Measuring Terminal Area Performance

A Proposed Methodology

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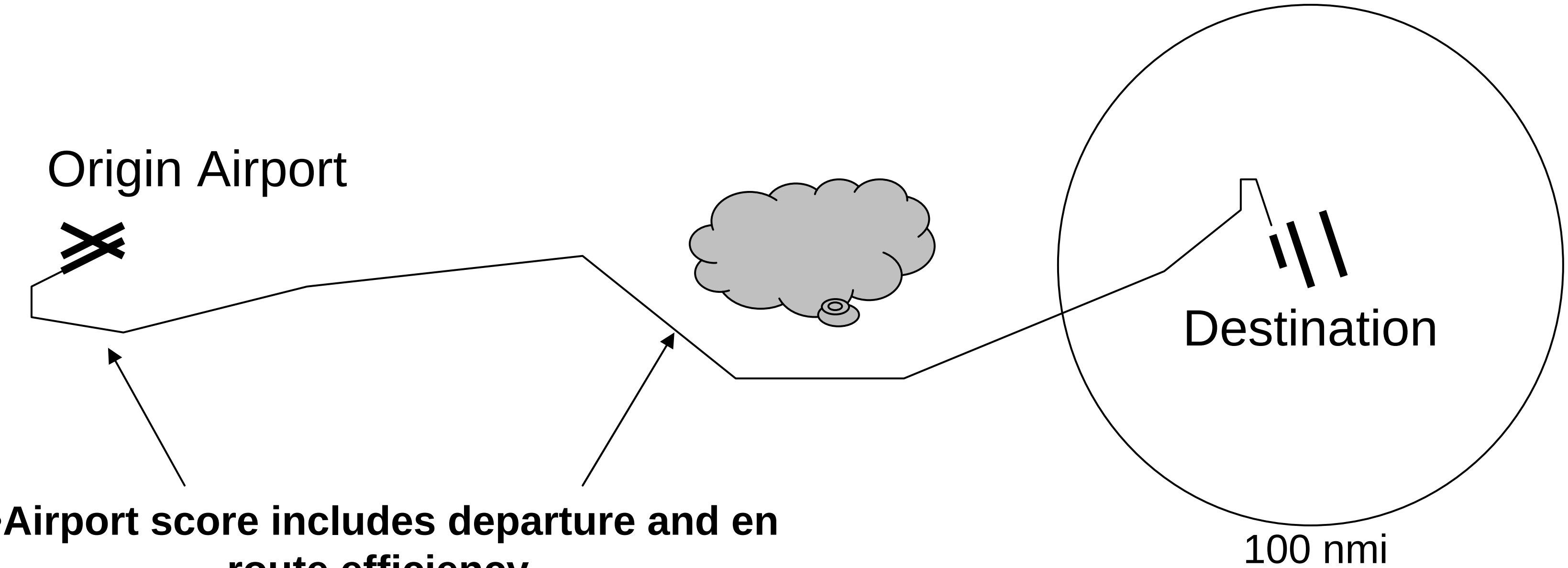
Background

- ATO goal is to measure performance at all levels
- Need a measure of Air Traffic Control performance for the arrival phase of flight
- Existing Airport Efficiency Rating (AER) includes en route inefficiencies

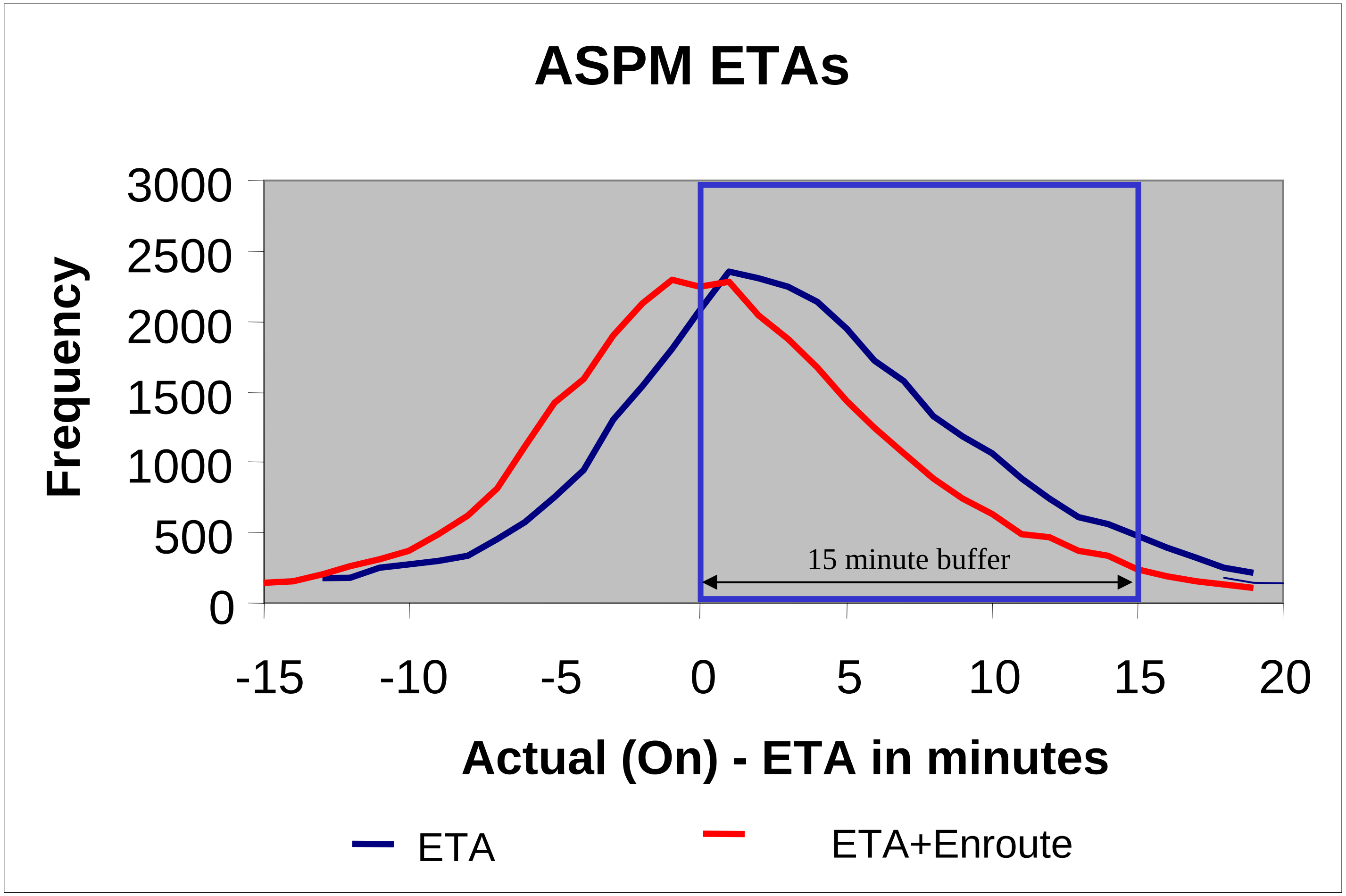
Current Airport Efficiency Rating

Airport Demand is based on ETA
ETA = Departure Time + User Filed ETE



- **Airport score includes departure and en route efficiency.**
- **Score is also affected by varying user adjustments to the filed ETE.**

Current Airport Efficiency Rating



Goal

- Develop a metric focused on air traffic control performance in the terminal environment
- Use existing route structure and acceptance rates as benchmark
- Metric should be valid under busy and non-busy conditions

Four Factors Influence ETA Accuracy

- A/C Type,Winds and Flight Plan Routing (incl. IFR/VFR and landing direction)
- Queue Length
- Order of Arrival
- ***TRACON/ATCT Performance***
    - Inter-arrival Spacing or “Rate”

Terminal Area Scoring Method

Model "Unimpeded" Trajectories to Runway

(from 100 miles)

Allocate demand to feasible "slots"

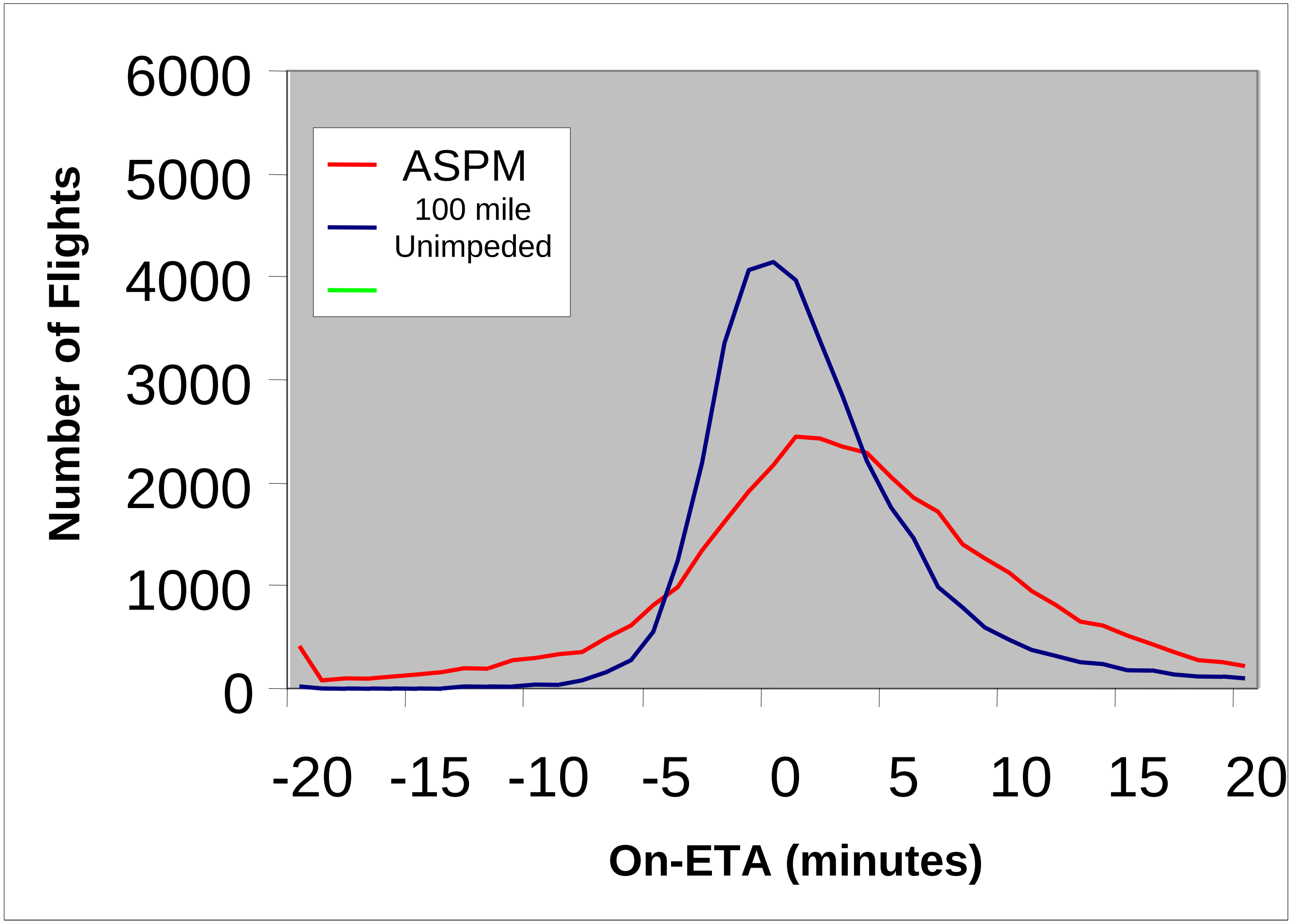
Capacity Constraints

Measure actual arrivals versus allocated slots

Use "TMA-like" scheduling logic to estimate feasible arrival slots.

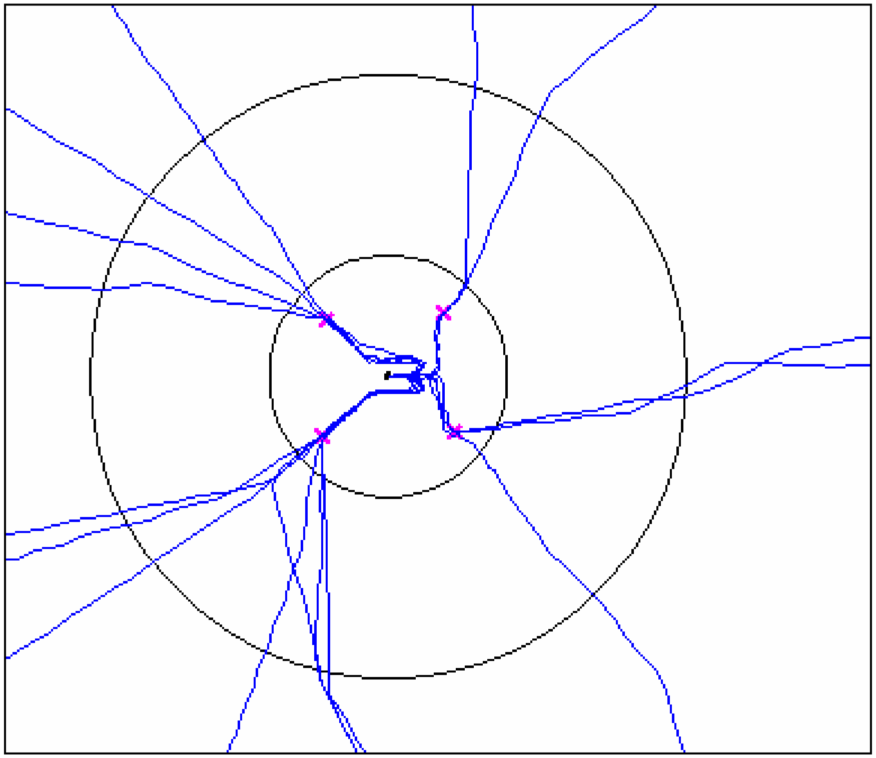
Unimpeded ETA

ASPM ETA = Off Time + ETE

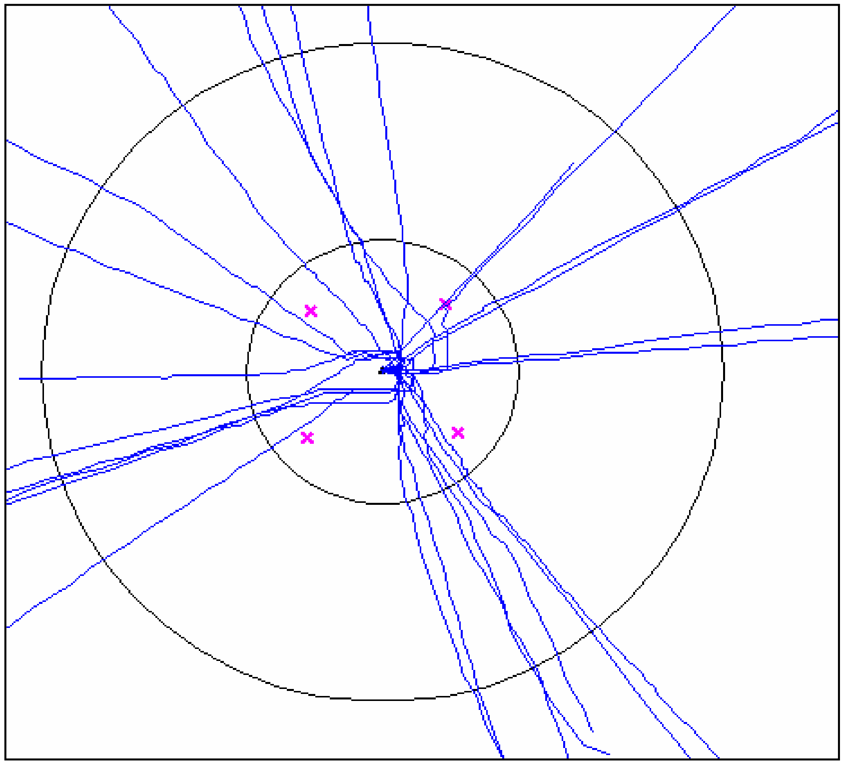


Unimpeded Flights

With and Without Structure

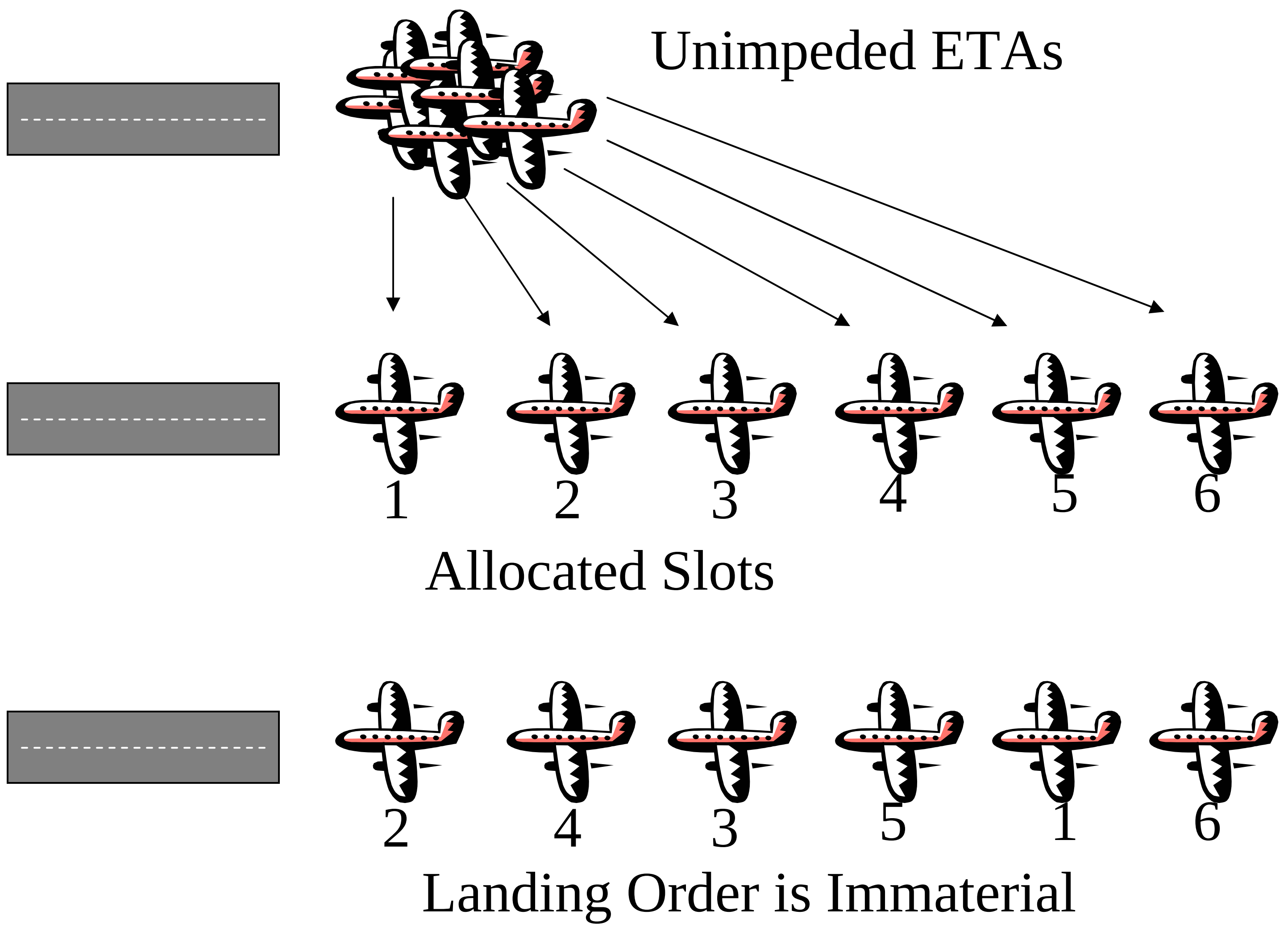


7/9/03 22:30-22:45

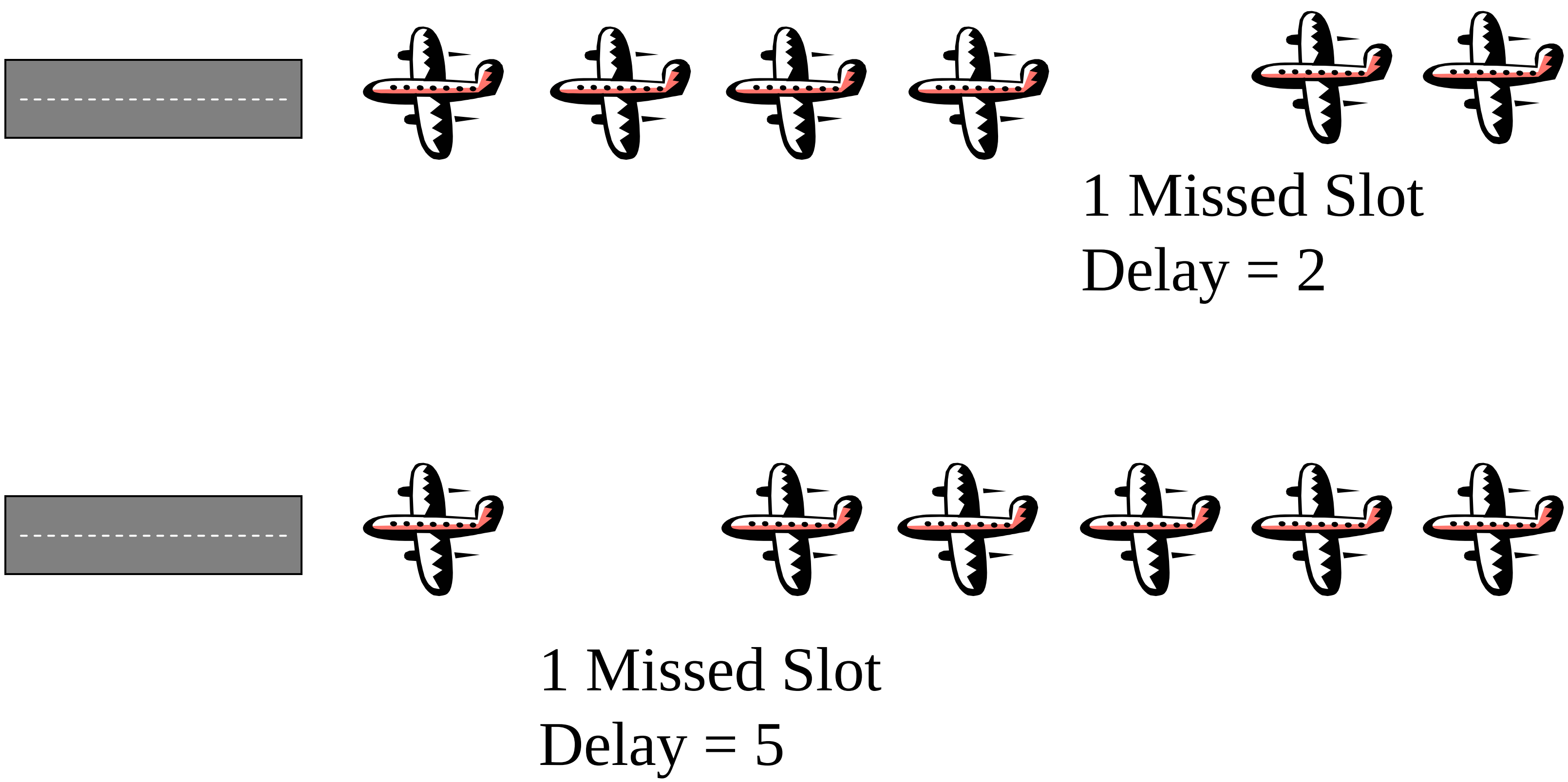


7/17/03 1:00 am – 4:00 am.

Slots Concept



Slot Method (cont)



Slot Scoring Methodology

Time	Demand	AAR Available	Available	Assigned	Arrivals	Assignment Queue	Service Queue	Delay	Missed Slots
7/9/2003 14:10	3	1	1	1	1	2	0	0	0
7/9/2003 14:11	1	2	2	2	1	1	1	1	1
7/9/2003 14:12	1	2	2	2	1	0	2	3	1
7/9/2003 14:13	2	1	1	1	1	1	2	1	0
7/9/2003 14:14	1	2	2	2	2	0	2	3	0
7/9/2003 14:15	1	2	2	1	1	0	2	1	1
7/9/2003 14:16	2	1	1	1	2	1	1	1	0
7/9/2003 14:17	1	2	2	2	1	0	2	5	1
7/9/2003 14:18	1	1	1	1	0	0	3	3	1
7/9/2003 14:19	1	2	2	1	1	0	3	2	1
7/9/2003 14:20	1	2	2	1	1	0	3	3	1
7/9/2003 14:21	0	1	1	0	2	0	1		0
7/9/2003 14:22	4	2	2	2	0	2	3	3	2
7/9/2003 14:23	2	1	1	1	2	3	2	2	0
7/9/2003 14:24	1	2	2	2	1	2	3	4	1
7/9/2003 14:25	1	2	2	2	2	1	3	7	0
7/9/2003 14:26	0	1	1	1	0	0	4	3	1
7/9/2003 14:27	2	2	2	2	1	0	5	7	1
7/9/2003 14:28	1	1	1	1	1	0	5	3	0
7/9/2003 14:29	2	2	2	2	2	0	5	7	0
7/9/2003 14:30	1	2	2	1	1	0	5	4	1
7/9/2003 14:31	1	1	1	1	2	0	4	3	0
7/9/2003 14:32	2	2	2	2	1	0	5	8	1
7/9/2003 14:33	0	1	1	0	1	0	4		0
7/9/2003 14:34	1	2	2	1	2	0	3	3	0
7/9/2003 14:35	1	2	2	1	1	0	3	3	1
7/9/2003 14:36	1	1	1	1	0	0	4	2	1
7/9/2003 14:37	1	2	2	1	2	0	3	3	0
7/9/2003 14:38	2	1	1	1	2	1	2	2	0
7/9/2003 14:39	0	2	2	1	0	0	3	1	1
7/9/2003 14:40	0	2	2	0	3	0	0		0
7/9/2003 14:41	2	1	1	1	2	1	1	0	0
7/9/2003 14:42	0	2	2	1	1	0	-1	-1	-1
7/9/2003 14:43	0	1	1	0	0	0	-1		
7/9/2003 14:44	1	2	2	1	2	0	-2	-2	0
7/9/2003 14:45	1	2	2	1	1	0	-2	-1	-1
7/9/2003 14:46	2	1	1	1	1	1	-2	-2	0
7/9/2003 14:47	2	2	2	2	0	1	0	-3	-2
7/9/2003 14:48	2	1	1	1	1	2	0	0	0
7/9/2003 14:49	0	2	2	2	2	0	0	0	0
7/9/2003 14:50	0	2	2	0	1	0	-1		
7/9/2003 14:51	0	1	1	0	0	0	-1		
7/9/2003 14:52	1	2	2	1	0	0	0	-2	-1
7/9/2003 14:53	0	1	1	0	1	0	-1		0
7/9/2003 14:54	1	2	2	1	0	0	0	-1	-1
7/9/2003 14:55	0	2	2	0	0	0	0		
7/9/2003 14:56	0	1	1	0	0	0	0		
7/9/2003 14:57	0	2	2	0	0	0	0		
7/9/2003 14:58	0	1	1	0	0	0	0		
7/9/2003 14:59	0	2	2	0	0	0	0		
7/9/2003 15:00	0	2	2	0	0	0	0		
7/9/2003 15:01	0	1	1	0	0	0	0		
7/9/2003 15:02	0	2	2	0	1	0	-1		
7/9/2003 15:03	0	2	2	0	1	0	-2		
7/9/2003 15:04	1	1	1	1	1	0	-2	-2	0
7/9/2003 15:05	0	2	2	0	0	0	-2		
7/9/2003 15:06	0	2	2	0	1	0	-3		
7/9/2003 15:07	1	1	1	1	1	0	-3	-4	0
7/9/2003 15:08	2	2	2	2	0	0	-1	-6	-2
7/9/2003 15:09	4	2	2	2	2	2	-1	-2	0
7/9/2003 15:10	1	1	1	1	1	2	-1	-1	0
7/9/2003 15:11	0	2	2	2	1	0	0	-1	-1
7/9/2003 15:12	2	2	2	2	1	0	1	1	1
7/9/2003 15:13	0	1	1	0	2	0	-1		0
7/9/2003 15:14	0	2	2	0	0	0	-1		
7/9/2003 15:15	2	2	2	2	1	0	0	-2	-1
7/9/2003 15:16	3	1	1	1	3	2	-2	0	0
7/9/2003 15:17	1	2	2	2	0	1	0	-2	-2
7/9/2003 15:18	0	1	1	1	1	0	0	0	0
7/9/2003 15:19	1	2	2	1	2	0	-1	0	0
7/9/2003 15:20	1	2	2	1	0	0	0	-1	-1
7/9/2003 15:21	2	1	1	1	2	1	-1	0	0
7/9/2003 15:22	1	2	2	2	2	0	-1	-1	0

Examine in More Detail

Real methodology more complicated:

1 Hour 15 minutes shown at left

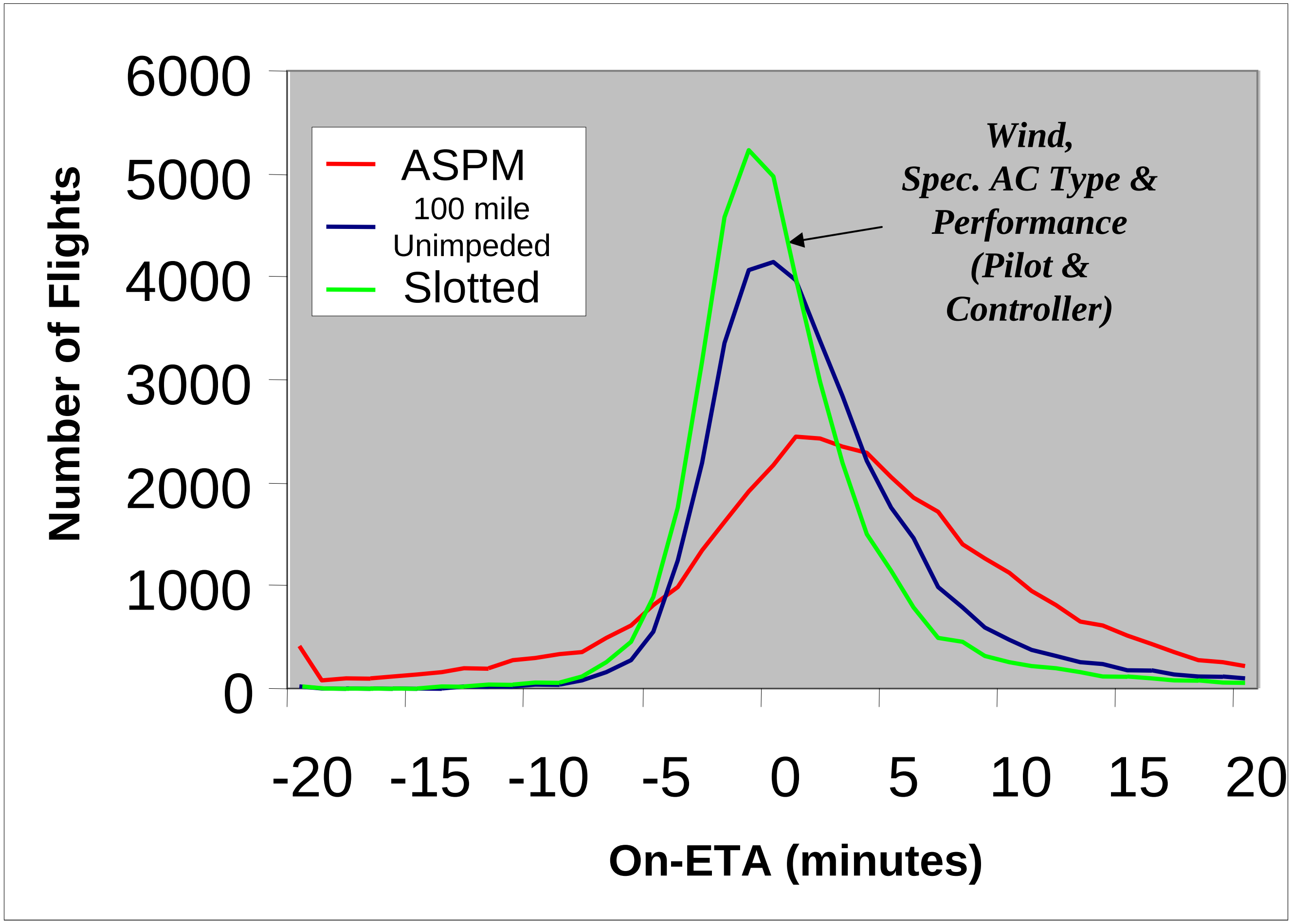
Detailed Slot Example

Time	Demand	AAR Available	Available	Assigned	Arrivals	Assignment Queue	Service Queue	Delay	Missed Slots
7/9/2003 14:10	3	1	1	1	1	2	0	0	0
7/9/2003 14:11	1	2	2	2	1	1	1	1	1
7/9/2003 14:12	1	2	2	2	1	0	2	3	1
7/9/2003 14:13	2	1	1	1	1	1	2	1	0
7/9/2003 14:14	1	2	2	2	2	0	2	3	0
7/9/2003 14:15	1	2	2	1	1	0	2	1	1
7/9/2003 14:16	2	1	1	1	2	1	1	1	0
7/9/2003 14:17	1	2	2	2	1	0	2	5	1
7/9/2003 14:18	1	1	1	1	0	0	3	3	1
7/9/2003 14:19	1	2	2	1	1	0	3	2	1
7/9/2003 14:20	1	2	2	1	1	0	3	3	1
7/9/2003 14:21	0	1	1	0	2	0	1		0
7/9/2003 14:22	4	2	2	2	0	2	3	3	2
7/9/2003 14:23	2	1	1	1	2	3	2	2	0
7/9/2003 14:24	1	2	2	2	1	2	3	4	1
7/9/2003 14:25	1	2	2	2	2	1	3	7	0
7/9/2003 14:26	0	1	1	1	0	0	4	3	1
7/9/2003 14:27	2	2	2	2	1	0	5	7	1
7/9/2003 14:28	1	1	1	1	1	0	5	3	0
7/9/2003 14:29	2	2	2	2	2	0	5	7	0
7/9/2003 14:30	1	2	2	1	1	0	5	4	1
7/9/2003 14:31	1	1	1	1	2	0	4	3	0
7/9/2003 14:32	2	2	2	2	1	0	5	8	1
7/9/2003 14:33	0	1	1	0	1	0	4		0
7/9/2003 14:34	1	2	2	1	2	0	3	3	0
7/9/2003 14:35	1	2	2	1	1	0	3	3	1
7/9/2003 14:36	1	1	1	1	0	0	4	2	1
7/9/2003 14:37	1	2	2	1	2	0	3	3	0
7/9/2003 14:38	2	1	1	1	2	1	2	2	0
7/9/2003 14:39	0	2	2	1	0	0	3	1	1
7/9/2003 14:40	0	2	2	0	3	0	0		0

AAR = 96 per Hour

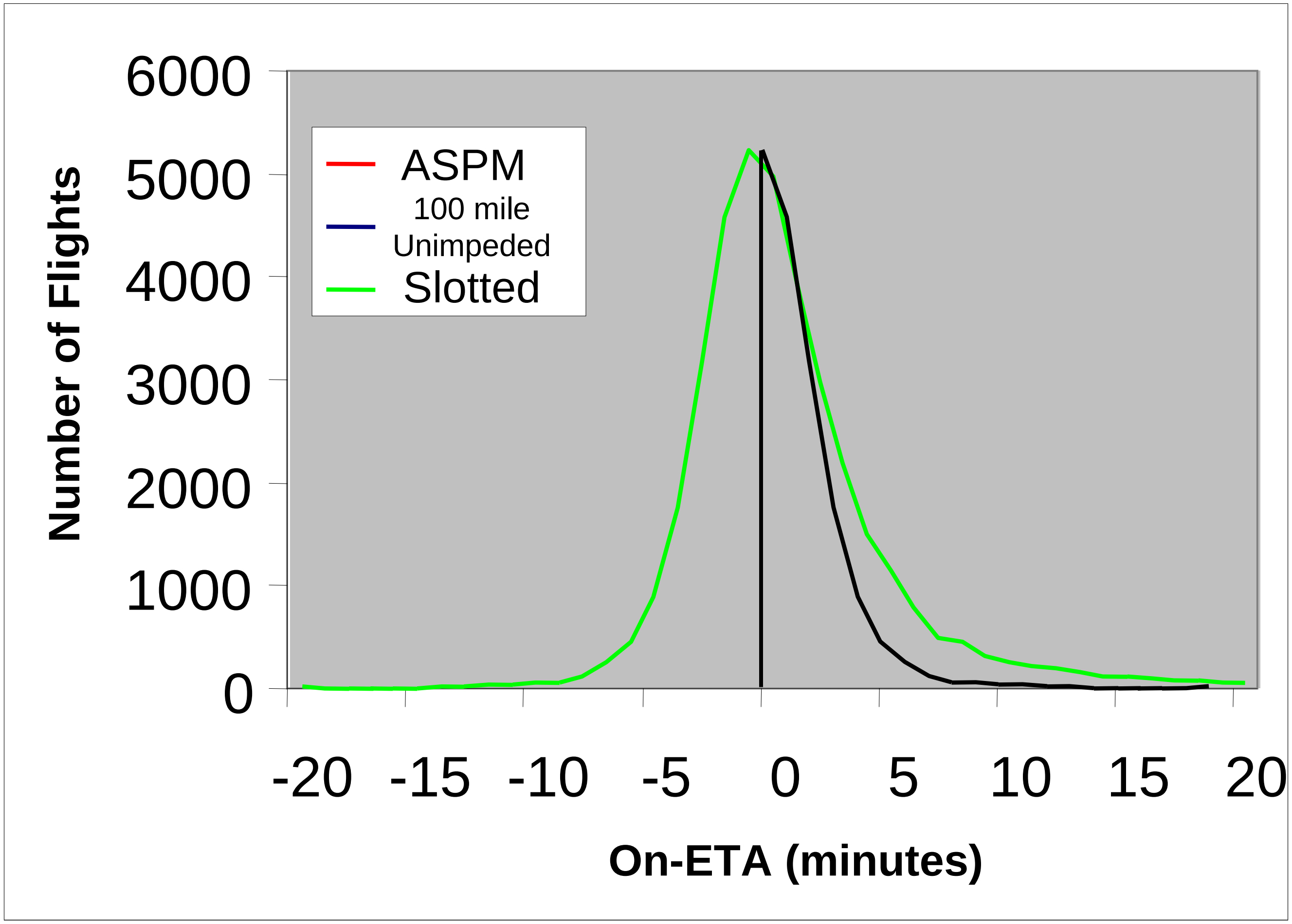
Unimpeded ETA

ASPM ETA = Off Time + ETE

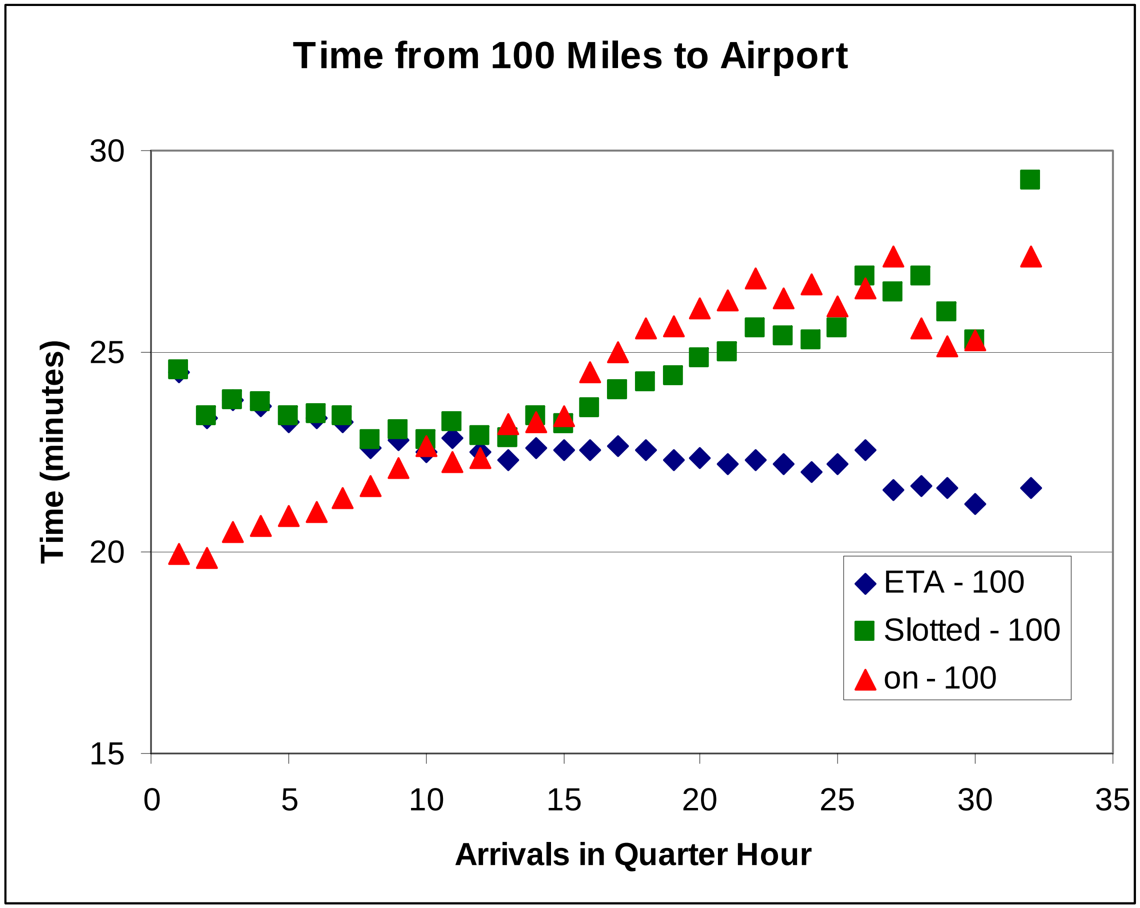


Unimpeded ETA

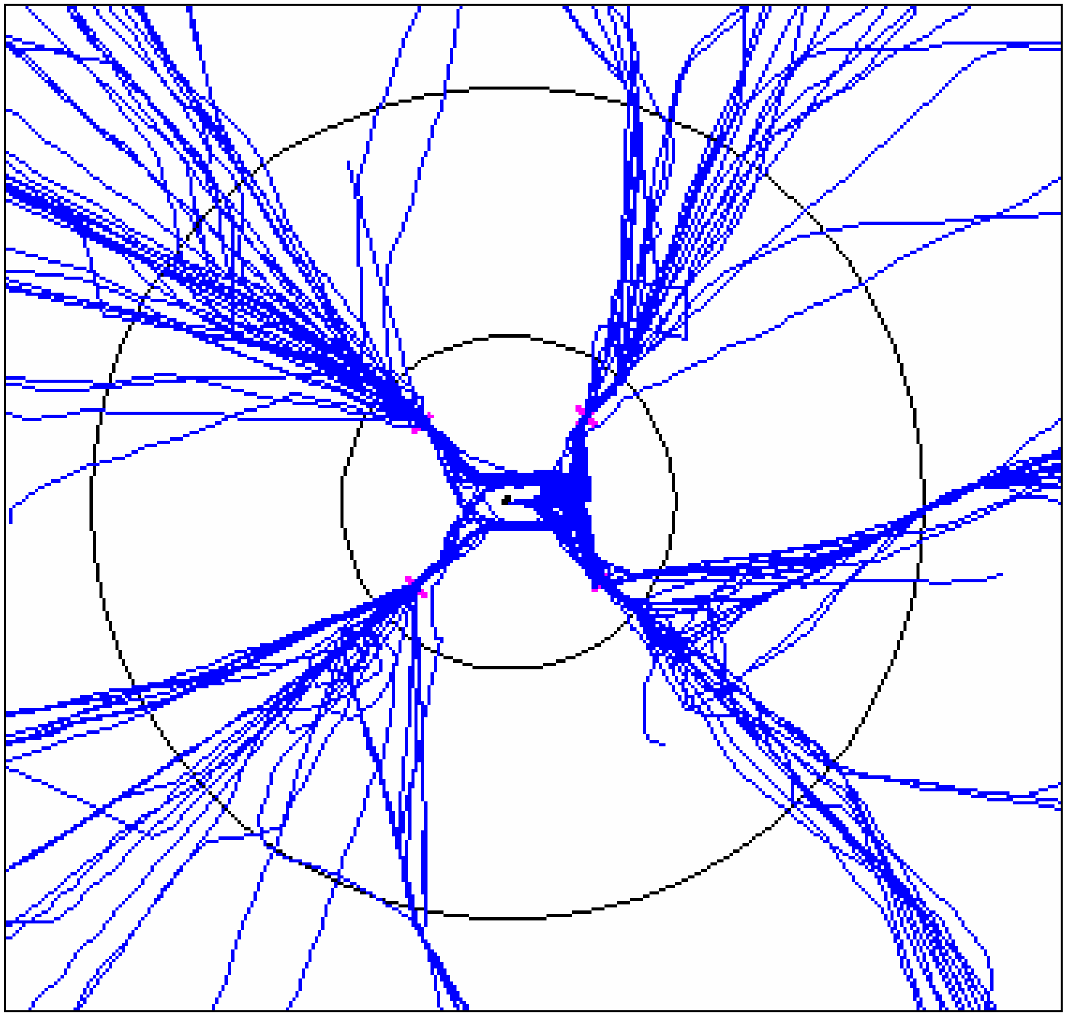
ASPM ETA = Off Time + ETE



Effect of Capacity on Flight Times

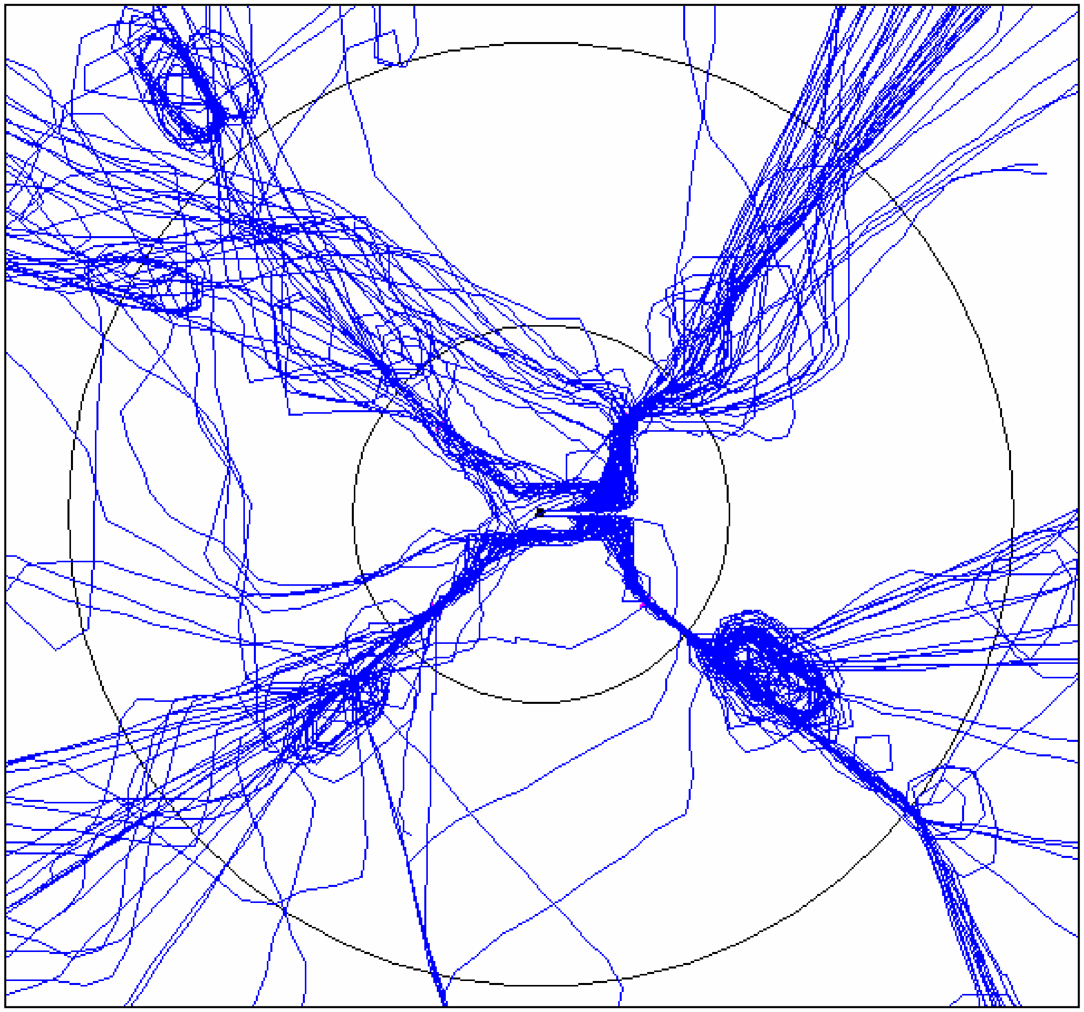


High Score Example



7/9/03 21:30 – 23:30 Score 121

Low Score Example



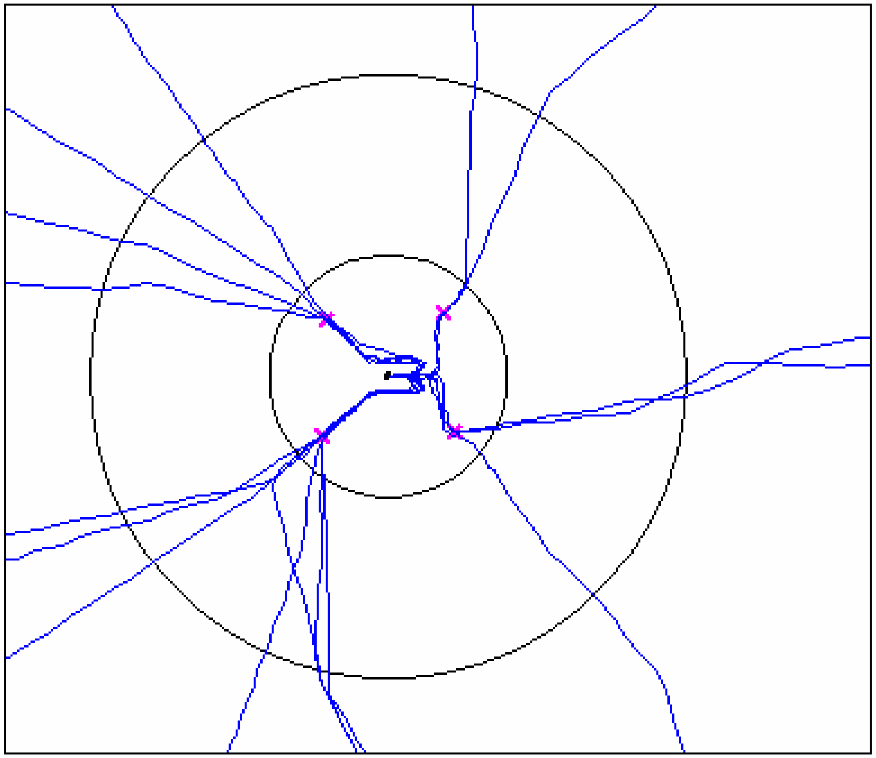
7/10/03 14:30-16:30 Score 60

Model Route Structure or Not?

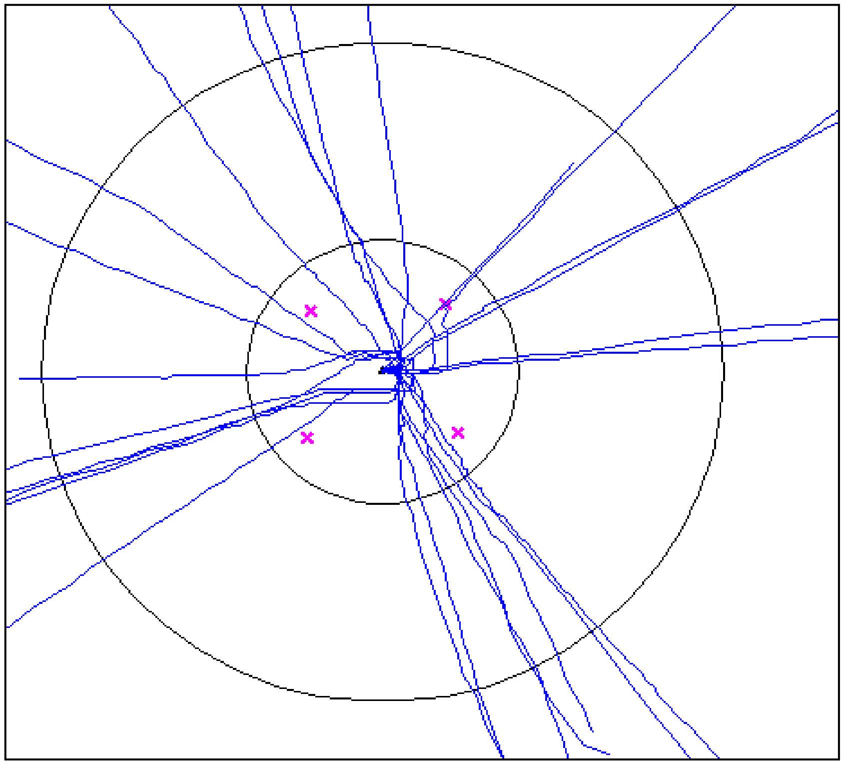
- Scoring depends on definition of Unimpeded
- Method 1 scores against optimal trajectories ignoring airspace constraints and procedures (similar to approaches during the middle of the night)
- Method 2 scores against trajectories which include airspace constraints and procedures

Unimpeded Flights

With and Without Structure



7/9/03 22:30-22:45



7/17/03 1:00 am – 4:00 am.

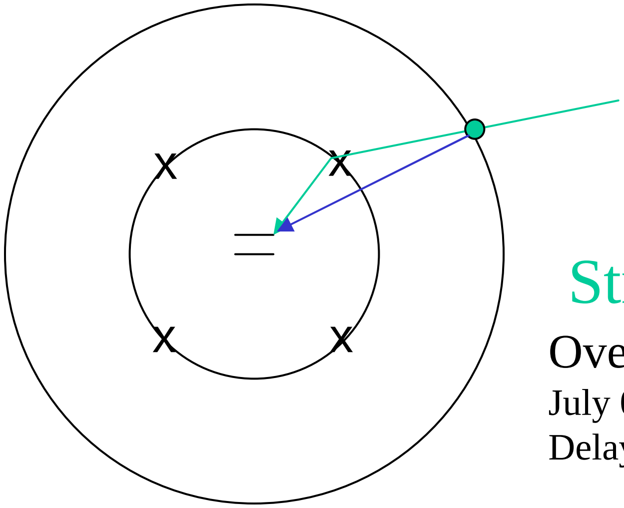
Effect of Structure on ETAs

Unstructured

Direct to Airport

July 03 Score – **79.2**

Delay/ Flight – **2.4 min**

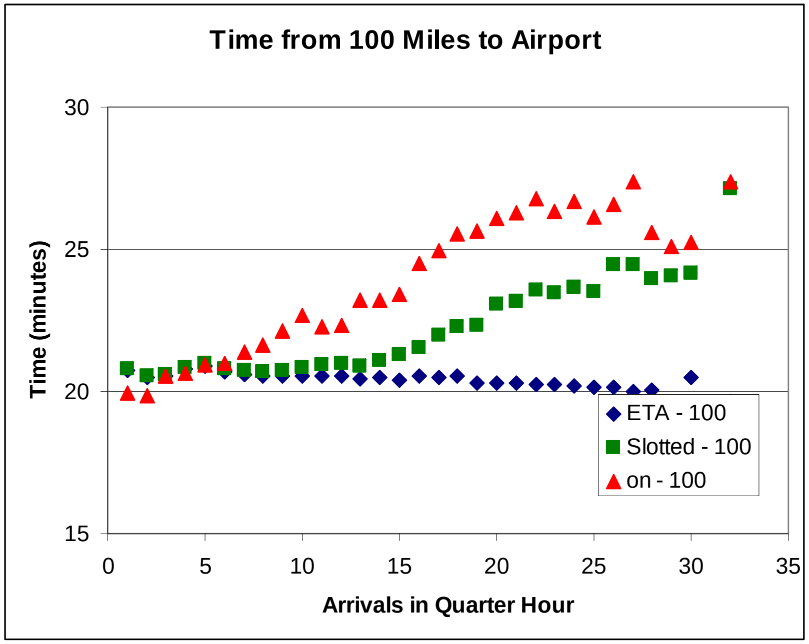


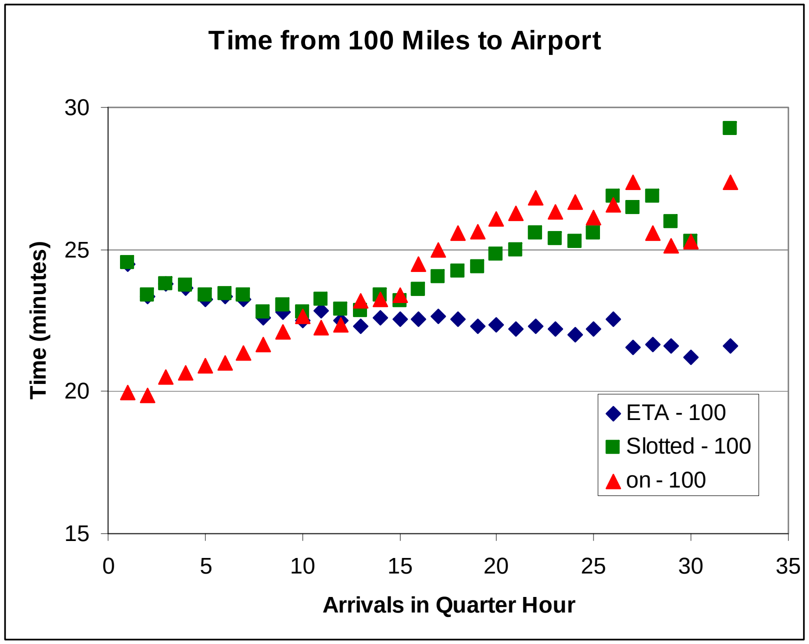
Structured

Over Arrival Fix

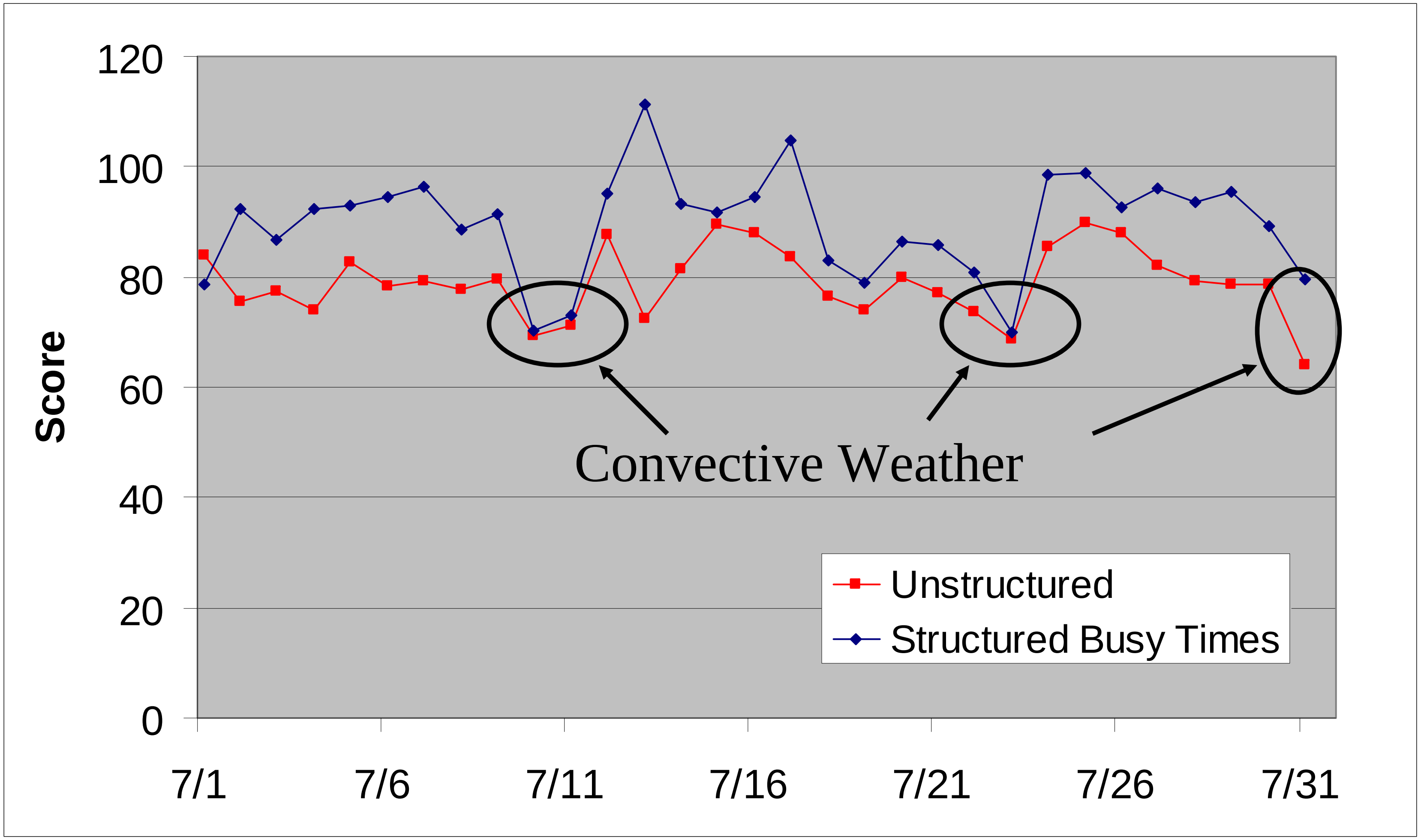
July 03 Score – **89.6**

Delay/Flight - **0.7 min**

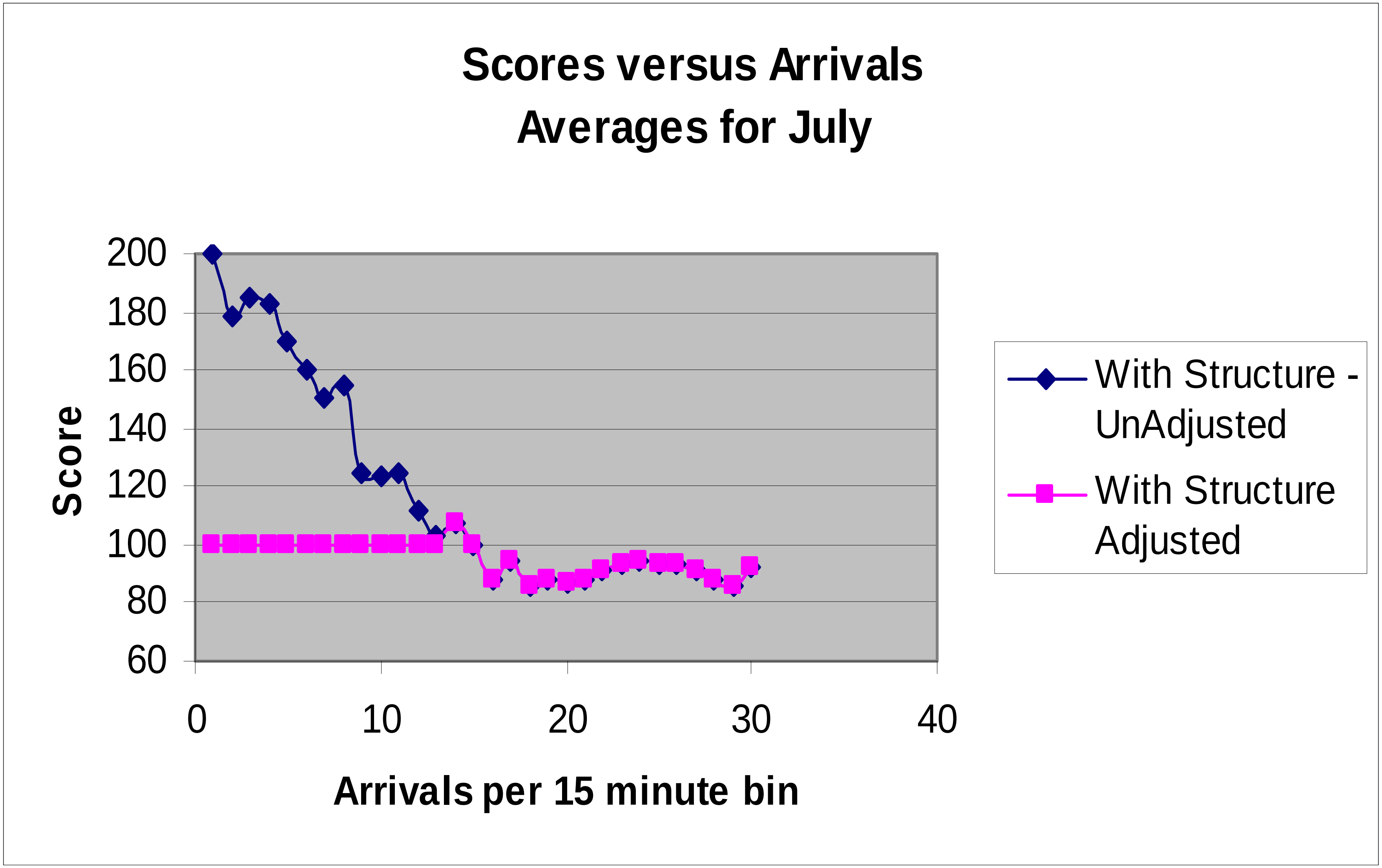




Scores



120
100
80
60
40
20
0
Score
7/1
7/6
7/11
7/16
7/21
7/26
7/31
Convective Weather
Unstructured
Structured Busy Times

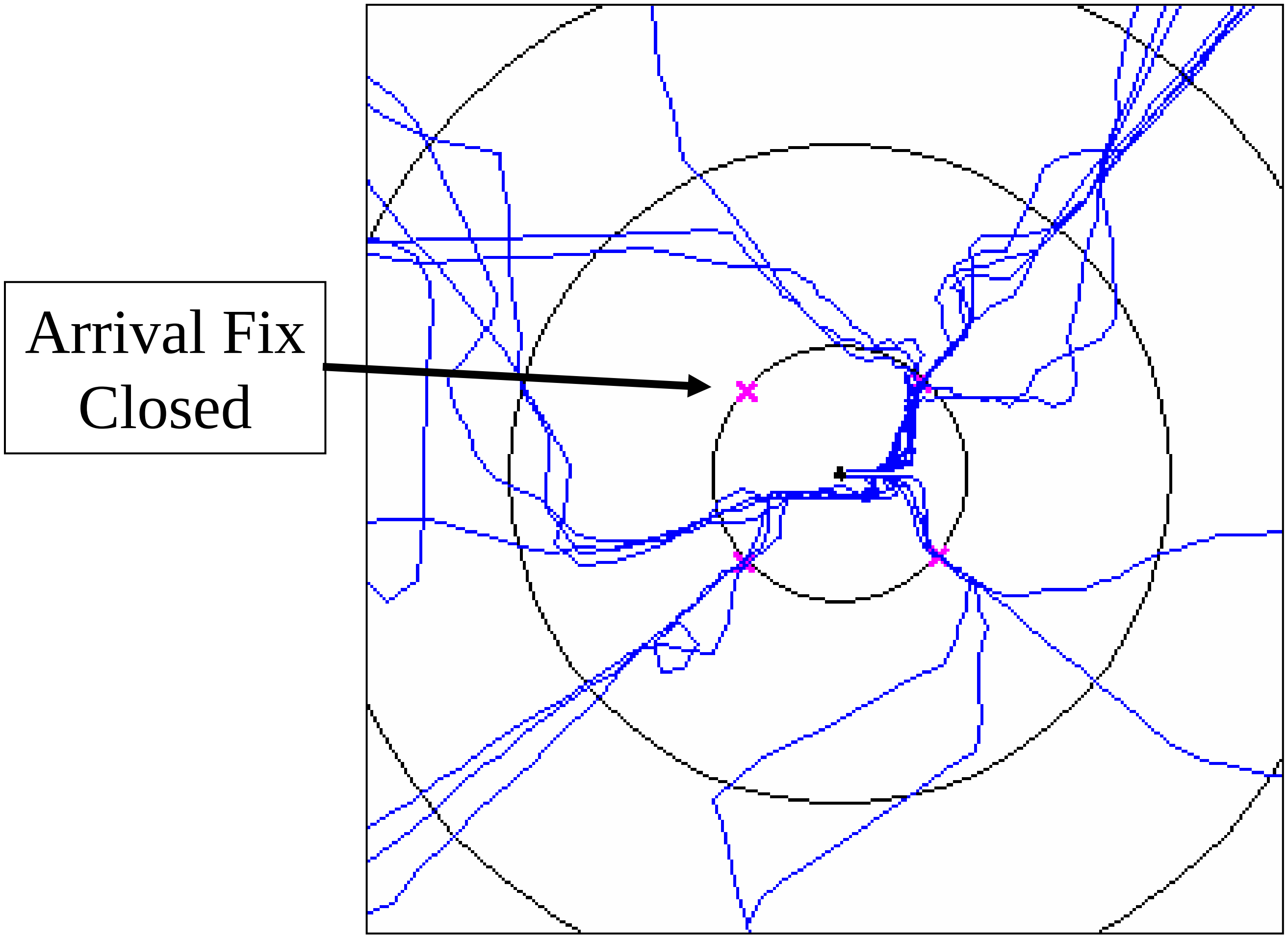

Scores versus Arrivals
Averages for July
Score
200
180
160
140
120
100
80
60
0
10
20
30
40
Arrivals per 15 minute bin
With Structure - UnAdjusted
With Structure Adjusted

Limitations of New Scoring Method

- Convective Weather
  - Need to develop convective weather filter
    - No score during convective weather
- AAR
  - Current ASPM AARs have data quality problems
  - Possible independent measure of AAR.
  - Proposed Near-Term AAR Correction
- Accuracy of ETA’s

Weather Disruption

7/10/03 4:15 pm



Proposed Near-Term AAR Correction:

- If AAR is set too low, then more aircraft will land than the AAR.
- If actual arrivals > AAR for two consecutive 15 minute periods, then AAR is adjusted upward for scoring purposes.
- Minimizes possibility of artificially high scores due to artificially low AARs.

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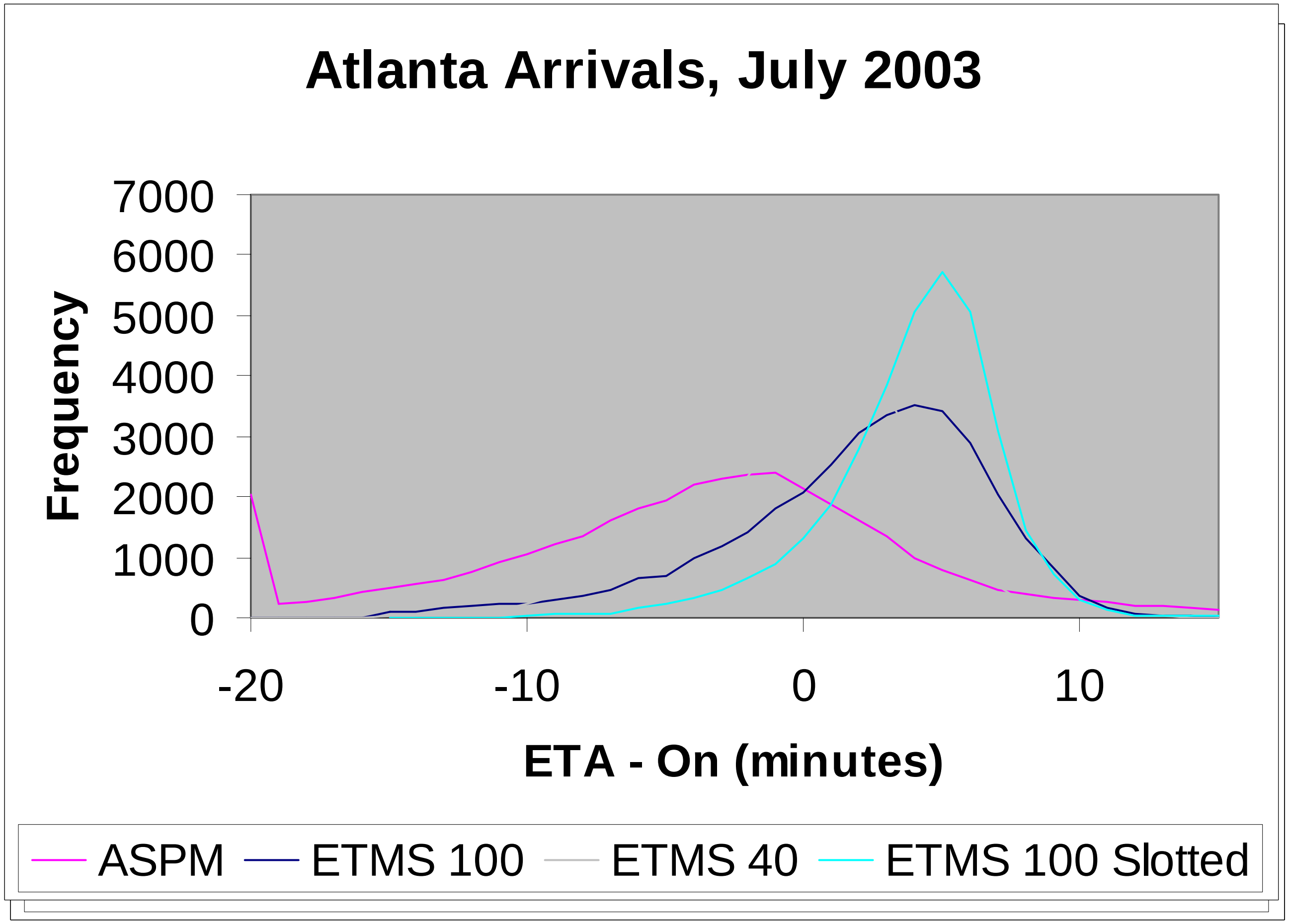
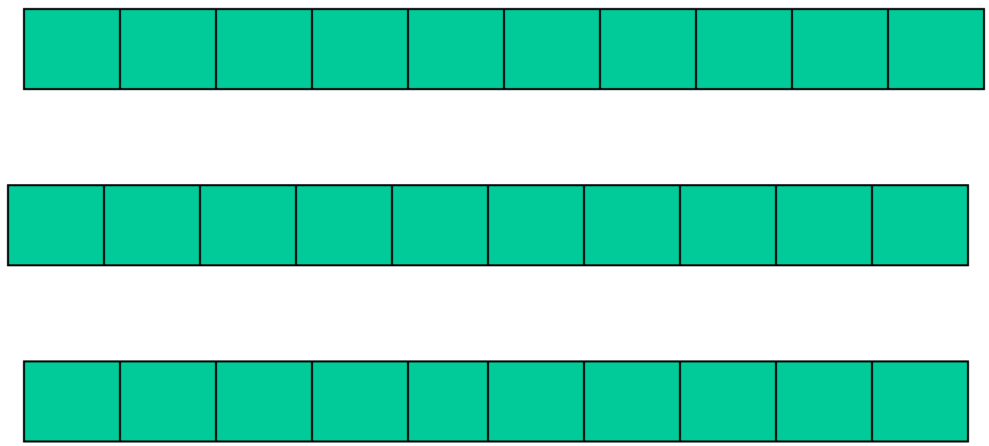
Current Airport Efficiency Rating

- Based on *Flight Plan ETE and actual departure time*
- Aggregates demand into 15 minute bins
- Compares actual arrivals to demand
- If early, demand is moved to actual 15 minute bin
- 15 minute buffer given to all flights


Atlanta Arrivals, July 2003
Frequency
7000
6000
5000
4000
3000
2000
1000
0
-20
-10
0
10
ETA - On (minutes)
ASPM
ETMS 100
ETMS 40
ETMS 100 Slotted

Slot Assignments (Example) w/Structure vs. w/o Structure



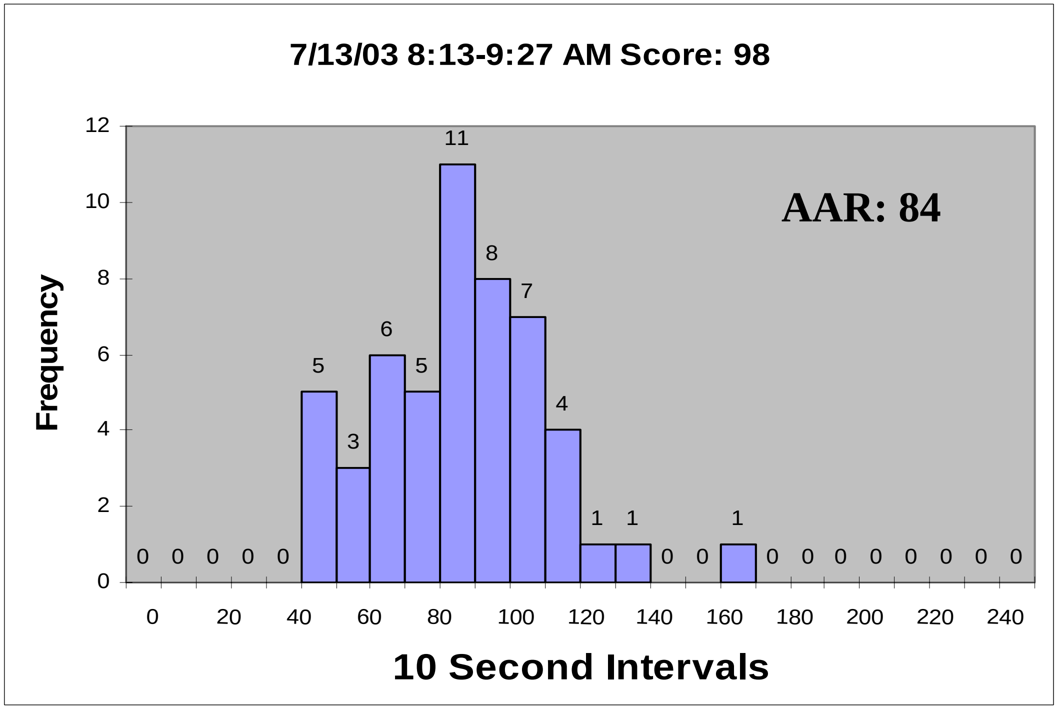
Issues addressed in model development

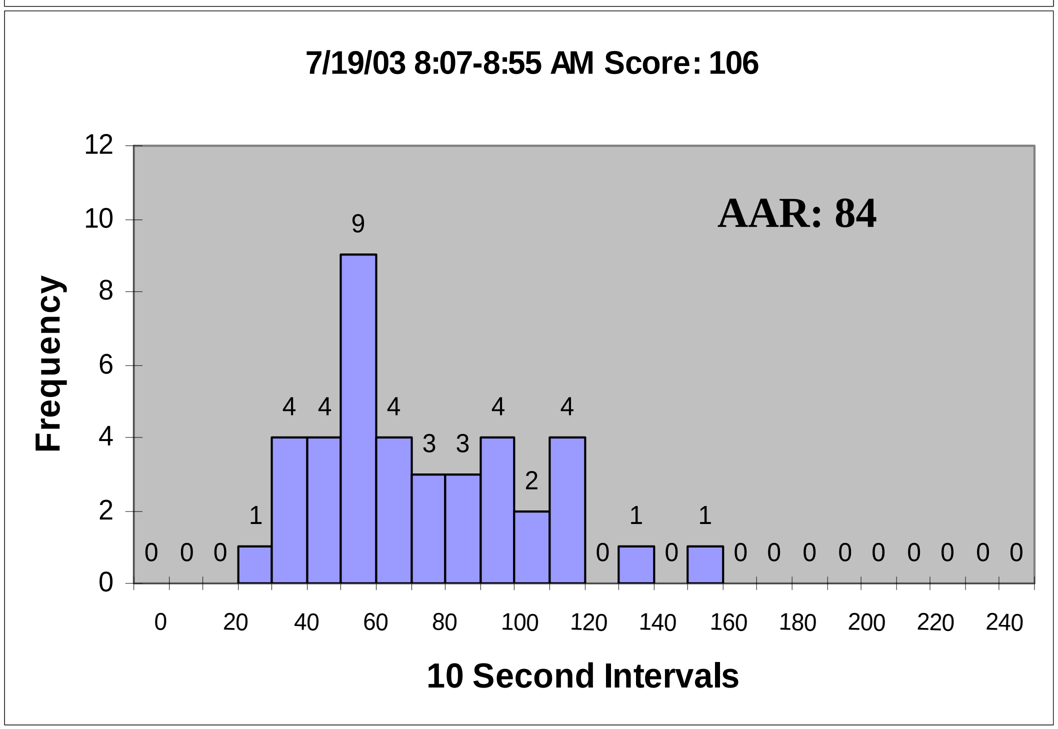
- If actual arrivals in 15 minute bin exceed AAR, set airport capacity to actual arrivals
  - An artificially low ARR will prevent scores greater than 100
- To avoid “avalanching” missed or made up slots, for each minute:
  - If arrivals = capacity, no slots can be missed or made up
  - If arrivals < capacity, can miss slots up to (capacity – arrivals)
    - If capacity = 2 and arrivals = 1, can only miss 1 slot
  - If arrivals > capacity, can make up slots up to (arrivals – capacity)
    - If capacity = 1 and arrivals = 2, can only make up 1 slot
- Scoring method
  - Applicable to any time frame of interest
  - Score = 100*(1 – (missed slots)/(assigned slots))
  - Reflects percentage of slots filled within 1 minute of when they are assigned

How do we Know if a metric is better?

- A measure that better correlates scores with levels of performance
- What constitutes levels of performance in the Terminal Area?
  - When demand exceeds capacity
    - Inter-arrival spacing or rate
  - When demand does not exceed capacity
    - Compare unimpeded to actual

Landing RW 26





ETMS Aircraft Descent Profile Data

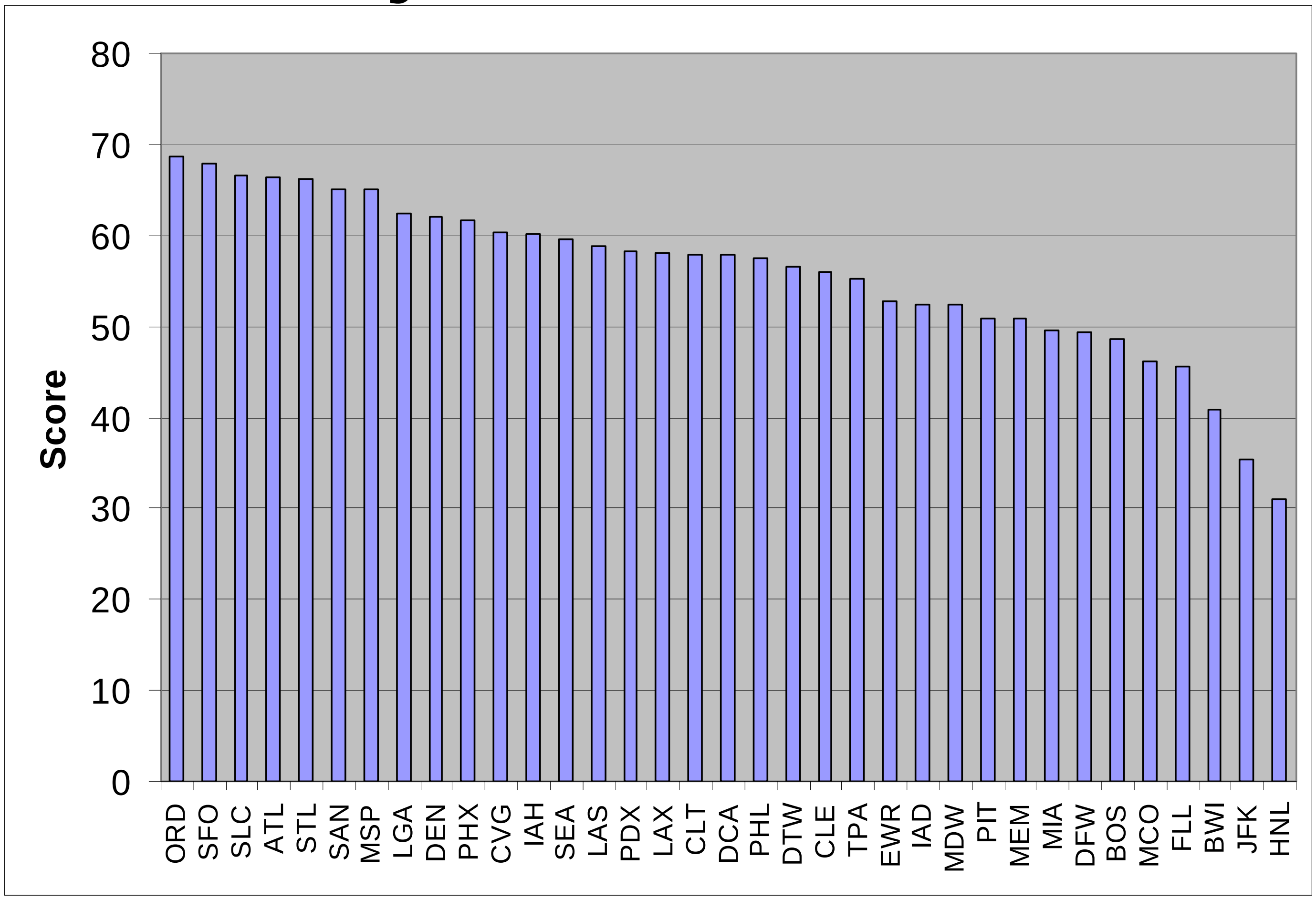
Aircraft Types	Initial Descent (Mach/IAS)	Speed Leaving 12000 feet (IAS)	Speed 10 Miles Out (IAS)	Landing Speed (IAS)
Heavy Jets, Fighters	.85/350 (kts) .80/330 .75/310 .70/290	250 (kts) 250 250 250	140 (kts) 140 140 140	140 (kts) 140 140 140
Large Jets	.85/350 .80/330 .75/310 .70/290	250 250 250 250	120 120 120 120	120 120 120 120
Turboprops, Piston props, Helicopters	.70/290	250	90	90

During the initial descent from cruising altitude, it is assumed that a flight holds a constant Mach speed until it reaches a given indicated air speed (IAS), which is then held constant until the flight reaches 12,000 feet. The flight is then **assumed to decelerate at a constant rate** to 250 knots while at 12,000 feet. The flight is **assumed to descend at constant deceleration until it reaches the specified speed at ten miles out**. The speed is held constant from 10 miles out to landing. During the flight profile modeling, the profile with the Mach speed closest to the cruising speed within the proper aircraft category is used for a given flight. If the cruising speed of a flight is less than any of the provided values, the flight is modeled as descending at its constant cruising speed until it reaches 12,000 feet.

Running Missed Slot Method

Available	Allocated	Landed	Missed-r
1			
1	1		
1			
1			
1			
1		1	4
1			
1	1		
1			
1			
1		1	3
1			
1		1	-1
1	1		
1			

Monthly Scores for OEP 35



Based on 7 minute offset from ETMS ETA

Example with Airport Acceptance Rate of 60

	Available Slots	Unimpeded Demand	Demand Sum	Allocated Slots	Arrivals	Allocated Sum	Arrivals Sum	Flight Delay
1	1	3	3	1	1	1	1	0
2	1		3	1	1	2	2	0
3	1	2	5	1	1	3	3	0
4	1		5	1	1	4	4	0
5	1	1	6	1	1	5	5	0
6	1	1	7	1	1	6	6	0
7	1	1	8	1	●	7	6	0
8	1	3	11	1	●	8	6	0
9	1		11	1	1	9	7	-2
10	1		11	1	●	10	7	0
11	1	2	13	1	1	11	8	-3
12	1	1	14	1	1	12	9	-3
13	1	1	15	1	●	13	9	0
14	1		15	1	1	14	10	-4
15	1		15	1	1	15	11	-4
16	1		15		1	15	12	-4
17	1	2	17	1	1	16	13	-4
18	1		17	1	1	17	14	-4
19	1	1	18	1	1	18	15	-4
20	1		18		1	18	16	-3
21	1	1	19	1	1	19	17	-3
22	1		19		1	19	18	-3
23	1		19		●	19	18	0
24	1	1	20	1	1	20	19	-3
25	1		20		1	20	20	-1
26	1		20		1	20	21	2
27	1		20			20	21	0
28	1	1	21	1		21	21	0
29	1		21			21	21	0
30	1		21			21	21	0
31	1		21			21	21	0
32	1		21			21	21	0
33	1	1	22	1	1	22	22	0
34	1		22			22	22	0

● Missed Slot

Current Airport Efficiency Rating