



# Evidence for the Safety-Capacity Trade-Off in the Air Transportation System

**G. L. Donohue**

**R. C. Haynie**

**D. Wang**

**J. F. Shortle**

**Dept. of Systems Engineering & Operations Research**

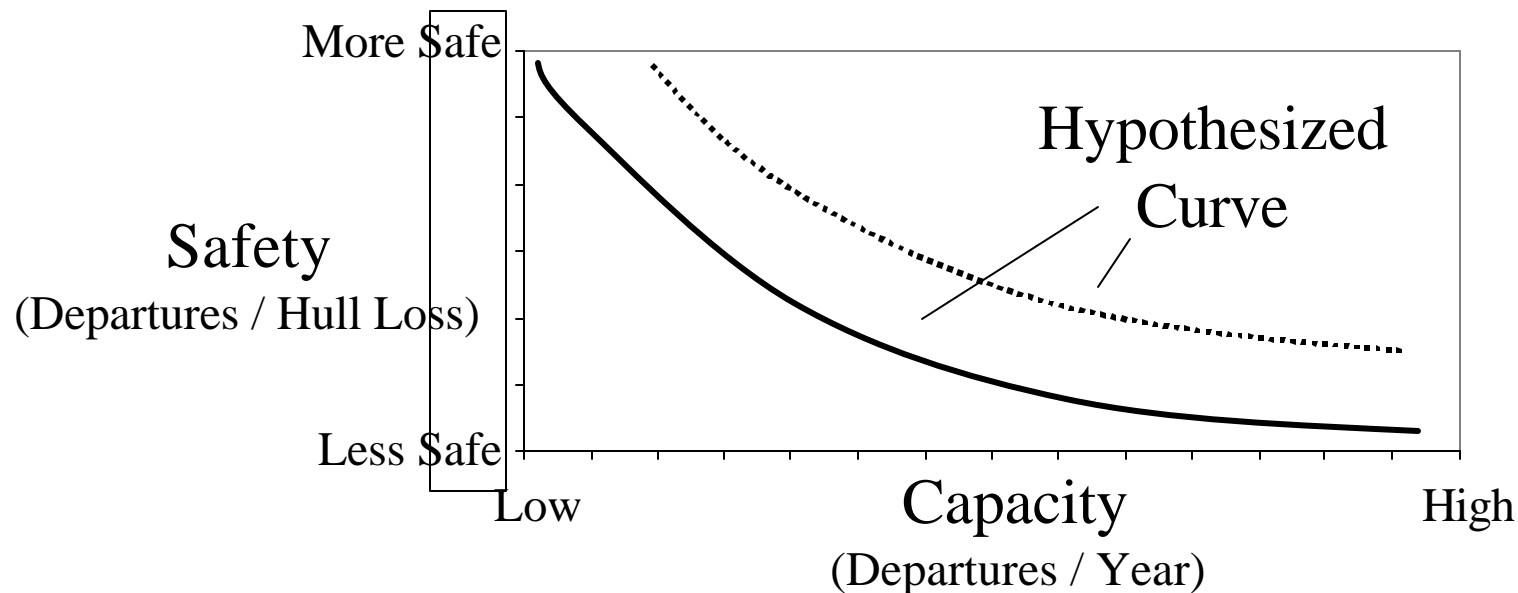
**George Mason University**

**Fairfax, VA**



# Research Questions

- **Is there a safety-capacity trade-off?**
- **What happens to safety during periods of high utilization?**



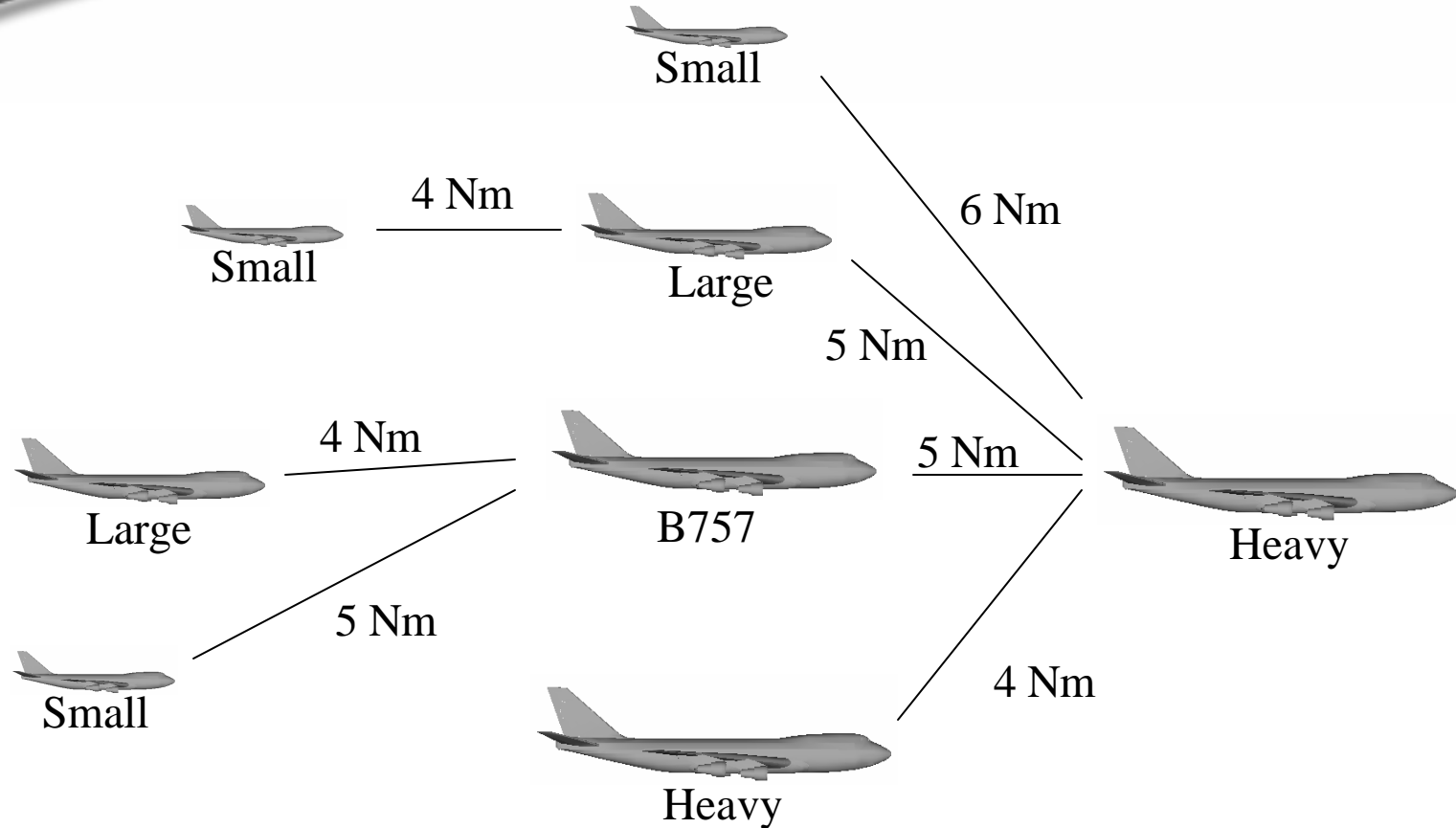


# Outline

- **Data collection process**
- **Results from data collection**
- **Further analysis**
- **Conclusions**



# Wake Vortex Separation Standards

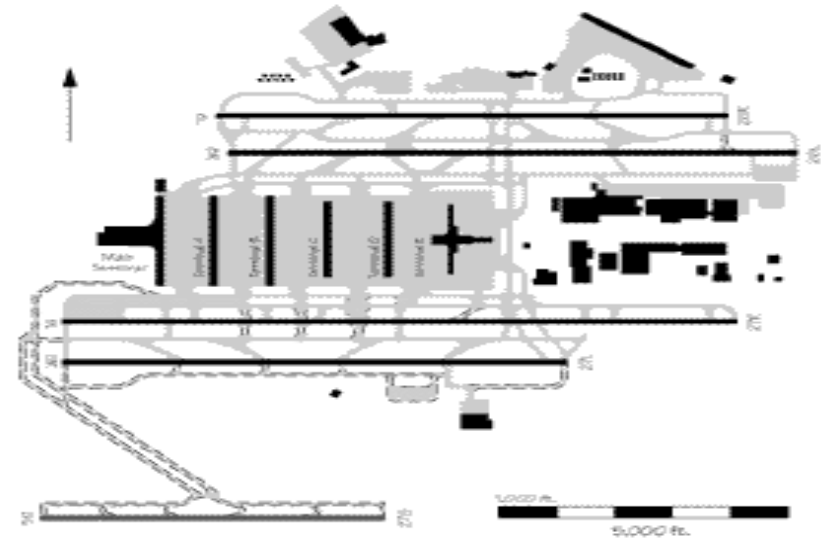


Heavy > 255,000 lbs  
Large 41,000 lbs to 255,000 lbs  
Small < 41,000 lbs

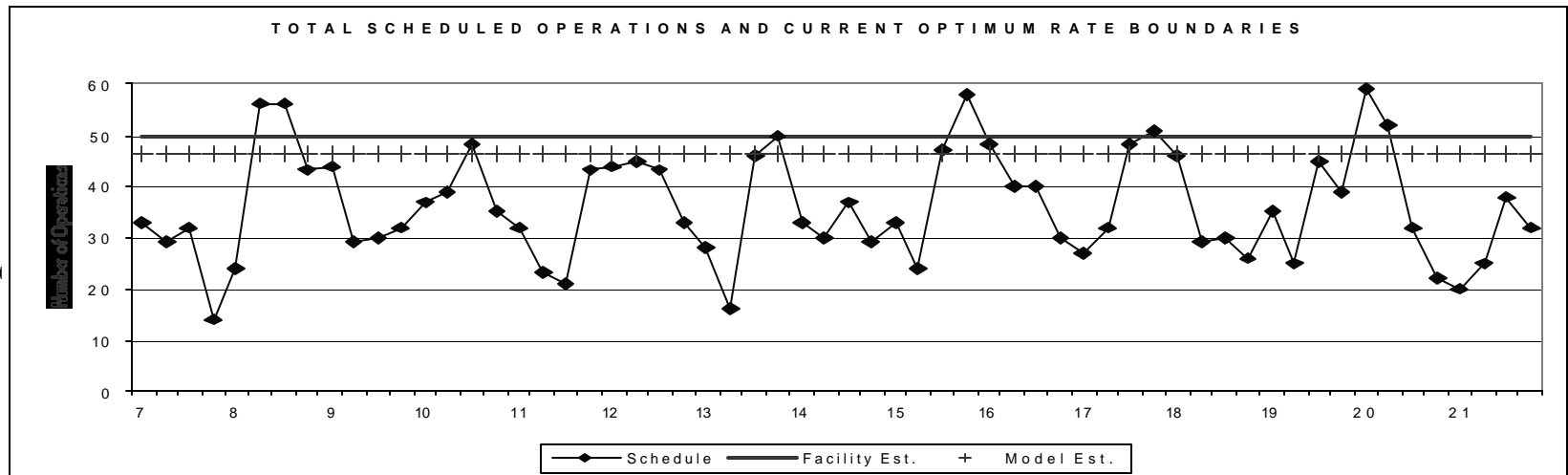


# Atlanta Airport

- **2 Runways – Arrivals**
- **2 Runways – Departures**
- **50 Arrivals / Hr / RW – Max**
- **72 Seconds between Arrivals**
- **3.1% – Operations Delayed (> 15 min)**

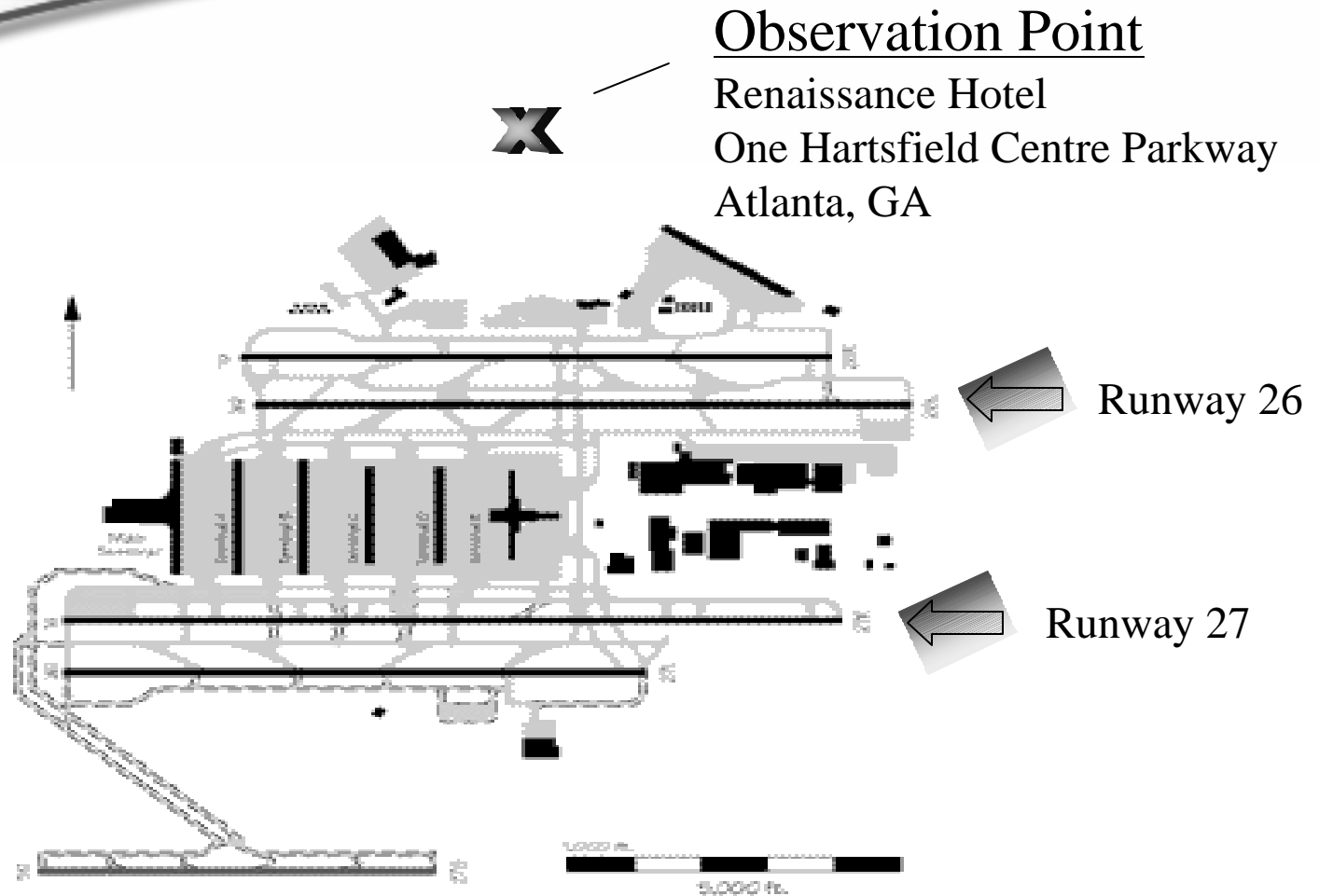


Total Operations,  
VMC, (per 15 min)





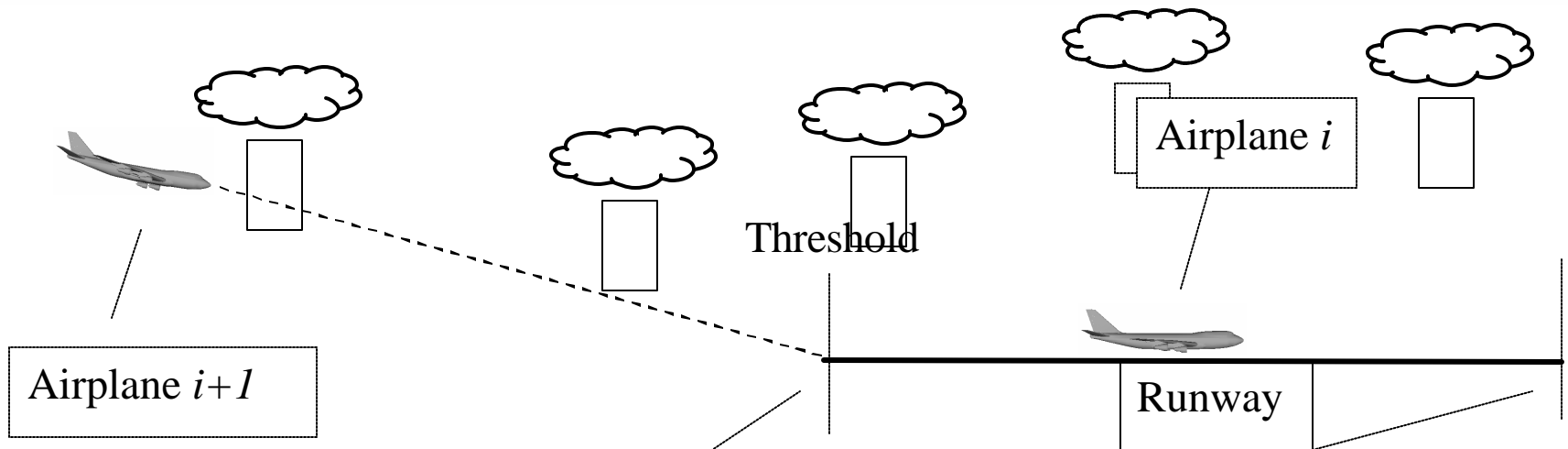
# Data Collection, Atlanta



## ATL Airport



# Data Collection Process



Aircraft Type	Threshold	Leave Runway
Heavy	10:23:14	10:24:04
Large	10:24:28	10:25:13
Large	10:26:16	10:27:12
Small	10:28:32	10:29:28

⋮

⋮

⋮



# Data Manipulation

*Runway Occupancy  
Time (RTI)* 45 sec

Aircraft Type	Threshold	Leave Runway
Heavy	10:23:14	10:24:04
Large	10:24:28	10:25:13
Large	10:26:16	10:27:12
Small	10:28:32	10:29:28

$$108 \text{ sec} - 77 \text{ sec} = +31 \text{ sec} \quad \textit{Relative Inter-Arrival Time}$$

Inter-Arrival  
Time

Wake Vortex Separation Standard  
Large following Large (3 Nm)  
(3 Nm / (140 knots / 3600 sec/hr))





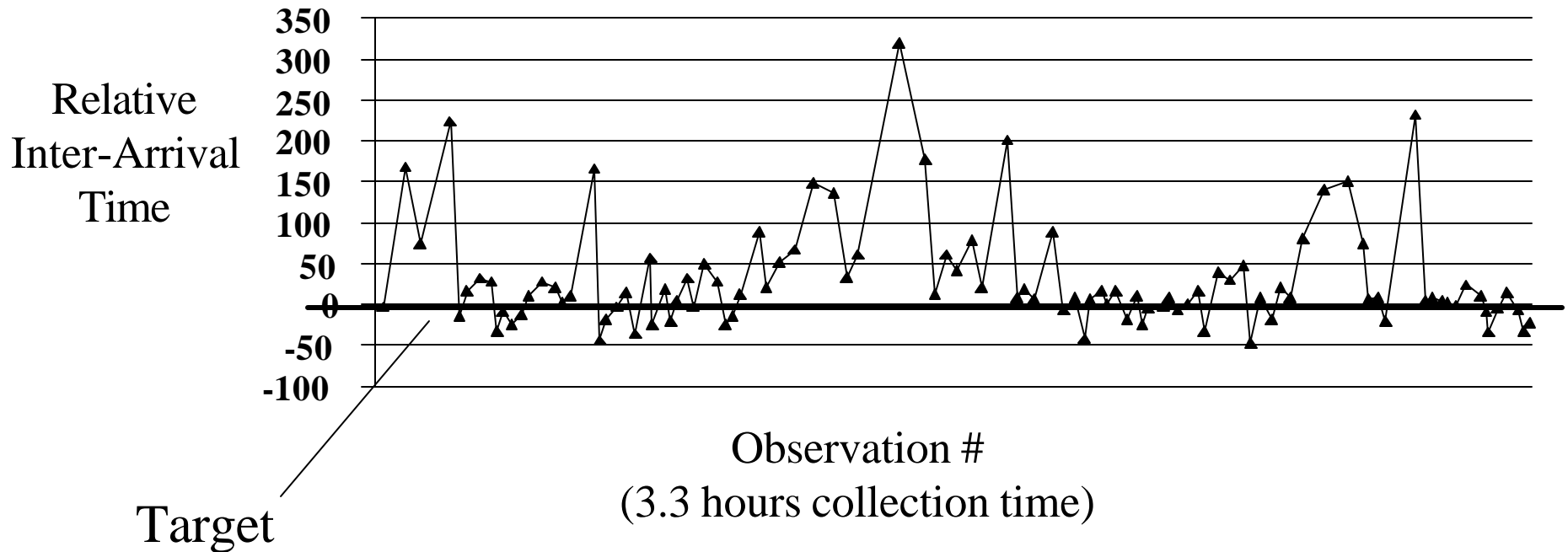
# Data Collection Summary

Airport	Days	Observations	Weather
Atlanta (ATL)	3	765	VMC
LaGuardia (LGA)	3	584	VMC / IMC
Baltimore (BWI)	2	135	IMC



## Atlanta Runway 27

Collection Day #1, VMC



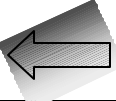
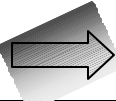
Total Observations: 103

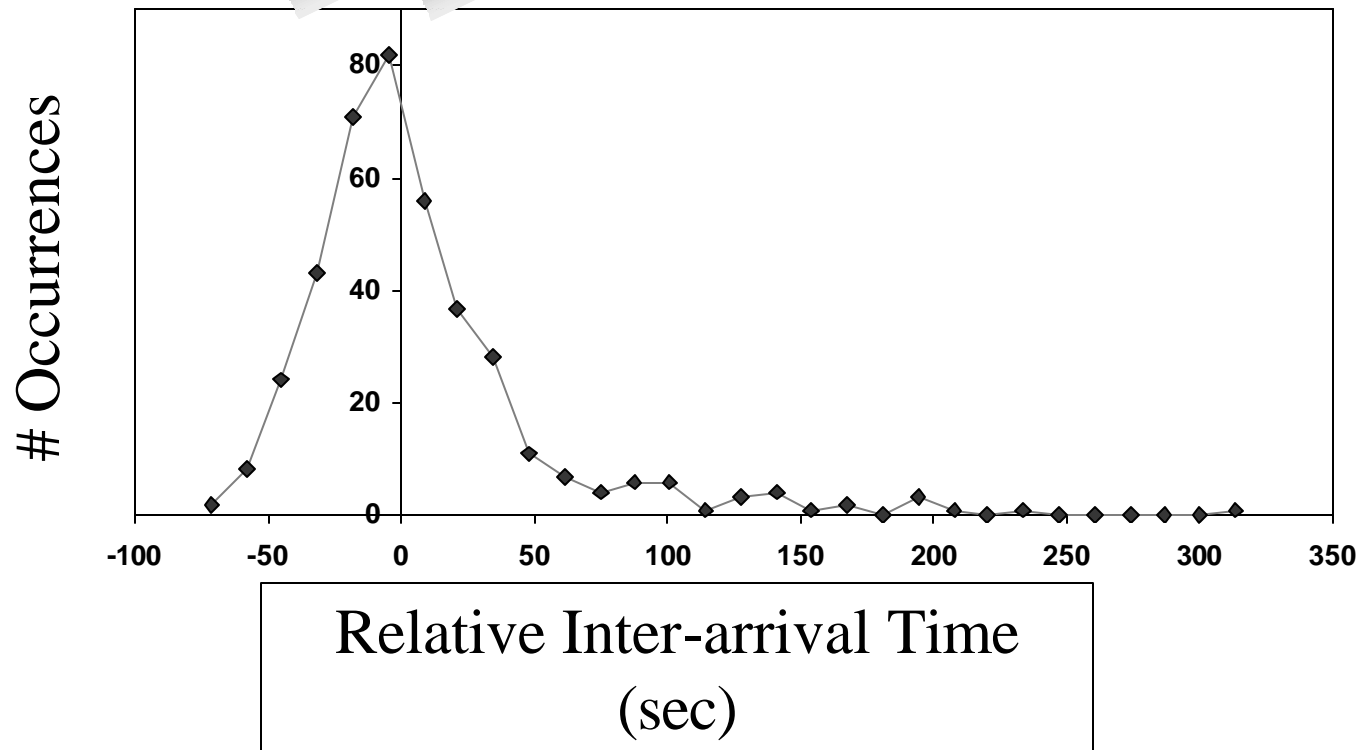
Arrivals / Hr: 31



## Atlanta Runway 27

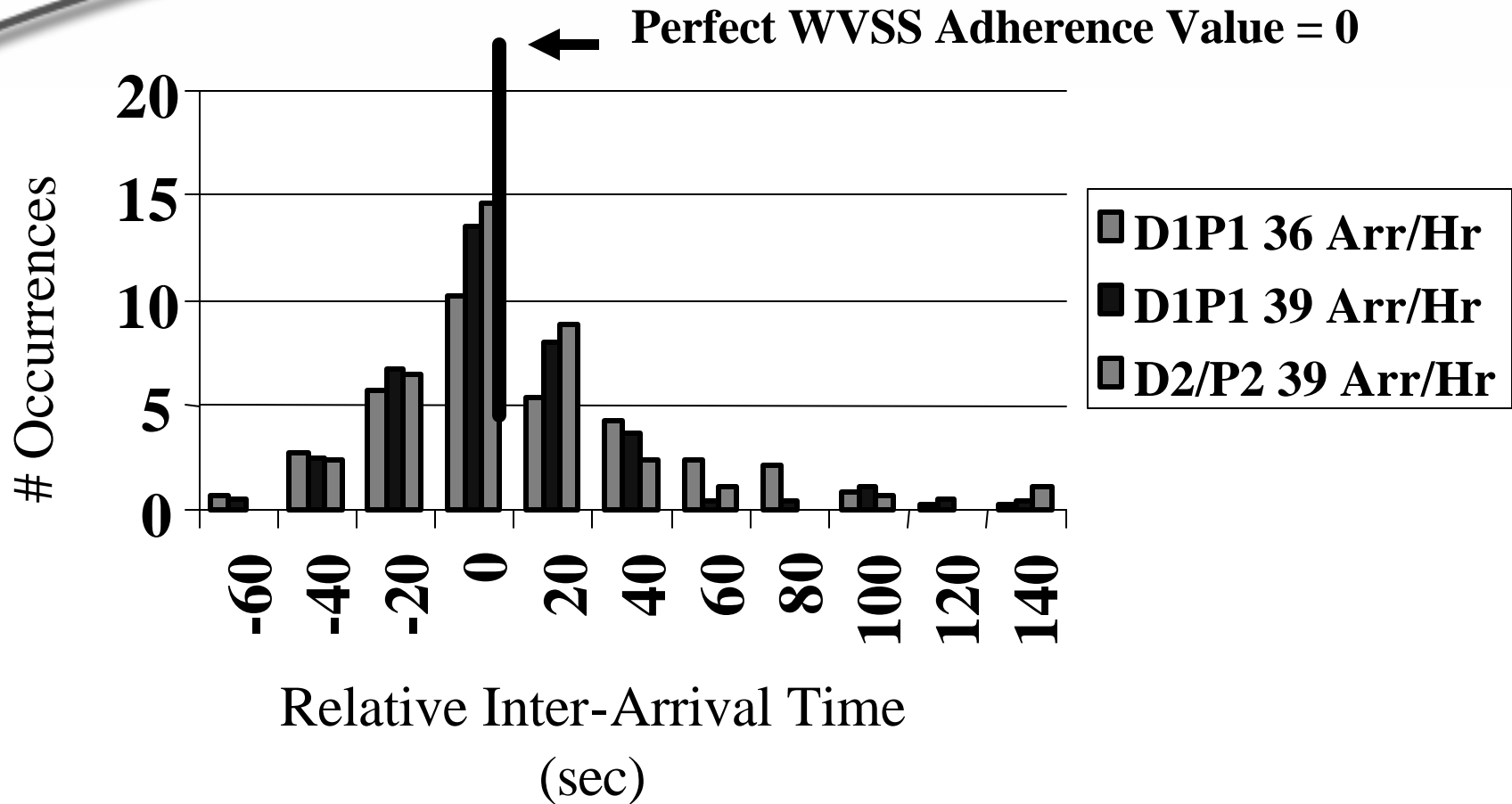
All Collection Days, VMC

Lost Safety   Lost Capacity





# ATL Summary

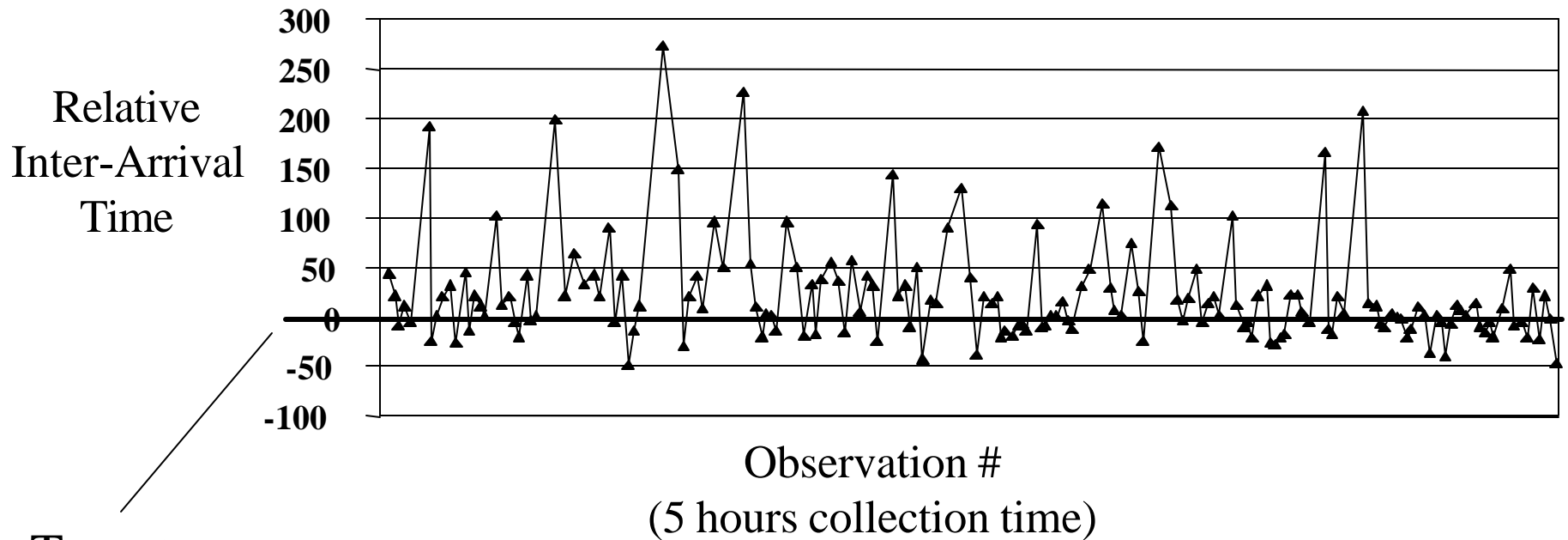




# Results

## LaGuardia

Collection Day #2, VMC



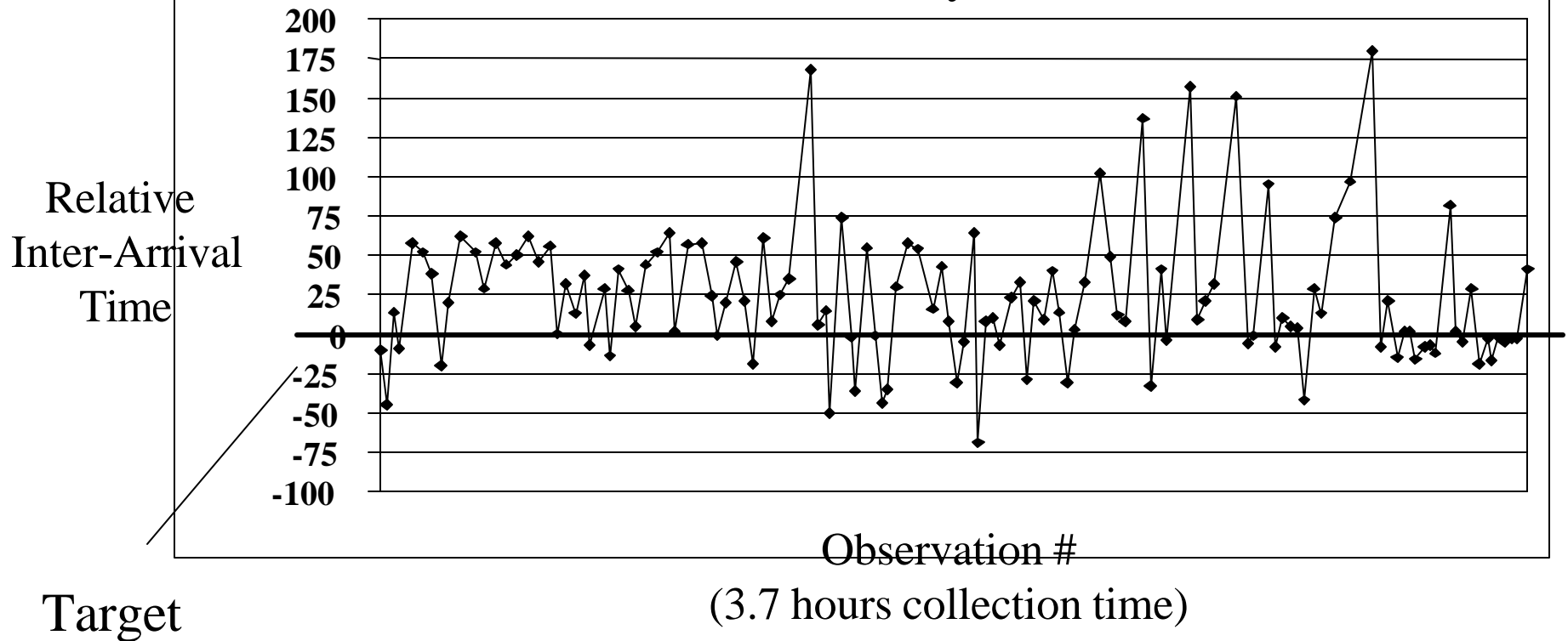
Target

Total Observations: 169  
Arrivals / Hr: 33.8



# Results

## LaGuardia Collection Day #3, IMC

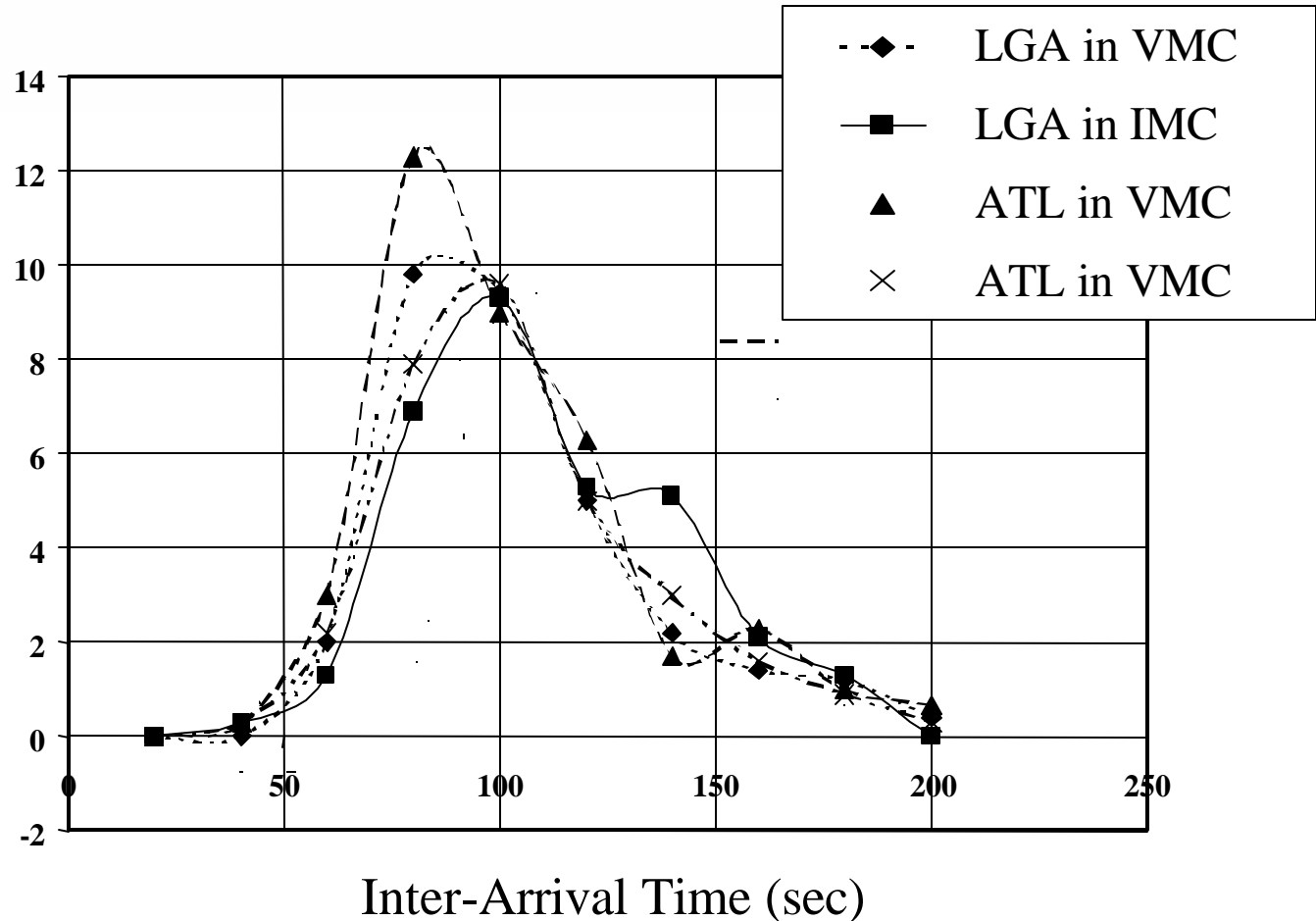


Total Observations: 126  
Arrivals / Hr: 34



# Comparison of Airports

Aircraft  
Per Runway  
Per Hour



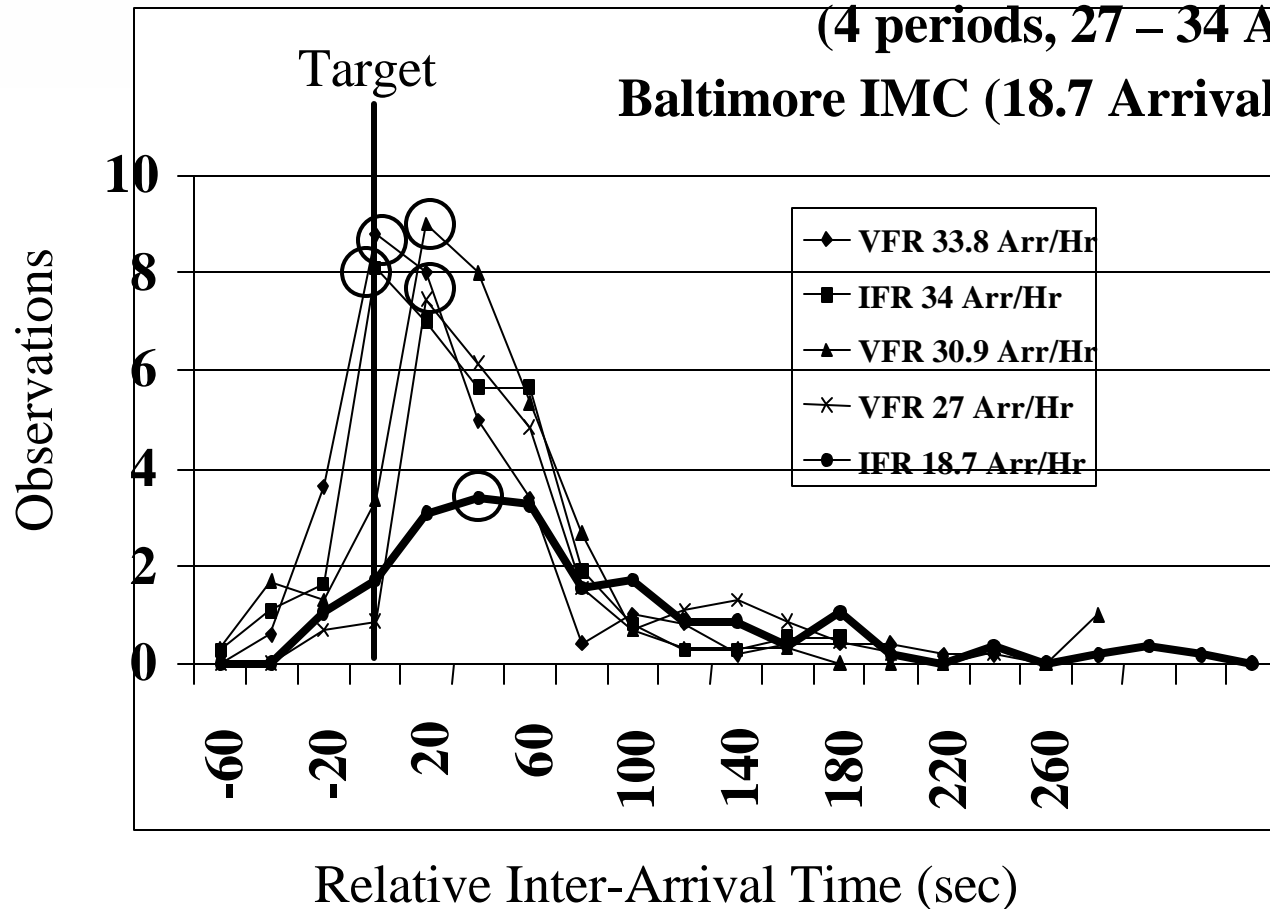


# LGA & BWI Comparison

## LaGuardia VMC / IMC

(4 periods, 27 – 34 Arrivals / Hr)

Baltimore IMC (18.7 Arrivals / Hr)





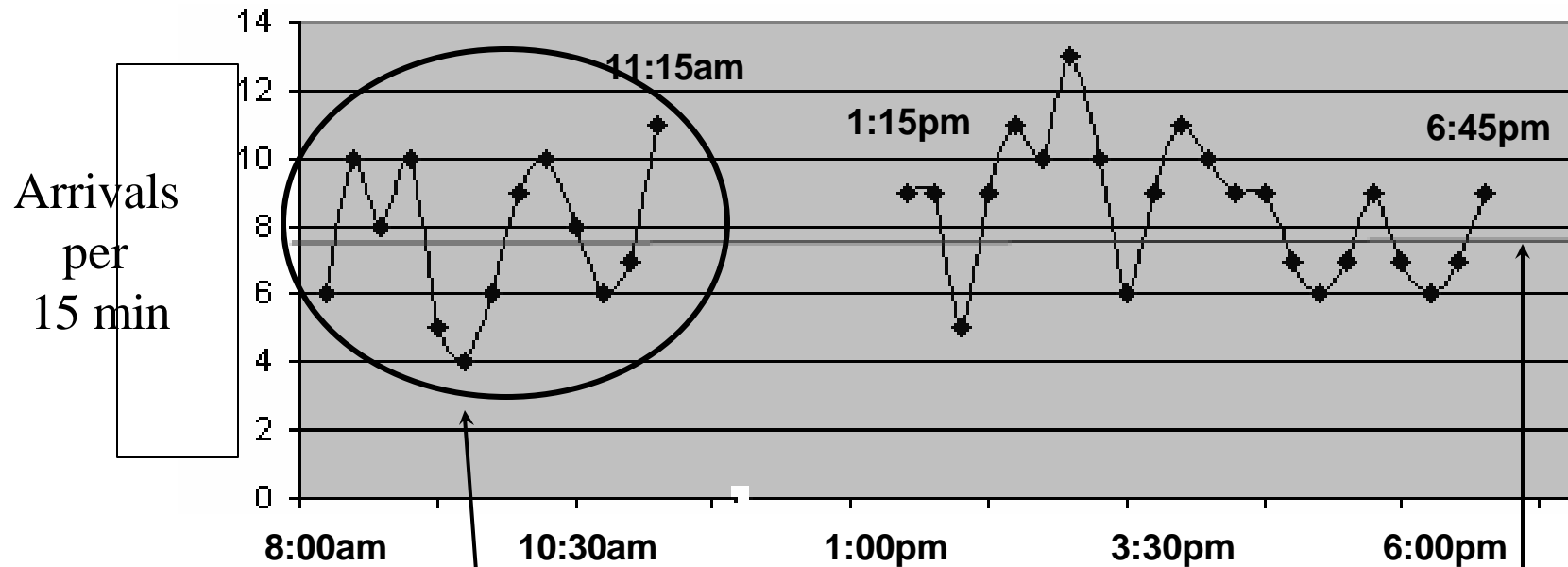


# 15 Min Arrival Rates

## Atlanta Airport

Collection Day #1, VMC

15 min averages



Arrivals  
per  
15 min

11:15am

1:15pm

6:45pm

8:00am

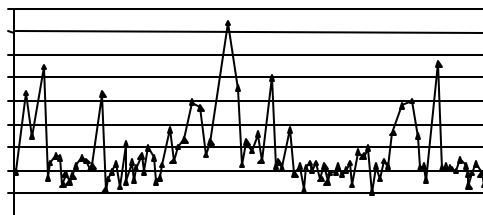
10:30am

1:00pm

3:30pm

6:00pm

Individual  
Flight Data

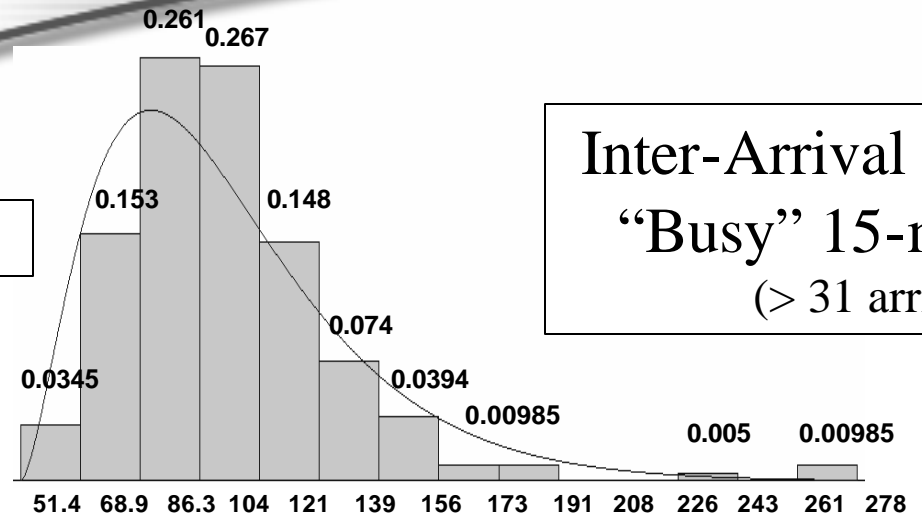


Average: 31 / hr



# Arrival Rates

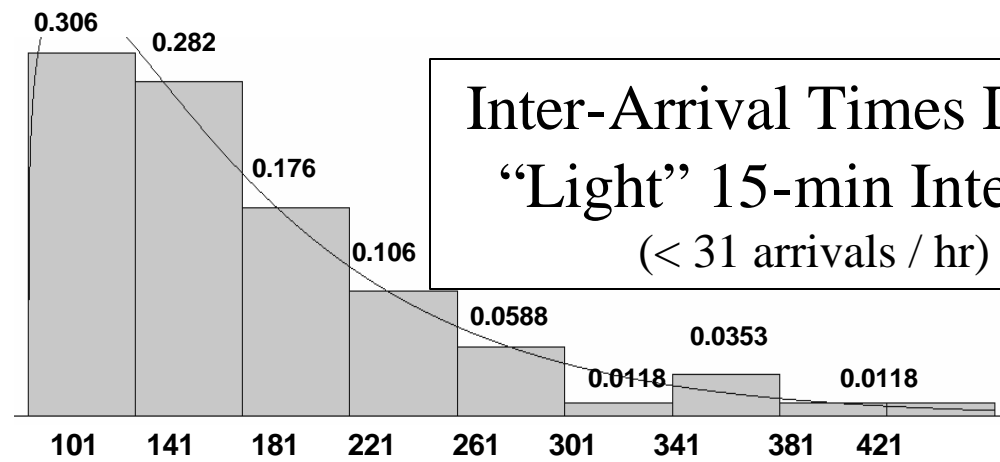
Frequency



Inter-Arrival Times During  
“Busy” 15-min Intervals  
( $> 31$  arrivals / hr)

Inter-Arrival Time (sec)

Frequency



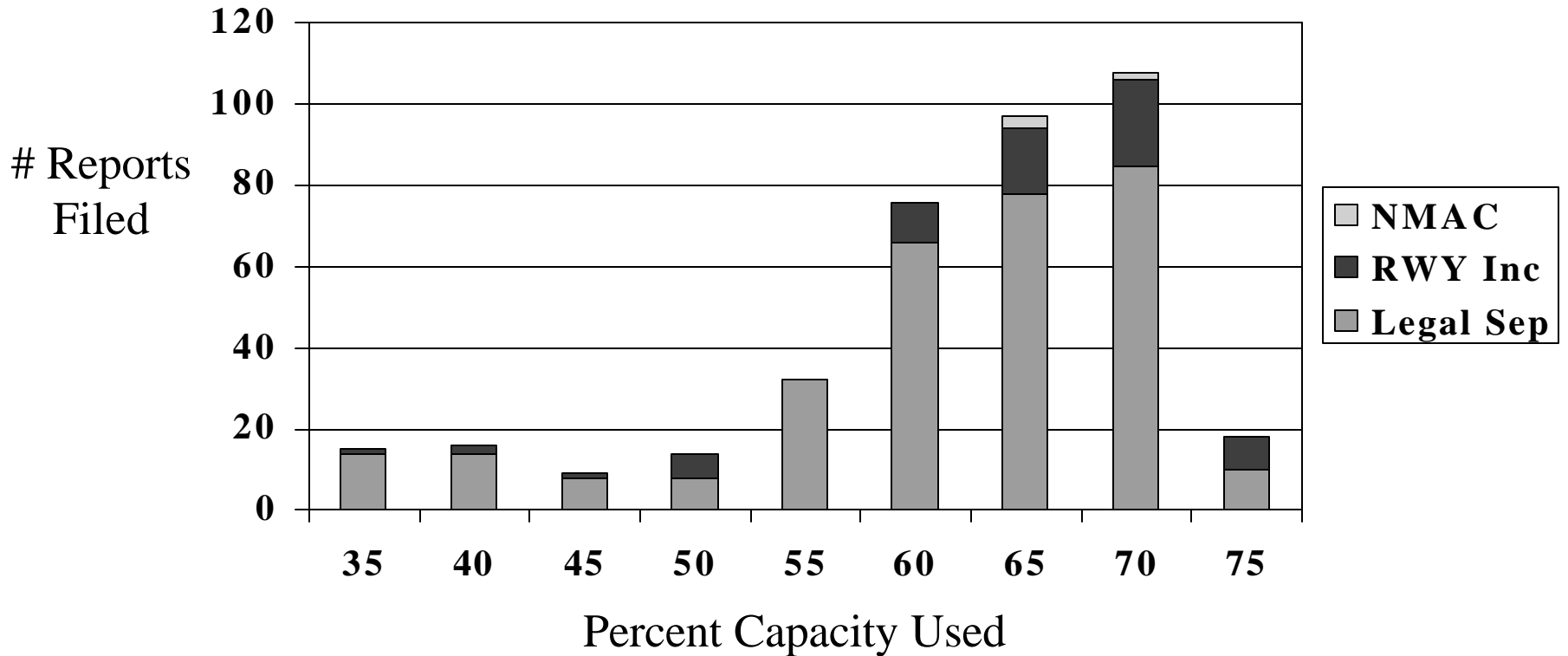
Inter-Arrival Times During  
“Light” 15-min Intervals  
( $< 31$  arrivals / hr)

Inter-Arrival Time (sec)



# Safety / Capacity Relationship

ATL, DCA, LGA Historical Reports  
1988-2001





# Summary

- **Inter-arrival times indicate frequent loss of WV separation**
- **Shape of inter-arrival distributions similar**
  - For different airports
  - For IMC / VMC
- **Some evidence for decline in safety for higher arrival rates**
- **Small data set (~ 1,500 points) – more needed**
- **Data can be used as input to more sophisticated safety models (TOPAZ)**



# Backup Slides

# Backup Slides



# Average Approach Speeds

Aircraft Type	Avg. Approach Speed
Small	130 knots
Large	140 knots
B757	140 knots
Heavy	145 knots

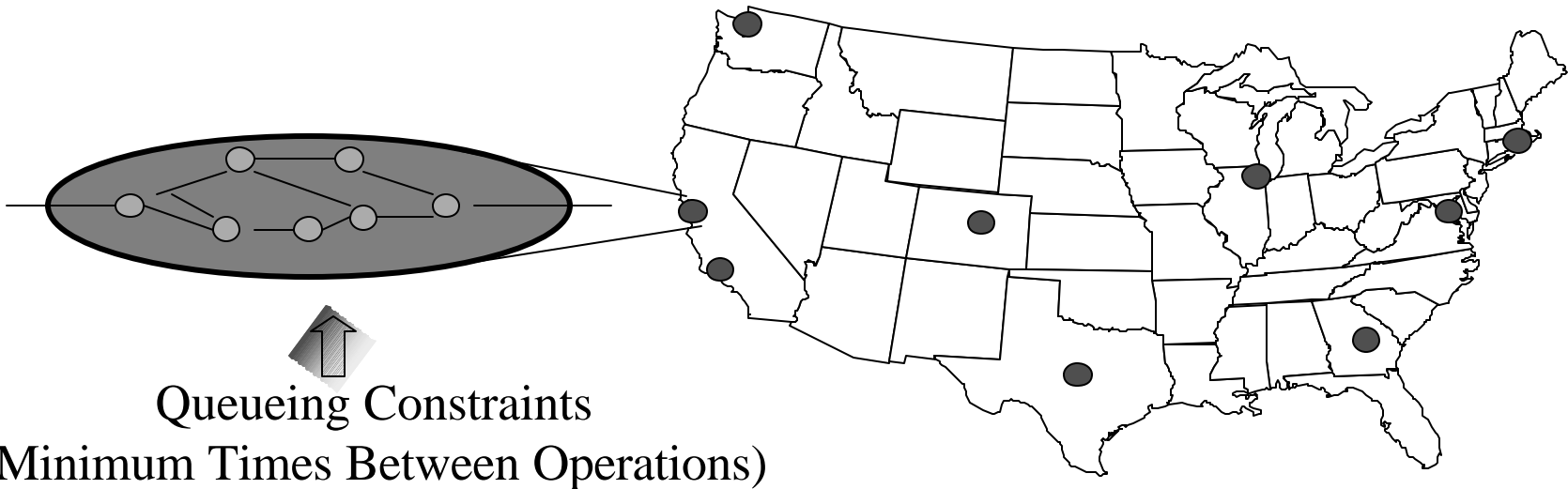




# Modeling Implications

- **Typical Modeling Approach**

- Safety is a *constraint* (Maximum rate through node in network)
- Capacity is metric of interest



- **New Approach**

- Safety is a function of capacity / demand