	23
1623	24

SLOT AVAIL	TIME	DELAY
19	1618	9
	1619	
21	1620	10
	1621	
23	1622	10
	1623	
25	1624	10

Once a congested state is reached all flights incur a cost of 10

An alternative approach: if high congestion is anticipated, maintain a very short queue of flights waiting to go thru the FCA by starting to reroute flights much earlier

An alternative idealized allocation:

Reroute

"cost" = RTC = 10

Reroute

"cost" = RTC = 10

Reroute

"cost" = RTC = 10

Reroute

"cost" = RTC = 10

SCHED TIME	Flight #	SLOT AVAIL	TIME	DELAY
1600	1	1	1600	0
1601	2		1601	
1602	3	3	1602	0
1603	4		1603	
1604	5	5	1604	0
1605	6		1605	
1606	7	7	1606	0
1607	8		1607	
1608	9	9	1608	0
1609	10		1609	
1610	11	11	1610	
1611	12		1611	
1612	13	13	1612	
1613	14		1613	
1614	15	15	1614	
1615	16		1615	
1616	17	17	1616	
1617	18		1617	

All rerouted flights (1/2) incur cost of 10; all other flights (1/2) incur 0 cost. ***In this ex w 25 flights, tot cost reduced from 195 to 120.***

Practical Approaches

1. Balanced Priority Resource Allocation (BPRA): Modify CTOP information and algorithms to support "short-queue" / reroute decisions
   - Airline provide flight priorities to determine, which to reroute, which to keep in queue
   - Method for insuring balance / equity among airlines
   - Dynamically start / stop

2. Apply Compression-Like procedure to enable intra- and inter- airline flight substitutions to achieve desired impact
   - When as each CTOP slot assignment is made an iteration of a compression-like algorithm can be made.
   - Vers 1 requires no new airline input; vers 2 achieves better benefits but requires additional airline information transfer.

Initial testing shows promise for both procedures but algorithmic enhancements and more testing required.

While this project has many different, specific components, its principal goal is to develop models and capabilities that help move CTOP to an effective tool broadly used within the NAS.