Runway Capacity Examples: Two Dependent Runways and 3 Runways

CEE 4674
Analysis of Air Transportation Systems

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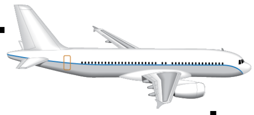
Professor

Example:
Two Dependent Parallel Runways



Problem Statement

- An airport has two parallel runways separated 800 meters away form each other (oriented 090-270 degrees)
- The following parameters are known for this airport

Technical Parameters (inputs)	Parameter	Values
Dep-Arrival Separation (nm)	δ	2
Common Approach Length (nm)	γ	8
Standard deviation of Position Delivery Error (s)	σ	20
Probability of Violation	Pv	5

- The airport operates under IFR conditions with the following separation matrices:

Minimum Separation Matrix (nm)			Arrivals-Arrivals
		Trailing	
	Small	Large	Heavy
Small	3	3	3
Large	5	3	3
Heavy	6	5	4

Arrival-Arrival

Problem Statement

- Departure-Departure Separations

Departure-Departure Separation Matrix (seconds)			
		Trailing	
	Small	Large	Heavy
Small	60	60	60
Large	90	90	90
Heavy	120	120	120

Departure-Departure

- Other parameters

	Small	Large	Heavy
ROT (s)	46	52	60
Percent Mix	30	40	30
Vapproach (knots)	100	140	150

Questions

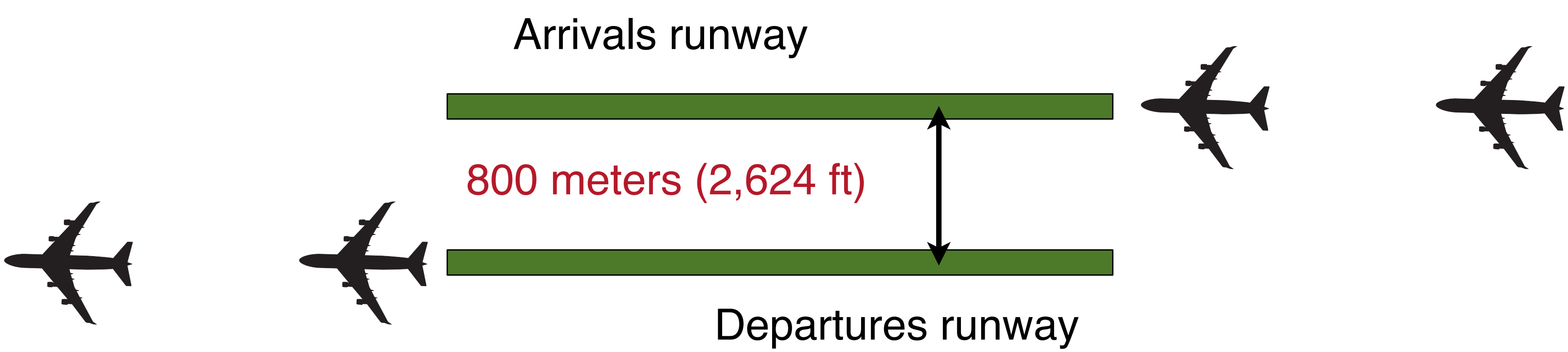
- Draw the Pareto capacity diagram for the airport if one runway is used for arrivals and one for departures
- Draw the Pareto capacity diagram for the airport if both runways are used in mixed operations mode (i.e., arrivals and departures on both runways). Do the analysis for IFR operations.

Solution

Using the Excel Spreadsheet for Calculations

Airport Runway Segregated Operations

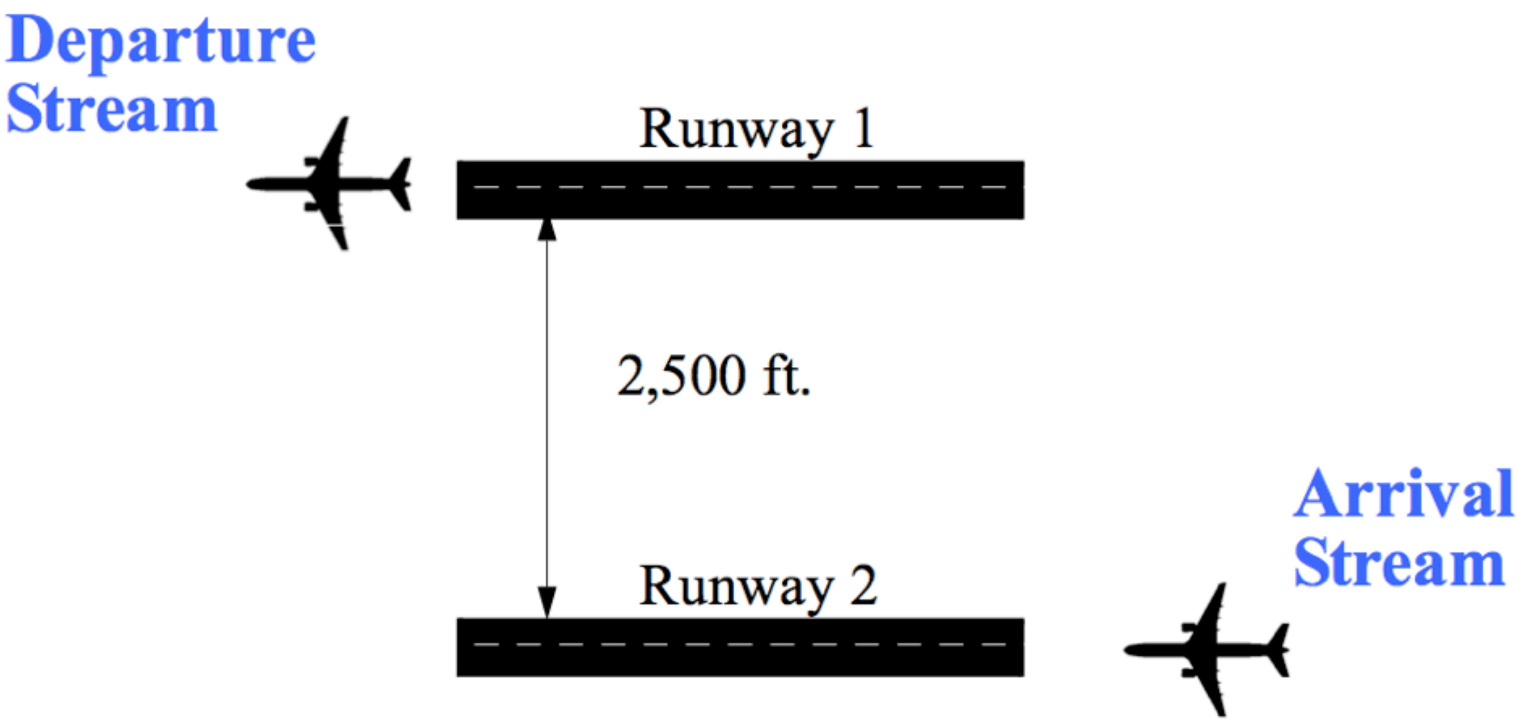
- Two parallel runways spaced 800 meters away (2,624 feet)
- Recall: FAA requires minimum of 2,500 feet and an airport surveillance radar system to allow one runway for arrivals and its parallel one for departures



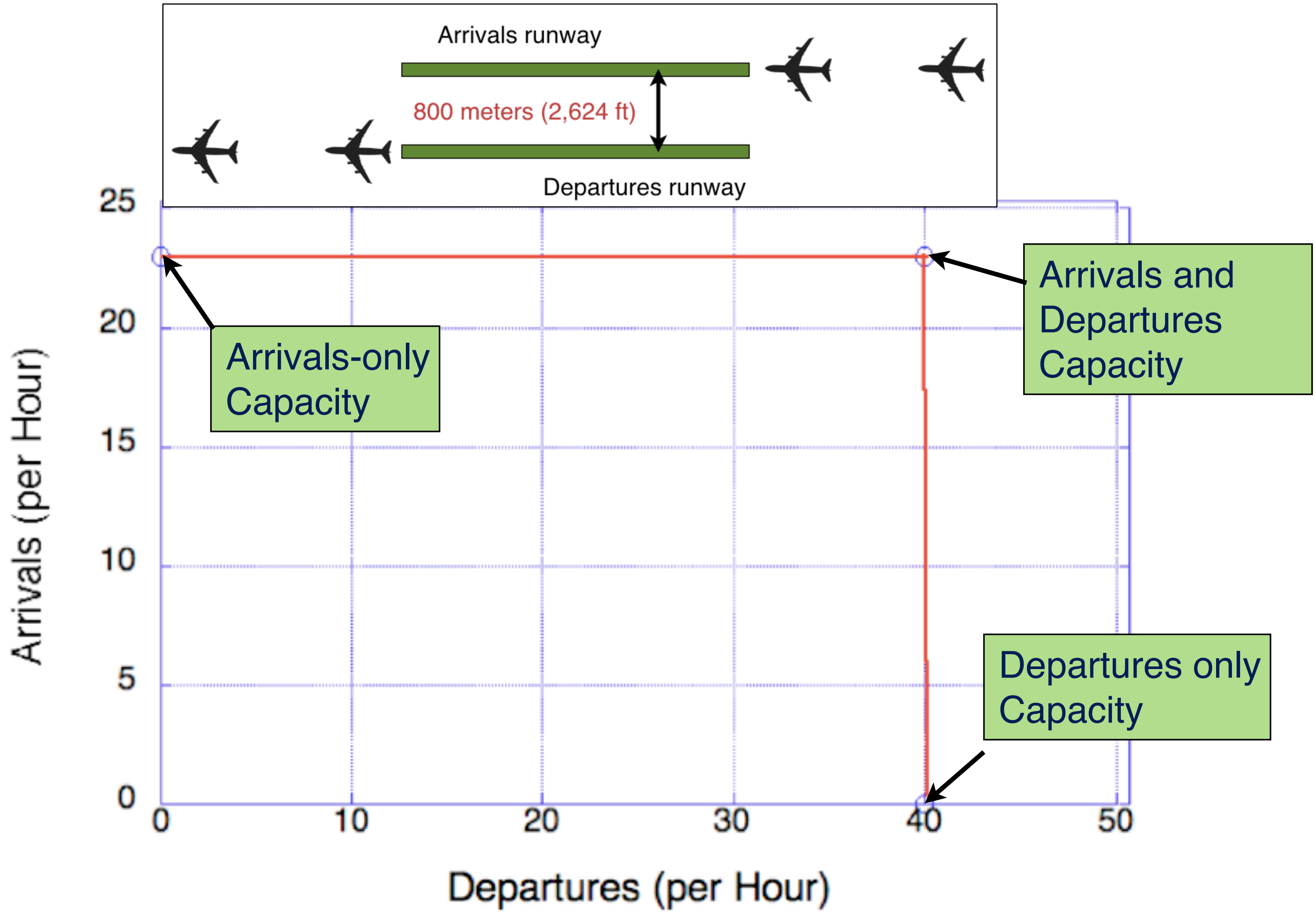
FAA Rule for Segregated Operations (see Notes # 5 Runway Separations)

When a surveillance radar is available at the airport,

- Simultaneous departures and arrivals can be conducted if two parallel runways are located 2,500 ft.

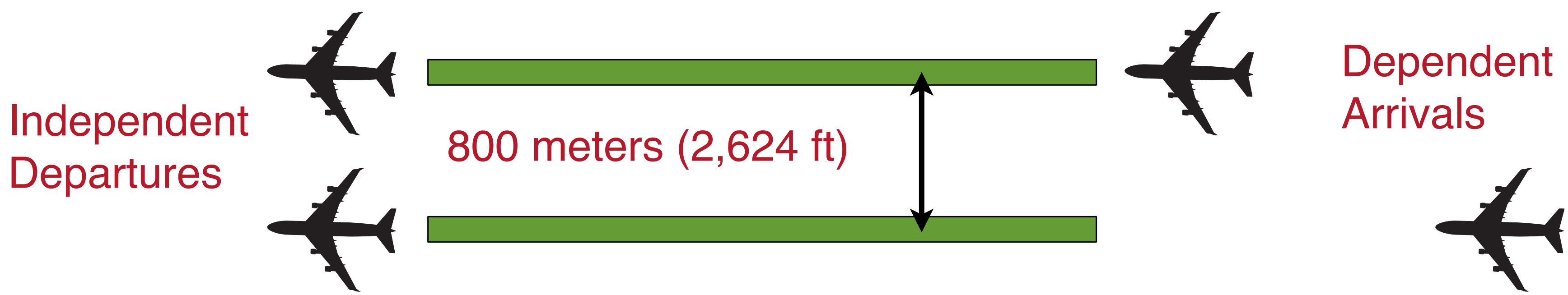


Pareto Diagram for Segregated Operations



Airport with Both Runways under Mixed Operations

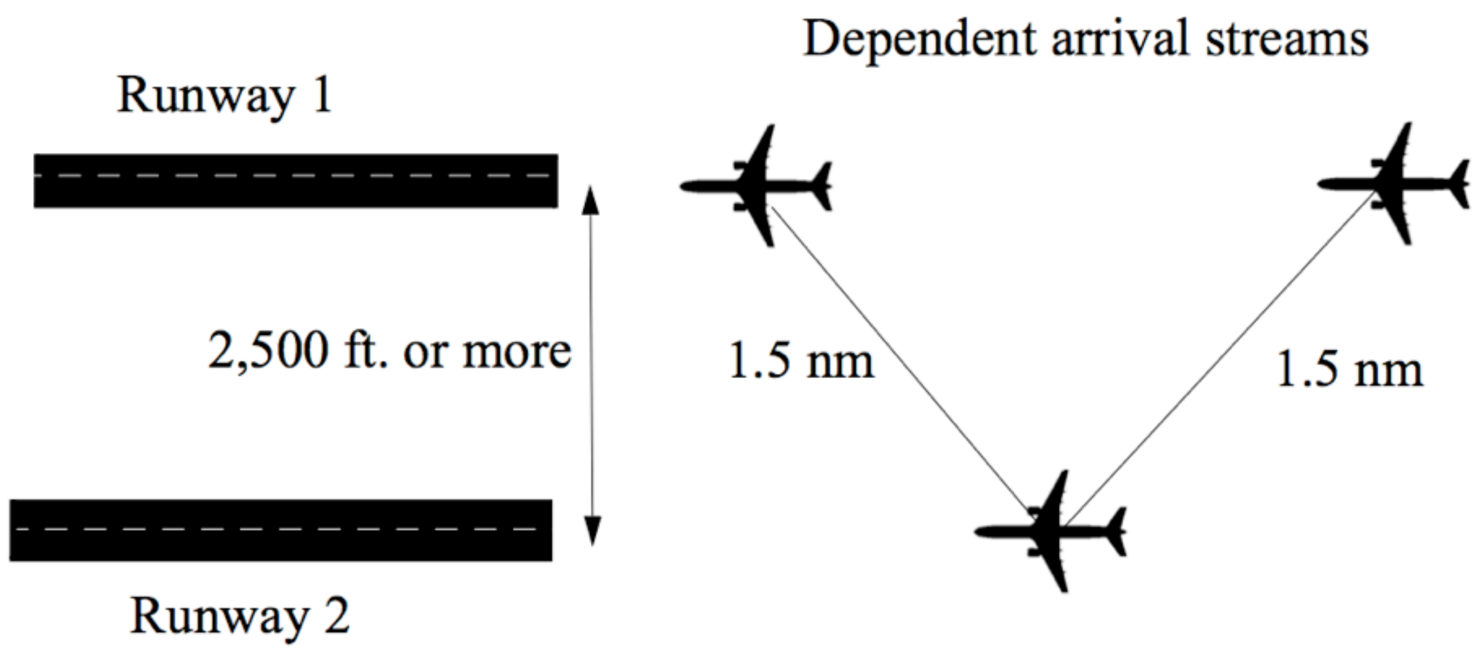
- Two parallel runways spaced 800 meters away (2,624 feet)
- Recall: FAA requires minimum of 3000 feet and a PRM (Precision Runway Monitor) system to allow simultaneous independent parallel approaches
- Therefore: runways are operated **with dependent arrivals but independent departures (2 rules)**



FAA Rule for *Dependent Runway Arrival* Operations (see Notes # 5 Runway Separations)

When a surveillance radar is available at the airport,

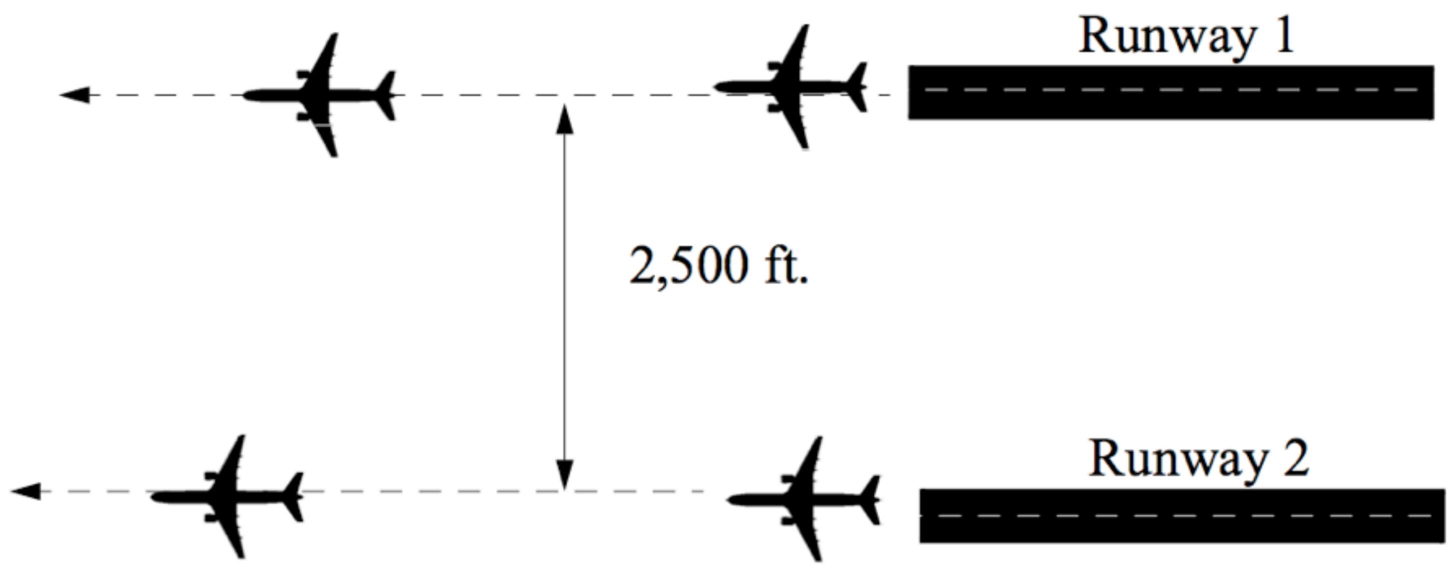
Procedures exist to conduct dependent arrivals when runway separation is below 4,300 ft. and above 2,500 ft. (standard radar).



FAA Rule for *Independent Runway Departure* Operations (Notes # 5 Runway Separations)

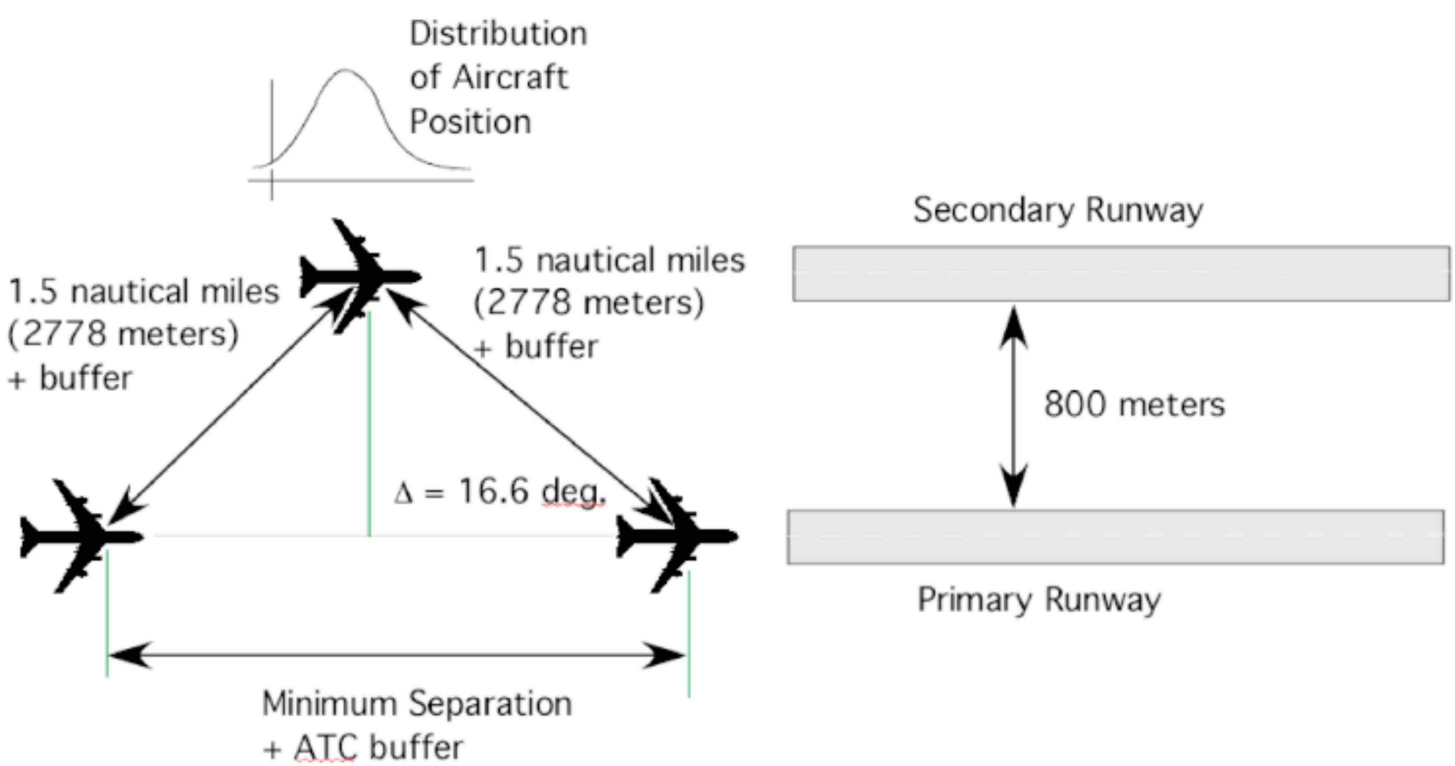
When a surveillance radar is available at the airport,

- Simultaneous departures can be conducted if two parallel runways are located 2,500 ft.



Solution for Dependent Arrivals

- Arrival to both runways are dependent
- Select a primary runway for analysis and then select the runway that is dependent on the primary runway (called secondary runway)



Solution and Analysis

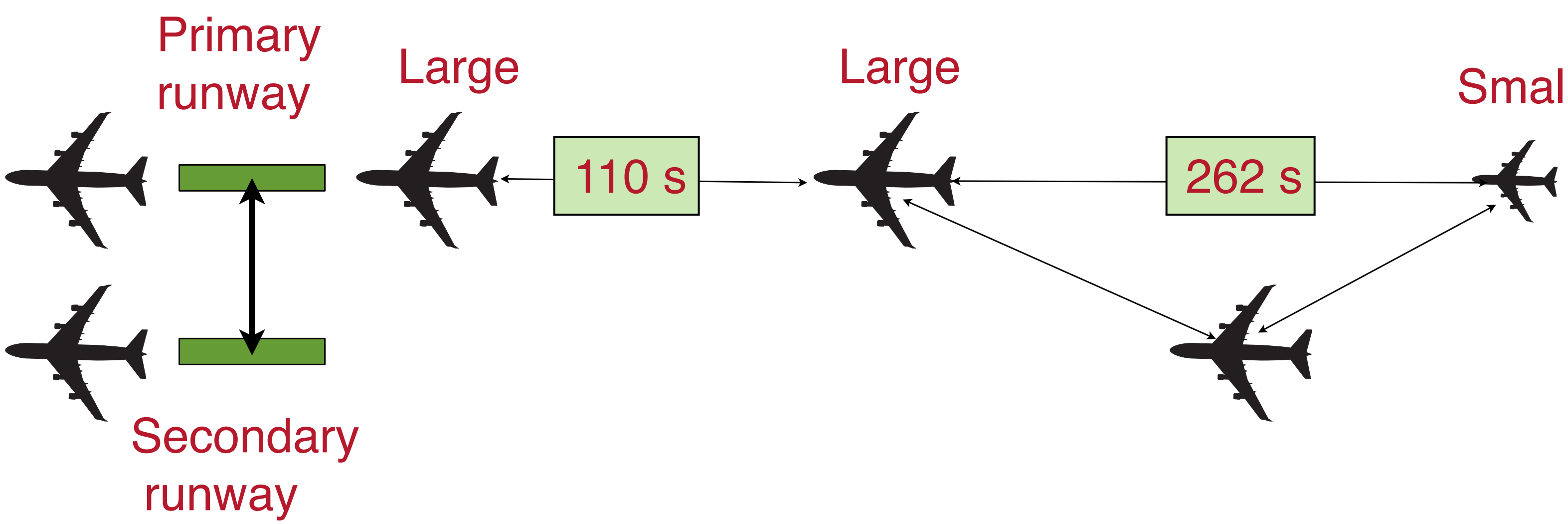
- Lets add two buffers of 33 seconds to simulate probability of violations of 5% (consistent with human factor studies)
- This brings the minimum gap for an arrival on the second runway to be : 147 seconds
- Now lets find gaps between successive arrivals on the primary runway with at least a gap of 140 seconds. The matrix of successive arrivals on the primary runway is shown below

49						
50	Augmented Matrix					
51			Trailing			
52		Small	Large	Heavy		Expected Value
53	Small	141.00	110.14	105.00		E(Tij) + B(Tij)
54	Large	262.29	110.14	105.00		156.75
55	Heavy	312.00	166.71	129.00		

Example Interpretation of Analysis

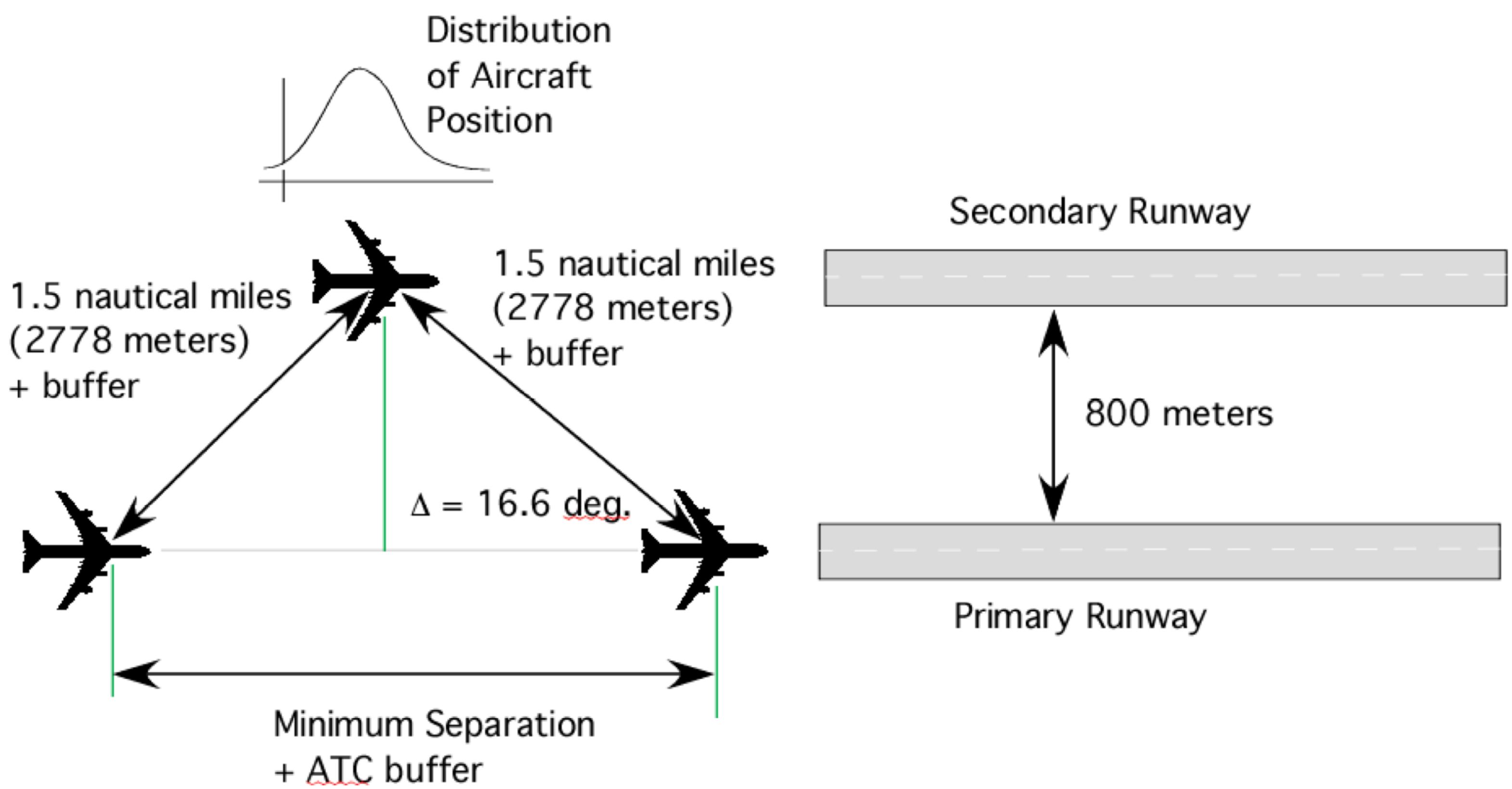
- When a **large-large** sequence exists, the arrival gap (110 seconds) is not large enough to allow a diagonal separation of 1.5 nm for an arrival on the secondary runway
- When **large-small** sequence exist, the arrival gap allows an arrival on the secondary runway

50	Augmented Matrix			
51			Trailing	
52		Small	Large	Heavy
53	Small	141.00	110.14	105.00
54	Large	262.29	110.14	105.00
55	Heavy	312.00	166.71	129.00



Solution for Diagonal Arrivals

- This solutions uses the rule that 1.5 nm is needed between diagonally operated tracks



Solution Ideas

- Note that for each arrival on the secondary runway we need to account for possible buffers (or position errors) since controllers do not have a fast update of the aircraft position in their radar scopes. The aircraft landing in the secondary runway thus pose a higher challenge to the air traffic controller because they require two buffers computed between arrivals in the primary runway.
- The minimum expected gap without buffers allowing an aircraft arrival on the secondary runway is calculated to be 5,320 meters (using simple geometry).

Solution

- A 5,320 meters distance translates into the following headways for each one of the three aircraft groups operating at this facility:
- T_{gap} – heavy = 69 seconds
- T_{gap} – large = 74 seconds
- T_{gap} – small = 103 seconds
- The expected headway for minimum gap (no buffers) is : (0.3) 103 + (0.4) (74) + (0.3) (69) = 81 seconds.

Diagonal Separation Solution

- Lets add two buffers of 33 seconds to simulate probability of violations of 5% (consistent with human factor studies)
- This brings the minimum gap for an arrival on the second runway to be : 147 seconds
- Now lets find gaps between successive arrivals on the primary runway with at least a gap of 140 seconds. The matrix of successive arrivals on the primary runway is shown below

Solution

- Lets add two buffers of 33 seconds to simulate probability of violations of 5% (consistent with human factor studies)
- This brings the minimum gap for an arrival on the second runway to be : 147 seconds
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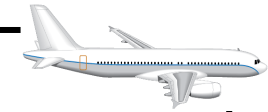


Solution

84	Arrivals on Secondary Runway per Gap				
85			Trailing		
86		Small	Large	Heavy	
87	Small	0.00	0.00	0.00	
88	Large	1.00	0.00	0.00	
89	Heavy	2.00	1.00	0.00	
90					

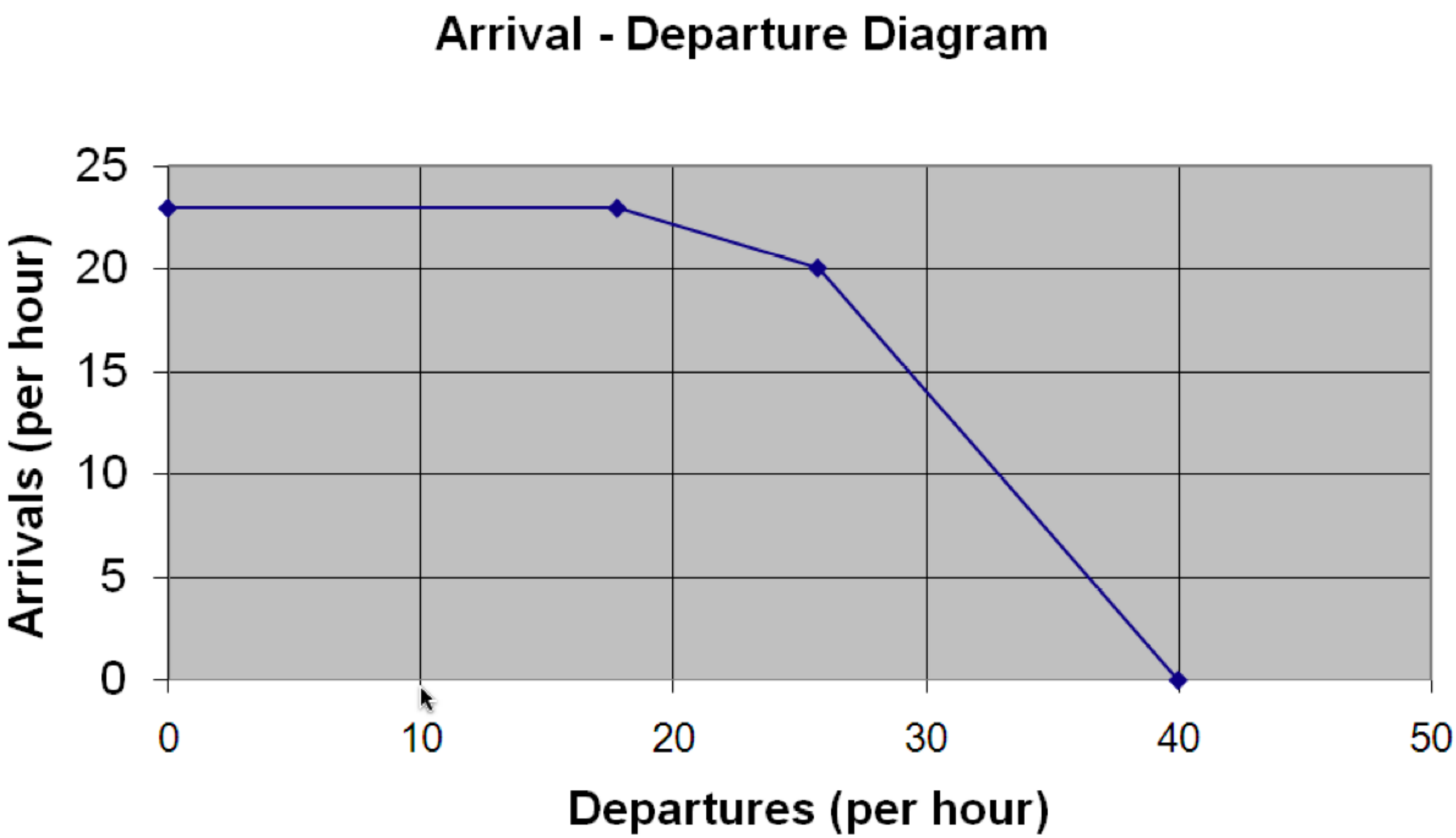
93			Trailing				
94		Small	Large	Heavy		Expected Value	
95	Small	0.00	0.00	0.00		0.00	
96	Large	2.64	0.00	0.00		2.64	
97	Heavy	3.95	2.64	0.00		6.59	
98						9.23	Total Arrivals on Secondary
99							

Solution

• Knowing the probability matrix for both runways, we can estimate the number of gaps where sufficient headway exit allowing and arrivals on the secondary runway

• The approach is similar to that explained in class and executed in the Excel program to estimate departures in the mixed mode case (see rows 93-97 in the Excel spreadsheet)

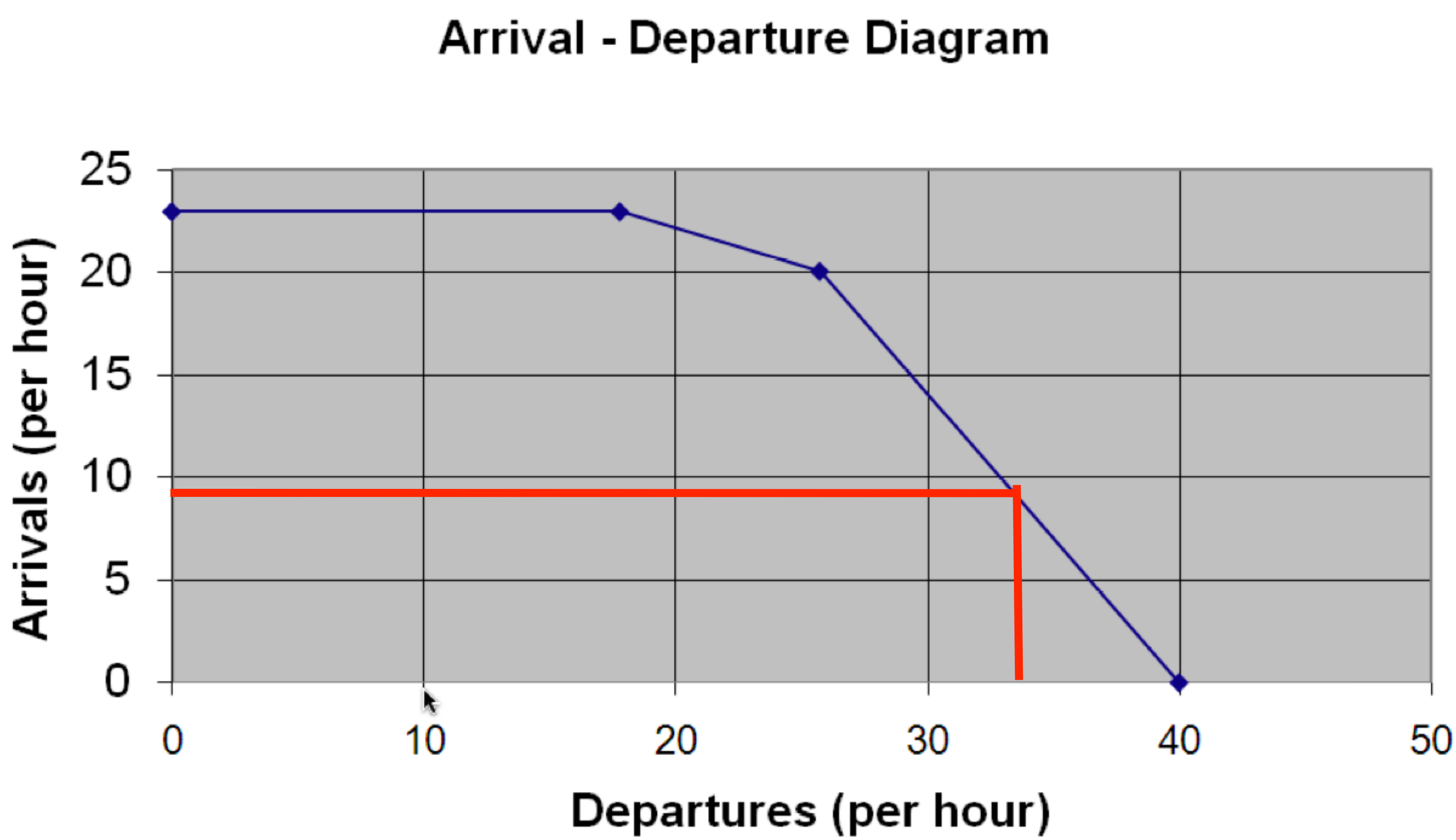
Solution for Primary Runway



Remarks

- If all conditions are met as stated, the airport can process 23 + 9 = **32 arrivals per hour** under the strategy that one runway is used at the saturation level and the second one is only used when available gaps on the primary allow arrivals in the secondary runway.
- To estimate the number of departures when the arrivals is 9.2 per hour we turn our attention to the original Pareto diagram for the primary runway only.
- The figure suggests that if arrivals are processed at a rate of 9/hr, we could process 33 departures/hr on the same runway.

Remarks

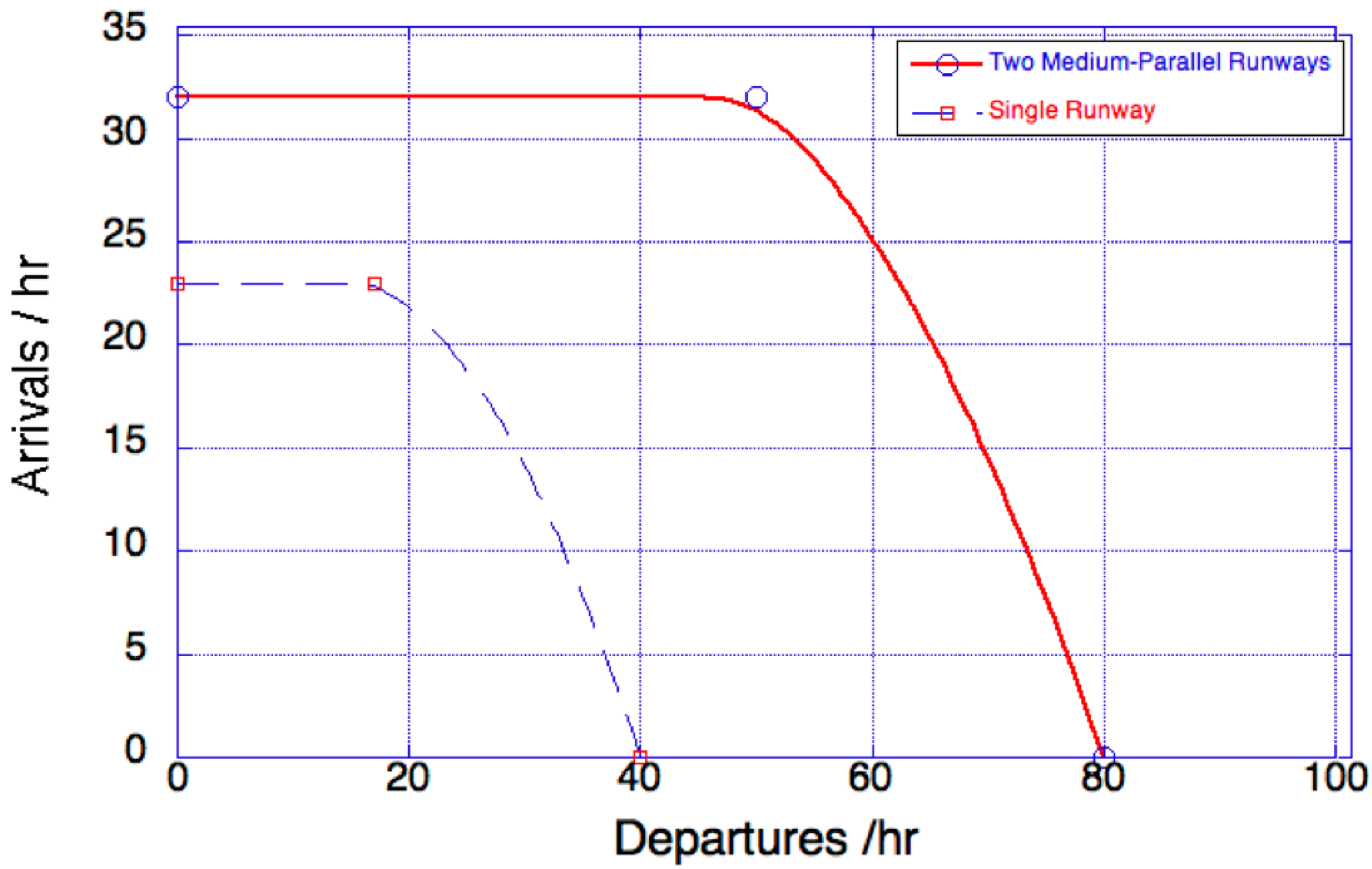


Arrival - Departure Diagram
25
20
15
10
5
0
Arrivals (per hour)
0
10
20
30
40
50
Departures (per hour)

Remarks

- This provides a first estimate of the number of departures on the secondary runway when 9 arrivals are processed in the same runway
- The primary runway handles 17 departures and 23 arrivals per hour
- Therefore, the new close-parallel configuration will handle (17 + 33 = 50) departures and 32 arrivals on two runways
- When only departures are allowed, the number of departures just doubles compared to the single runway case (i.e., 80 departures per hour as shown in the Pareto diagram)

Final Solution



Example:
Three Dependent Runways

Problem Description

- The airport to be studied in this problem is shown in Figure 1
- The airport has two 9,000 foot runways with a configuration shown in the Figure 1 (see Page 5)
- The airport has an airport surveillance radar (ASR) which tracks aircraft up to 60 miles form the airport site
- Tables 1 and 2 show the typical ATC separations at the airport under IMC conditions
- Tables 3 and 4 show the separations under VMC conditions
- The airport has the following technical parameters: a) in-trail delivery error of 16 seconds, b) departure-arrival separation for both VMC and IMC conditions is 2 nautical miles, c) probability of violation is 5%
- Arriving aircraft are “vectored” by ATC to the final approach fix (see Figure) located 7 miles from the runway threshold

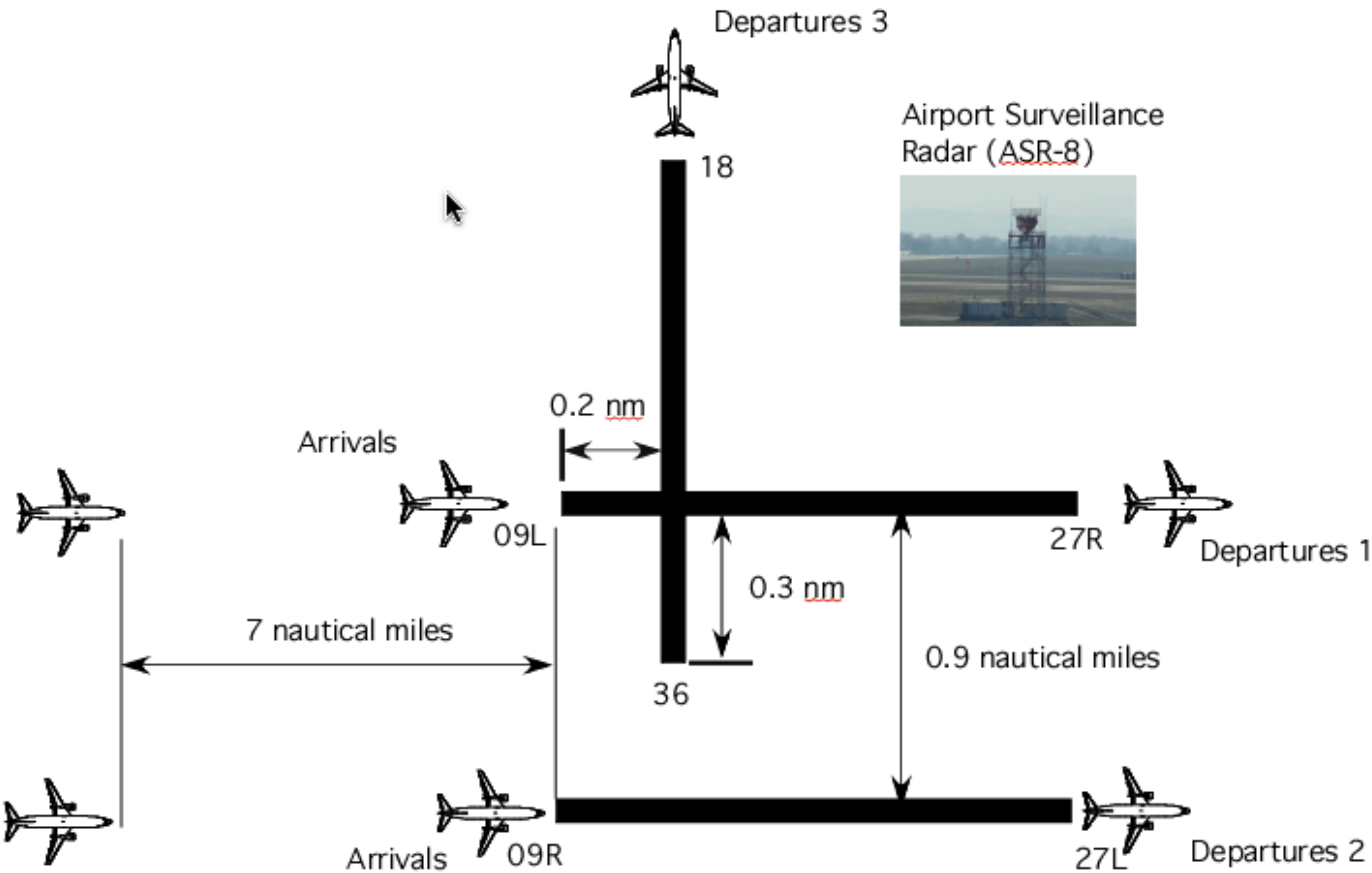
Problem Description

- The airport has an aircraft fleet mix made up of 10% small, 65% large and 25% heavy wake class aircraft
- The characteristics of the aircraft are given in Table 5
- Observed runway occupancy times in the field are: 48, 55, and 62 seconds for small, large and heavy aircraft, respectively
- Assume the 3-point runway deceleration calculation method applies to this problem to estimate the time to cross the intersection

Problem Description

- In your analysis assume departing aircraft accelerate on the runway at a constant rate of 2.2 m/s^2
- Assume that ATC controllers release departures on runway 18-36, around 10 seconds after an arriving aircraft crosses the intersection between runways 09L-27R and 18-36
- Arrivals and departures are not airborne at the intersection
- For departures on runway 18-36 to occur, it is desired that when the departing aircraft is released from the takeoff position, the next arrival to runway 09L be no less than 2.0 nm from the arrival threshold
- This rule is used by ATC controllers to schedule departures on runway 36

Problem Description



Problem Description (IFR Separations)

Table 1. Minimum arrival-arrival separations under IMC conditions. Values in are nautical miles.

Minimum Separation Matrix (nm)			Arrivals-Arrivals
Lead		Trailing	
	Small	Large	Heavy
Small	3	3	3
Large	5	3	3
Heavy	6	5	3

Table 2. Minimum departure-departure separations under IMC conditions. Values in are in seconds.

Departure-Departure Separation Matrix (seconds)			
Lead		Trailing	
	Small	Large	Heavy
Small	60	60	60
Large	60	60	90
Heavy	120	120	120

Problem Description (VFR Separations)

Table 3. Minimum arrival-arrival separations under VMC conditions. Values in are nautical miles.

Minimum Separation Matrix (nm)			Arrivals-Arrivals
Lead		Trailing	
	Small	Large	Heavy
Small	2.4	2.4	2.4
Large	5	2.4	2.4
Heavy	6	4	2.7

Table 4. Minimum departure-departure separations under IMC conditions. Values in are in seconds.

Departure-Departure Separation Matrix (seconds)			
Lead		Trailing	
	Small	Large	Heavy
Small	50	50	50
Large	50	50	75
Heavy	90	90	90

Problem Description
(Runway Performance)

Table 5. Runway Performance Data.

Aircraft Group	Parameters	Representative Aircraft
Small aircraft	Approach speed = 125 knots Touchdown location = 1,200 feet Average deceleration = -4.2 ft/s^2 Free roll time = 2.0 seconds (after touchdown and before braking)	Cessna Citation 560, Citation 500, Beechcraft Jet 400
Large aircraft	Approach speed = 145 knots Touchdown location = 1,300 feet Average deceleration = -4.2 ft/s^2 Free roll time = 2.0 seconds	Boeing 737-400 (B-737-400), Airbus A320 (A-320-200)
Heavy aircraft	Approach speed = 155 knots Touchdown location = 1,400 feet Average deceleration = -4.2 ft/s^2 Free roll time = 2.0 seconds	Boeing 747-400, Airbus A340-600

Questions

1. Calculate the arrival-departure saturation capacity diagram (Pareto diagram) under IMC conditions for this airport
2. Calculate the arrival-departure saturation capacity diagram (Pareto diagram) under VMC conditions for this airport

- State all your assumptions in your calculations

Solution Steps to the Problem

- Start with a single runway analysis for IMC conditions
- Identify interactions between runways
- Use the principle of superposition whenever possible (i.e., study independent runways and then add their capacity)
- Set-up a manual simulation scheme to look at various operational strategies for the airport

Single Runway Analysis (Arrival Operations)

- Use the spreadsheet program provided in class or your own manual calculations

Pij Matrix			
		Trailing	
	Small	Large	Heavy
Small	0.010	0.065	0.025
Large	0.065	0.423	0.163
Heavy	0.025	0.163	0.063

IFR Conditions

Augmented Matrix (Tij + Bij)			
		Trailing	
	Small	Large	Heavy
Small	112.80	100.88	96.08
Large	178.34	100.88	96.08
Heavy	211.82	153.74	96.08

Arrivals-Only Capacity 30.98 per hour

Single Runway Analysis (departure operations)

Pij Matrix			
		Trailing	
	Small	Large	Heavy
Small	0.010	0.065	0.025
Large	0.065	0.423	0.163
Heavy	0.025	0.163	0.063

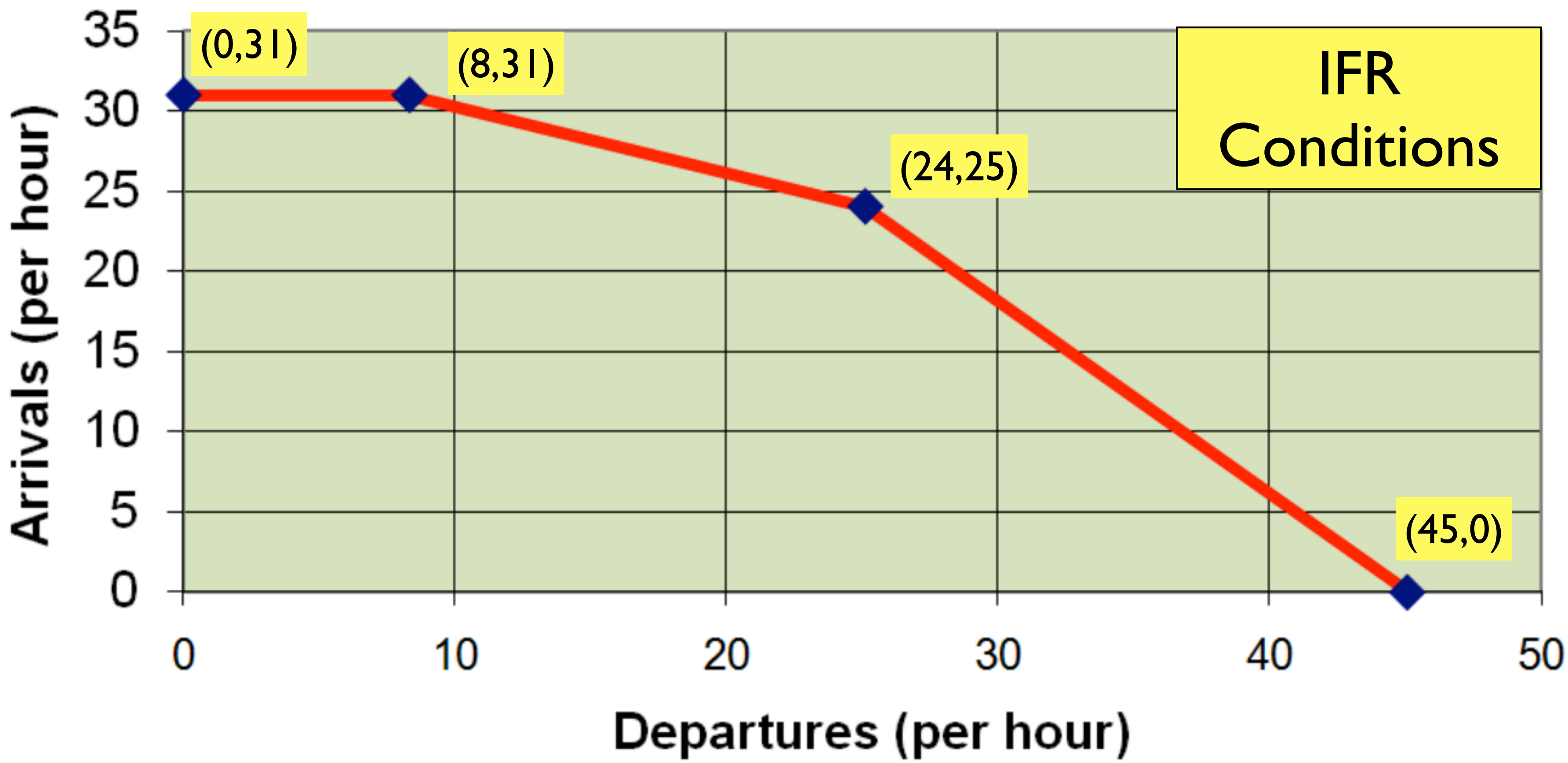
IFR Conditions

Departure-Departure Separation Matrix (seconds)			
		Trailing	
	Small	Large	Heavy
Small	60	60	60
Large	60	60	90
Heavy	120	120	120

Departures-Only Capacity 45.07 per hour

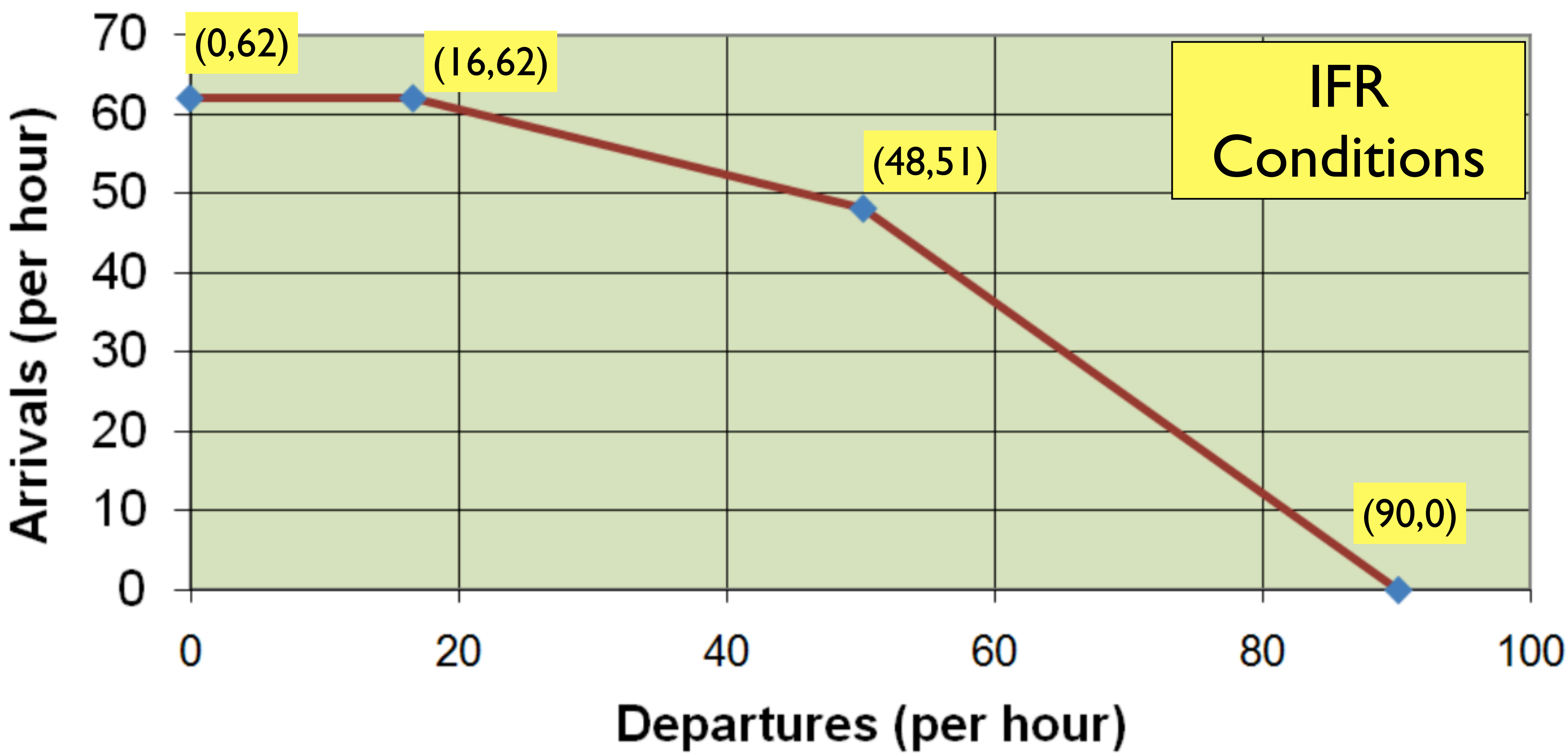
IFR Capacity Pareto Diagram (Single Runway Analysis)

Saturation Capacity for a Single Runway at the Airport under Various Operational Conditions. The diagram applies to one runway (either 09L-27R or 09R-27L)



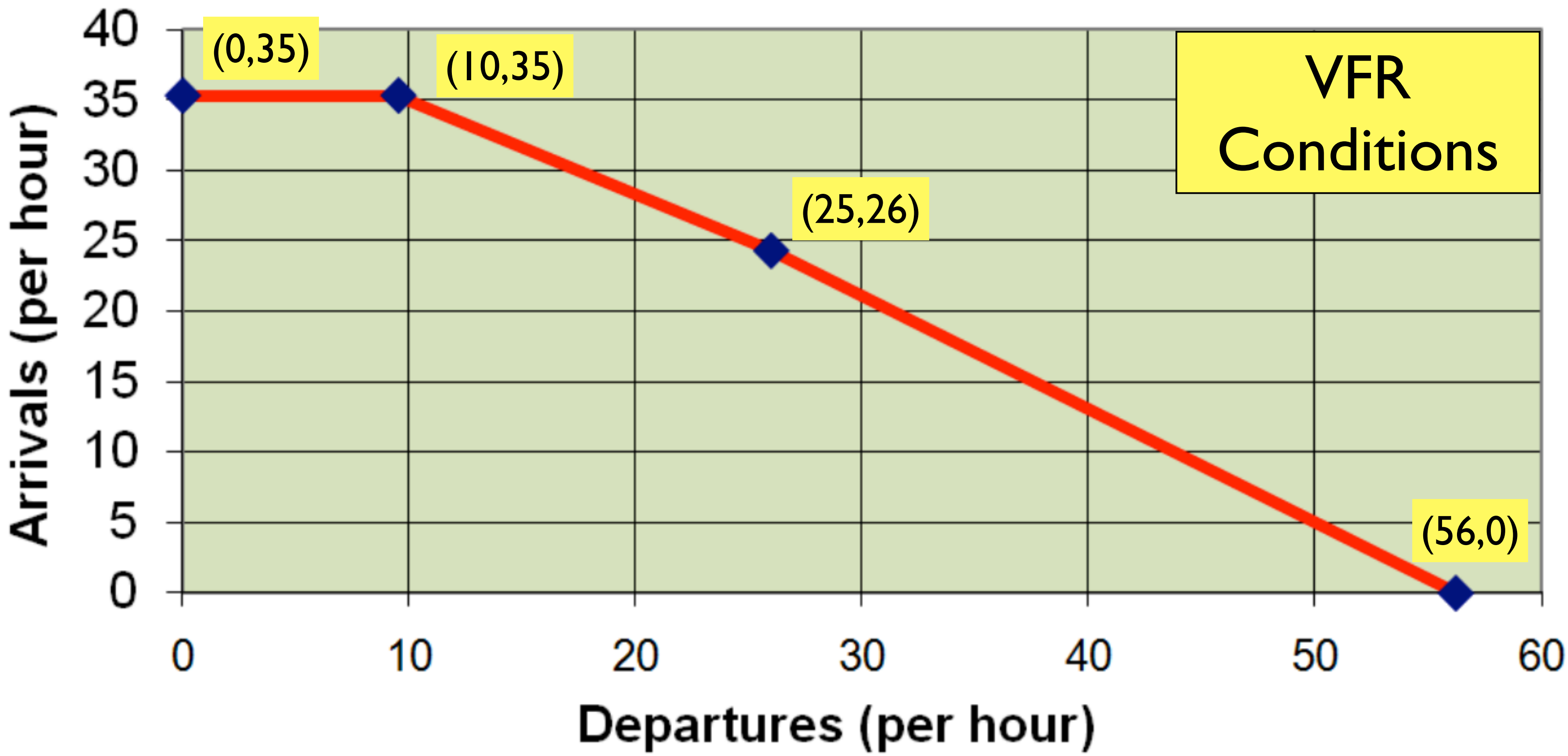
IFR Capacity Pareto Diagram (Two Parallel and Independent Runways)

Saturation Capacity for two runways at the Airport under Various Operational Conditions. The diagram applies to one runway (either 09L-27R or 09R-27L)



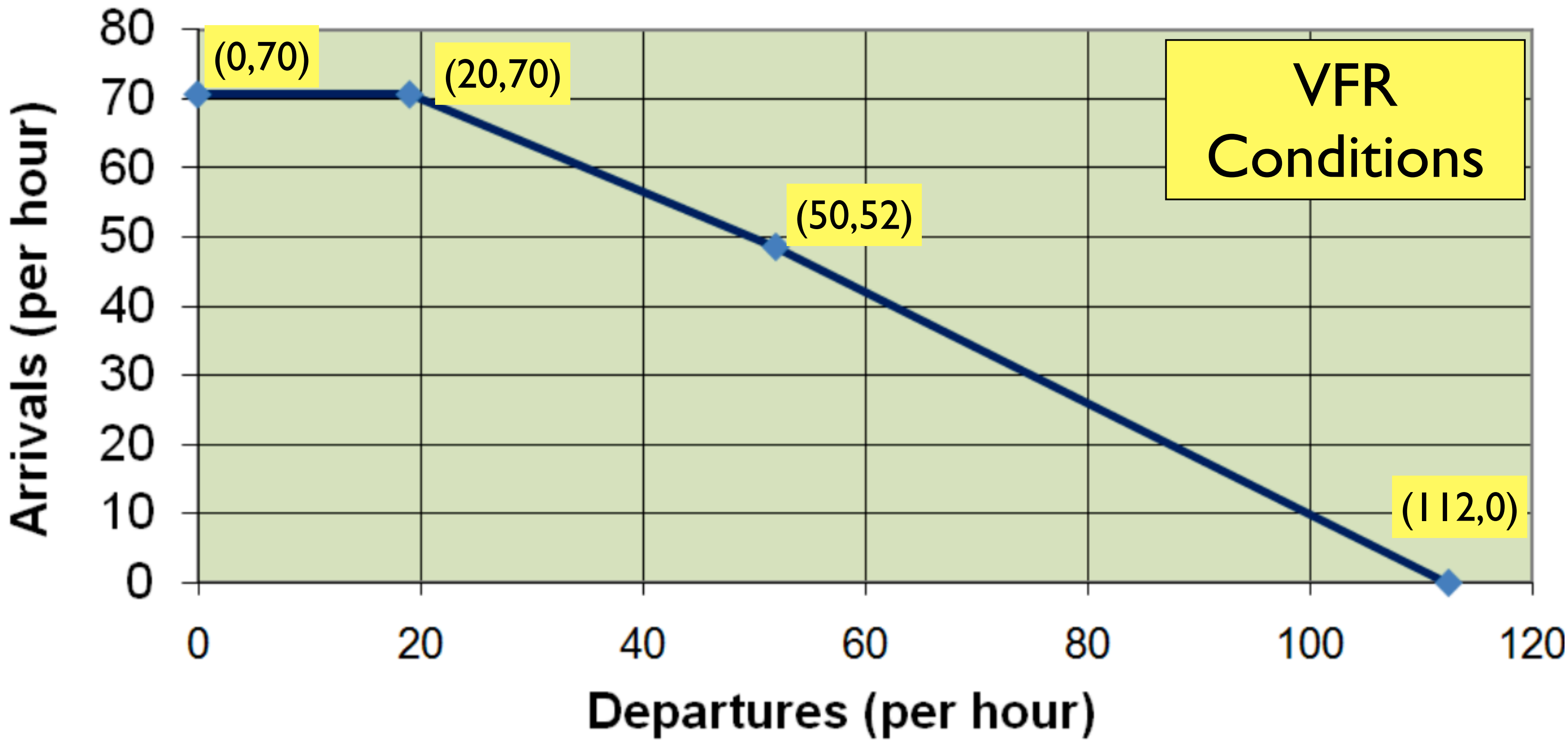
VFR Capacity Pareto Diagram (Single Runway Analysis)

Saturation Capacity for a Single Runway at the Airport under Various Operational Conditions. The diagram applies to one runway (either 09L-27R or 09R-27L)



VFR Capacity Pareto Diagram (Two Parallel and Independent Runways)

Saturation Capacity for a Single Runway at the Airport under Various Operational Conditions. The diagram applies to one runway (either 09L-27R or 09R-27L)



Observations

- Arrivals on runways 09L and 09R are independent (> 4300 ft separation) (radar available)
- The Pareto diagram found for one runway replicates for the second parallel runway (also used in mixed operations mode)
- The arrivals-only saturation capacity of the two-runway system is 62 per hour
- The departures-only saturation capacity for two parallel runways is 90 per hour

Detailed Analysis for Intersecting Runways

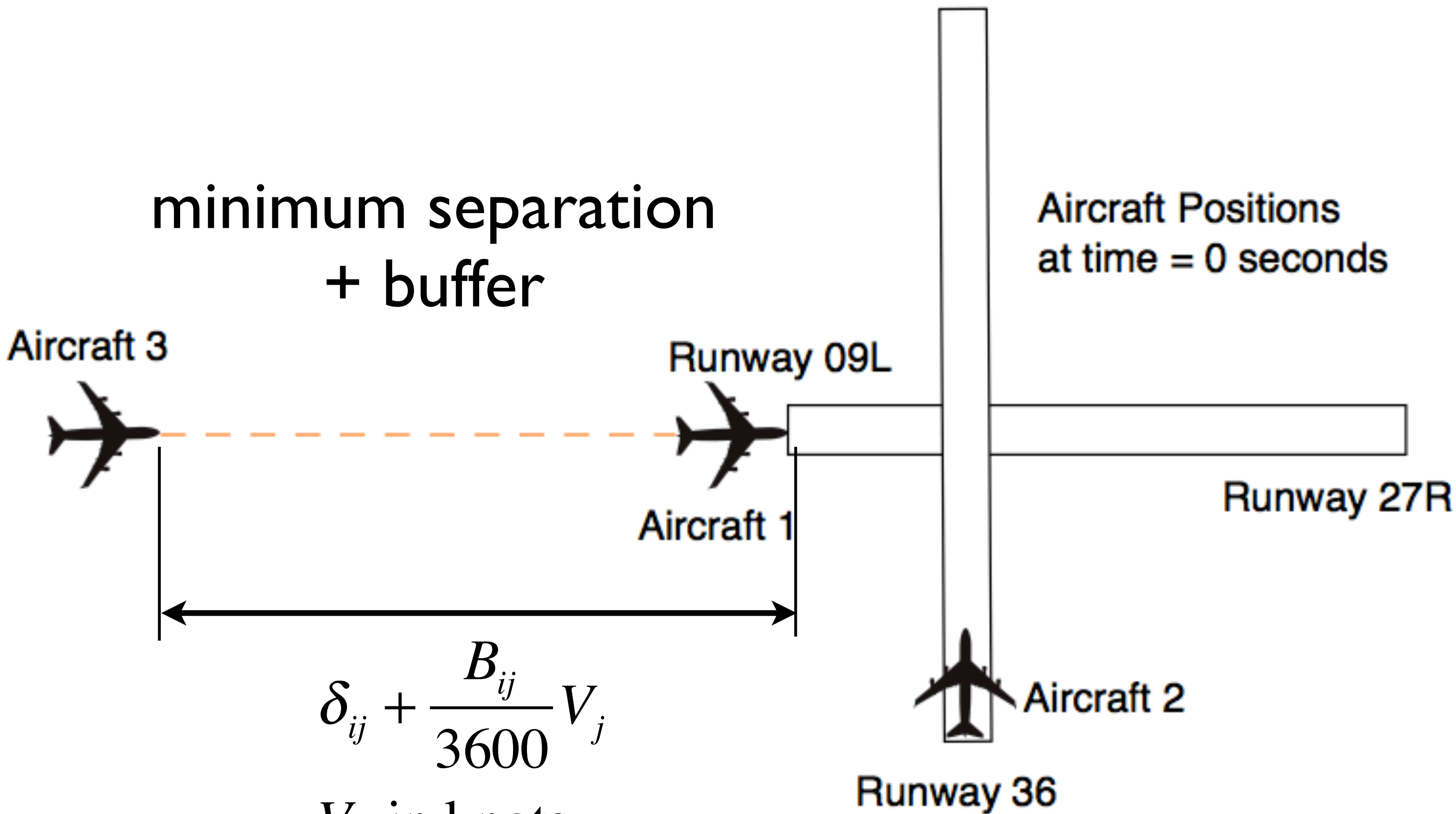
- The intersecting runway is treated as another asset at the airport
- Need to answer the fundamental questions:
- Are there any gaps left by successive arrivals (do nothing) allowing departures from runway 36?
- Quantify the capacity benefit for IFR conditions

Approach

- Visualize the situation by drawing various operations
- Determine the added number of departures on runway 36 allowed with the "natural" arrival gaps on runway 09L
- Assume that departures on runway 09L are not processed since runway 36 offers clear advantages
- The diagrams that follow illustrate various steps in the sequence of events likely to happen at the airport **as "closing" case, pairwise arrival sequences**

Aircraft Positions at Time t = 0 s

minimum separation
+ buffer



$$\delta_{ij} + \frac{B_{ij}}{3600} V_j$$

V_j in knots

B_{ij} in seconds

Aircraft 1 crosses runway 09L threshold . Aircraft 3 follows in-trail at the required separation behind aircraft 1

Calculations of Travel Time for Landing Aircraft to Cross Runway Intersection

- Calculation of the travel times from threshold crossing point to runway intersection point
- The travel times to cross the intersection of runway 18-36 (as the aircraft lands on runway 09L) are: 5.8, 5.0 and 4.6 seconds for small, large and heavy aircraft, respectively
- These travel times influence the ATC tower controller (i.e. local controller) decision on when to clear a departure on the crossing runway

Calculations of Travel Time to Cross Runway Intersection for Departing Aircraft on Runway 36

$$S = V_i t + \frac{1}{2} a t^2$$

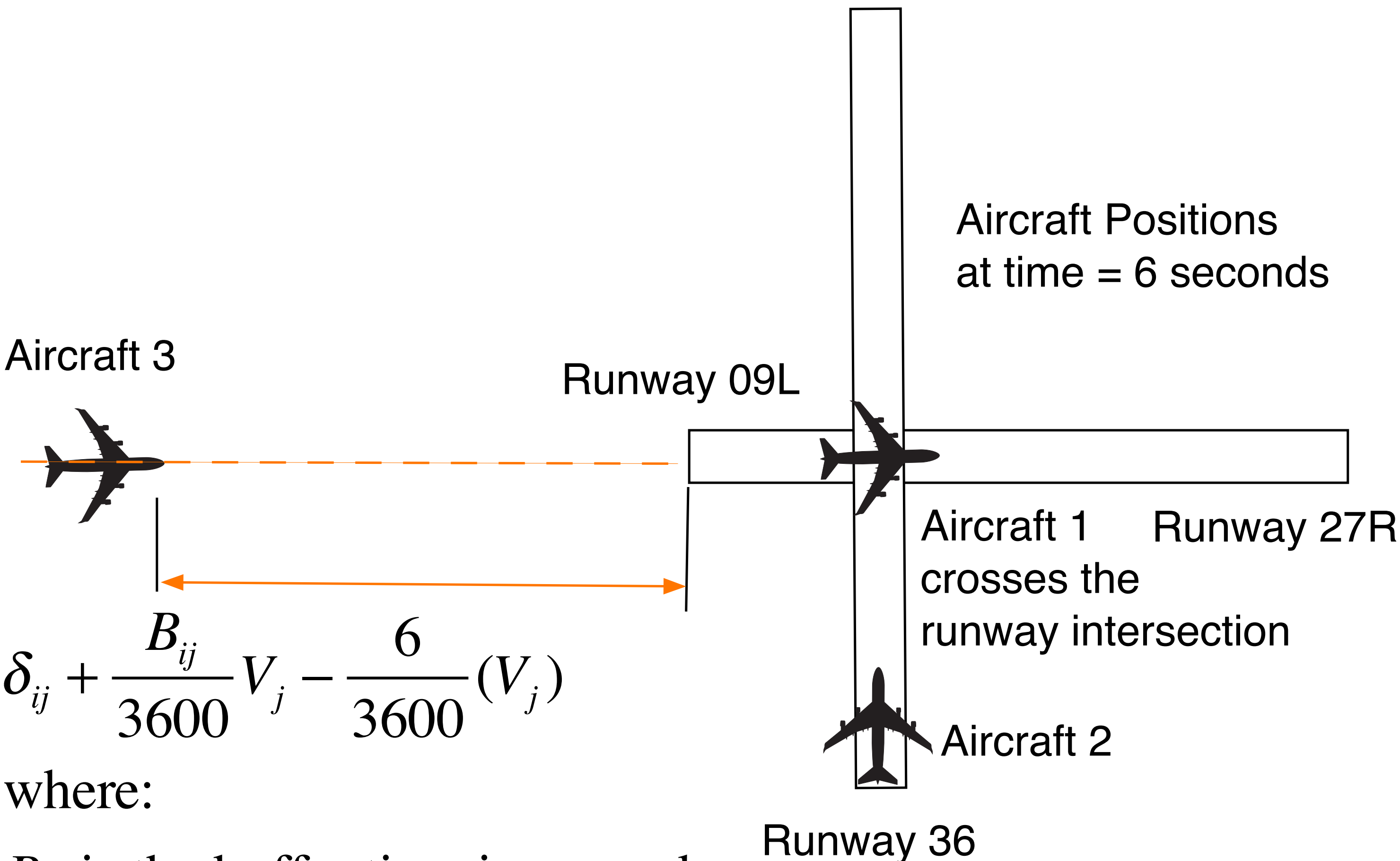
$$t^2 = \frac{2S}{a}$$

$$t = \sqrt{\frac{2S}{a}}$$

$$t = \sqrt{\frac{2S}{a}} = \sqrt{\frac{2(555.6 \text{ m})}{2.2 \text{ m/s}^2}} = 22.5 \text{ seconds}$$

Aircraft departing runway 36 take ~23 seconds to cross the runway intersection

Aircraft Positions at Time t=6 s



$$\delta_{ij} + \frac{B_{ij}}{3600} V_j - \frac{6}{3600}(V_j)$$

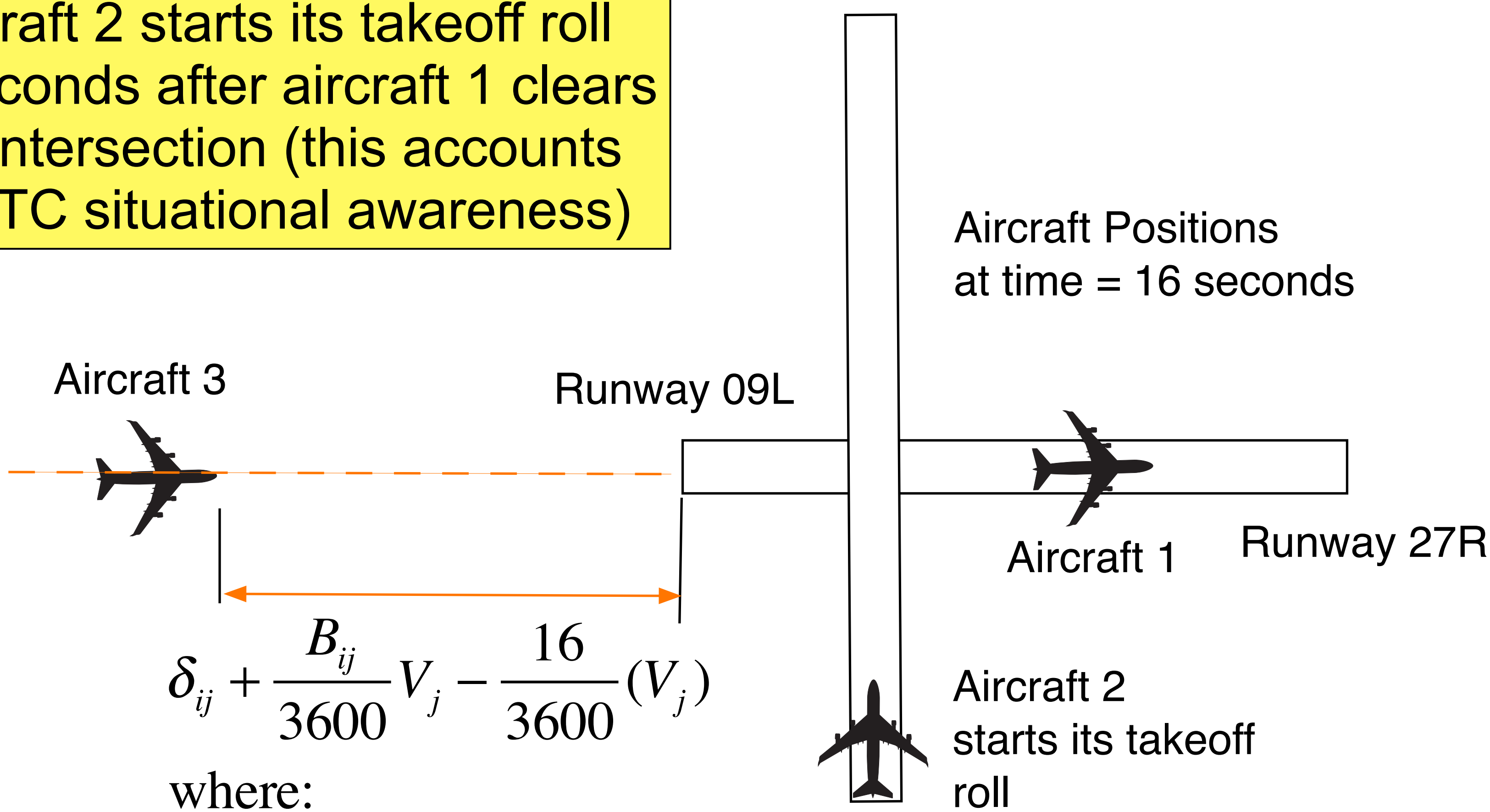
where:

B_{ij} is the buffer time in seconds

V_j is the following aircraft speed in knots

Aircraft Positions at Time t=16 s

Aircraft 2 starts its takeoff roll 10 seconds after aircraft 1 clears the intersection (this accounts for ATC situational awareness)



$$\delta_{ij} + \frac{B_{ij}}{3600} V_j - \frac{16}{3600}(V_j)$$

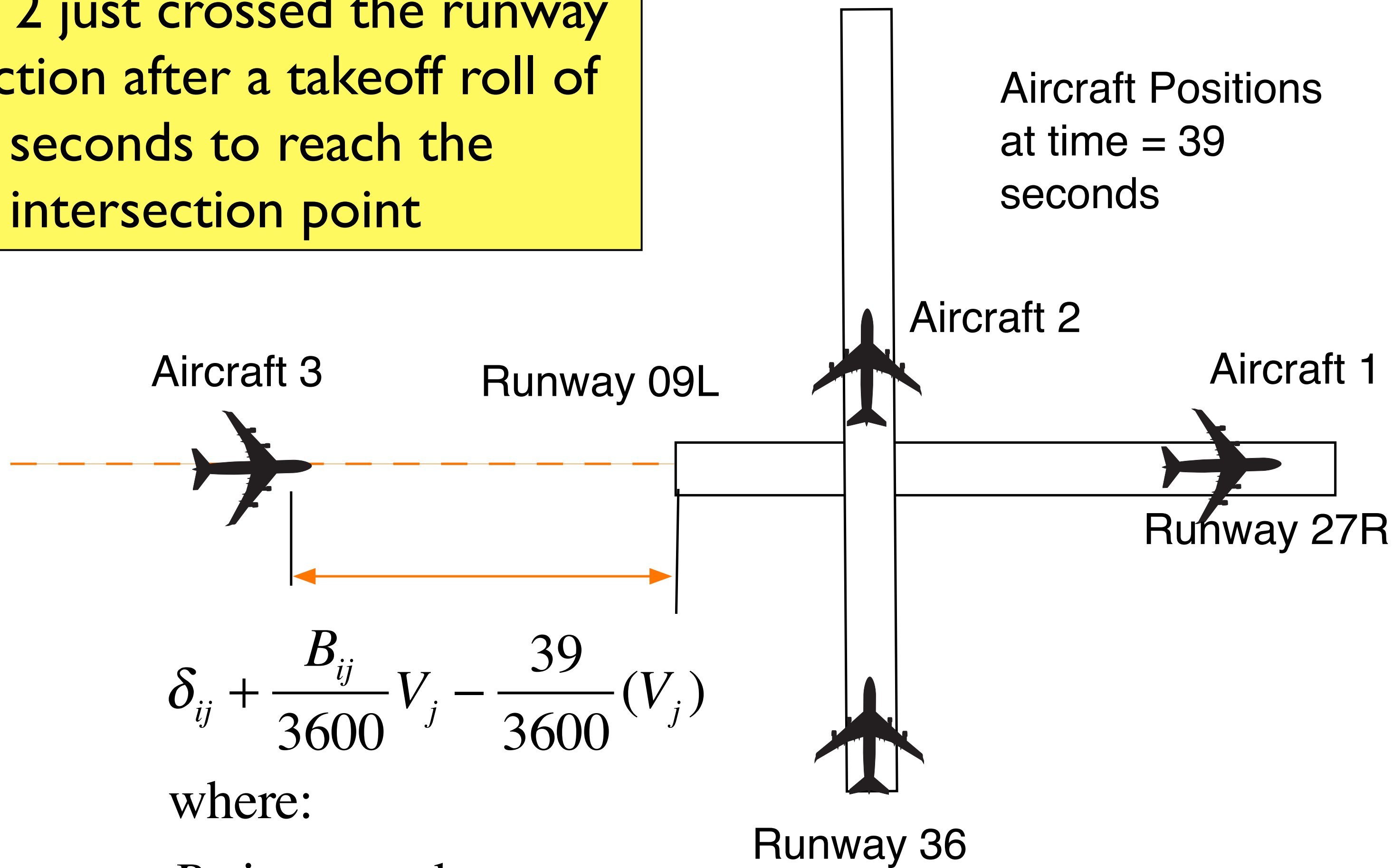
where:

B_{ij} in seconds

V_j in knots

Aircraft Positions at Time t = 39 s

Aircraft 2 just crossed the runway intersection after a takeoff roll of 23 seconds to reach the intersection point



$$\delta_{ij} + \frac{B_{ij}}{3600} V_j - \frac{39}{3600}(V_j)$$

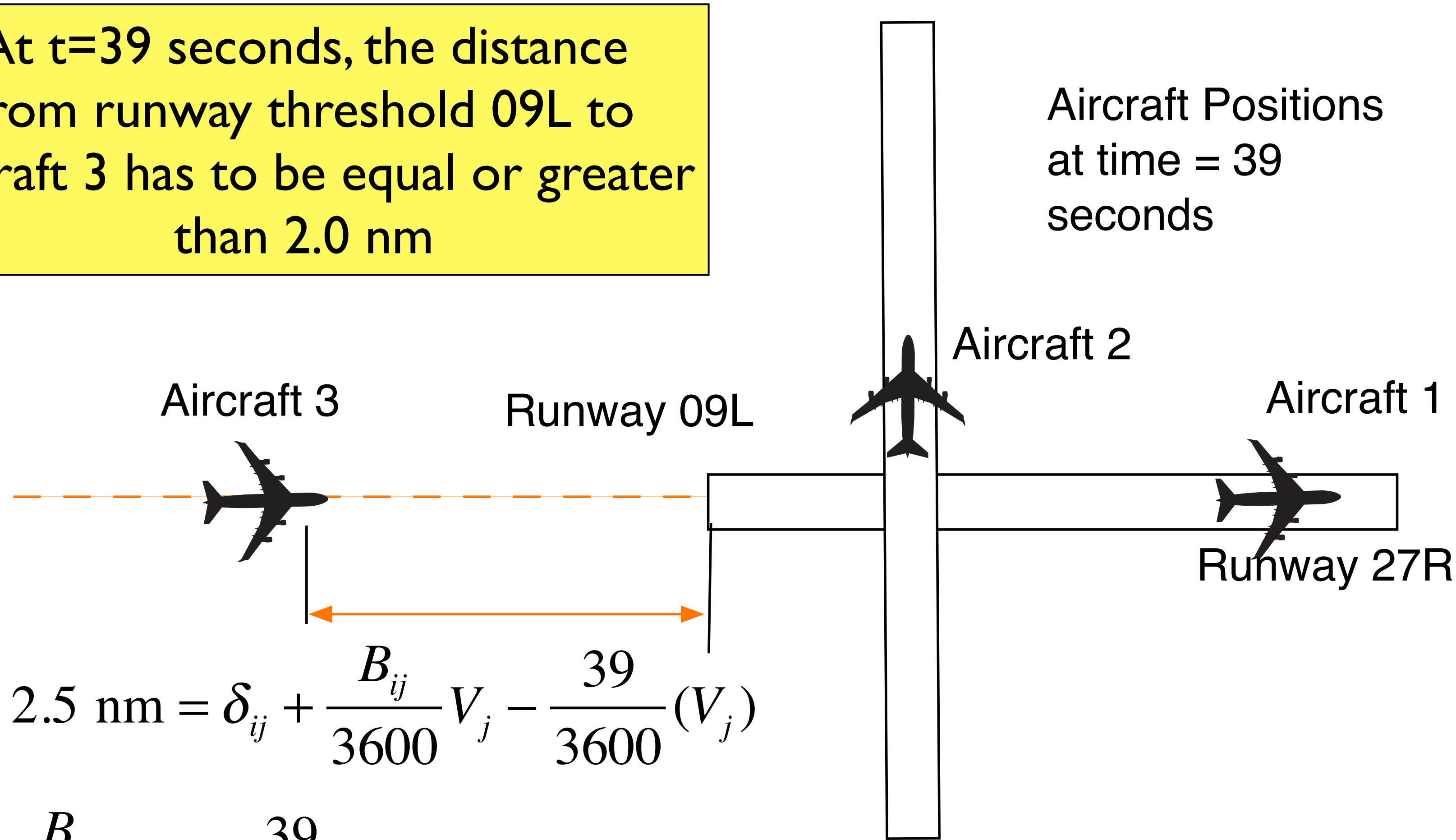
where:

B_{ij} in seconds

V_j in knots

Critical Distance at t = 39 s

At t=39 seconds, the distance from runway threshold 09L to aircraft 3 has to be equal or greater than 2.0 nm



$$\delta = 2.5 \text{ nm} = \delta_{ij} + \frac{B_{ij}}{3600} V_j - \frac{39}{3600}(V_j)$$

$$\delta_{ij} + \frac{B_{ij}}{3600} V_j - \frac{39}{3600} V_j \geq 2.0 \text{ nm}$$

Condition to release a departure between arrival gaps

General Observations

- The time period between the leading aircraft arrival (i) on runway 09L and a single departure on runway 36 is around 39 seconds. Define,

$$t_{n-36} = \text{time for n departures on runway 36}$$

$$t_{1-36} = 39 \text{ seconds}$$

$$t_{2-36} = (39 + 80) = 119 \text{ seconds}$$

$$t_{3-36} = (39 + 80 + 80) = 199 \text{ seconds}$$

$$t_{n-36} = 39 + E(t_d)(n-1) \text{ seconds}$$

where:

$n =$ number of departures on runway 36 per arrival gap on runway 09L

$E(t_d) =$ expected value of time between successive departures on runway 36

General Observations

$$t_{n-36} = \text{time for n departures on runway 36}$$

- For each successive pair of arrivals on the primary runway (runway 09L-27R), we would have to subtract (t_{n-36}) seconds and check the suitability of each natural gap to release n departures on runway 36
- The procedure is analogous to a single runway with mixed operations

Analysis of Crossing Runway Operations (IFR Case)

Augmented Matrix (Tij + Bij)			
		Trailing	
	Small	Large	Heavy
Small	112.80	100.88	96.08
Large	178.34	100.88	96.08
Heavy	211.82	153.74	96.08

Arrival-arrival matrix (Tij+Bij)

- 39 seconds

Time remaining on following aircraft approach segment (seconds)			
n=1		Trailing	
	Small	Large	Heavy
Small	73.80	61.88	57.08
Large	139.34	61.88	57.08
Heavy	172.82	114.74	57.08

Time left for following aircraft to reach runway 09L threshold

Analysis of Crossing Runway Operations (IFR Case)

Distance left between following aircraft and runway threshold (nm)			
n=1		Trailing	
	Small	Large	Heavy
Small	2.56	2.49	2.46
Large	4.84	2.49	2.46
Heavy	6.00	4.62	2.46

Distance between following aircraft on runway 09L to runway threshold

verify

$$\delta_{ij} + \frac{B_{ij}}{3600} V_j - \frac{39}{3600} V_j \geq 2.0 \text{ nm}$$

Number of Departures on runway 36 per arrival gap on 09L			
n		Trailing	
	Small	Large	Heavy
Small	1.00	1.00	1.00
Large	2.00	1.00	1.00
Heavy	2.00	1.00	1.00

Potential departures on runway 36 per arrival gap on runway 09L

Analysis of Crossing Runway Operations (IFR Case)

VirginiaTech
Invent the Future

Pij Matrix (dim)			
		Trailing	
	Small	Large	Heavy
Small	0.010	0.065	0.025
Large	0.065	0.423	0.163
Heavy	0.025	0.163	0.063

$ED_{g-ij} = P_{ij} DG_{ij} TG$

ED_{g-ij} = equivalent departures per gap between aircraft i and j

P_{ij} = probability of i following j

DG_{ij} = Departures per gap between i and j

TG = total gaps per hour

Number of Departures on runway 36 per arrival gap on 09L			
n		Trailing	
	Small	Large	Heavy
Small	1.00	1.00	1.00
Large	2.00	1.00	1.00
Heavy	2.00	1.00	1.00

Sample calculation

$ED_{s-s} = 0.010 * 1.0 * (30.97 - 1) = 0.3$

Number of departures on runway 36			
n		Trailing	
	Small	Large	Heavy
Small	0.30	1.95	0.75
Large	3.90	12.67	4.87
Heavy	1.50	4.87	1.87
Sum of departures on runway 36			32.68

Total departures on runway 36 considering all arrival gaps on runway 09L

Preliminary Conclusions

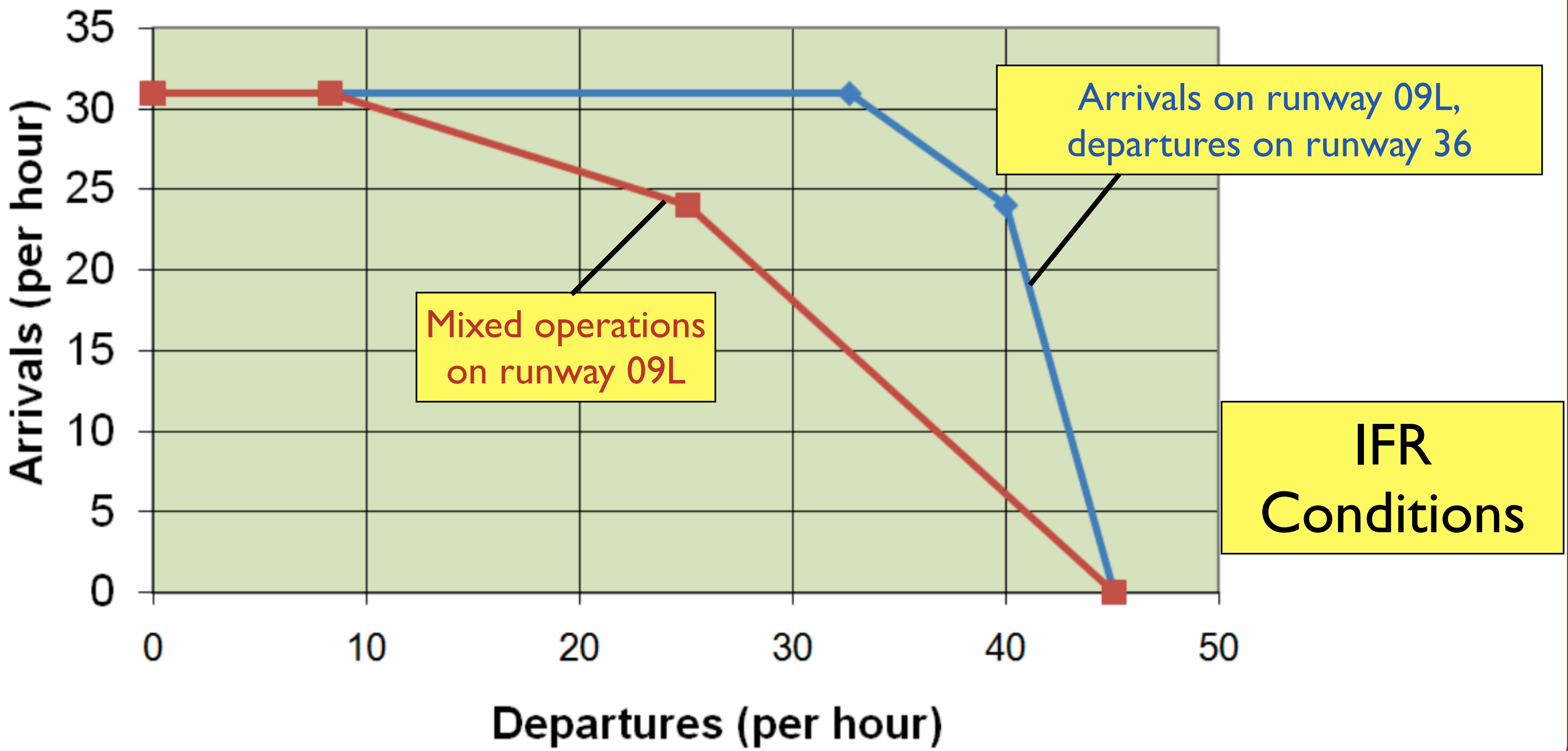
- The total number of departures on runway 36 is estimated to be **33 per hour**
- This is slightly more than the number of arrivals on the primary runway (09L)
- Processing departures on runway 36 is advantageous:
  - 8 departures on runway 09L-27R per hour
  - 33 departures on runway 36-18 per hour
  - Both results assume arrival priority on runway 09L-27R

Extending the Analysis for Runway 09L and 36 as Dependent Pair

- It is clear that departures operations on runway 36 are clearly coupled to arrivals to runway 09L
- Now we study the situation where arrival gaps on runway 09L are increased allowing more departures on runway 36
- As arrival gaps grow to infinity, the number of departures on runway 36 increase to 45 per hour
- The advantages in the Pareto diagram are shown in the next page

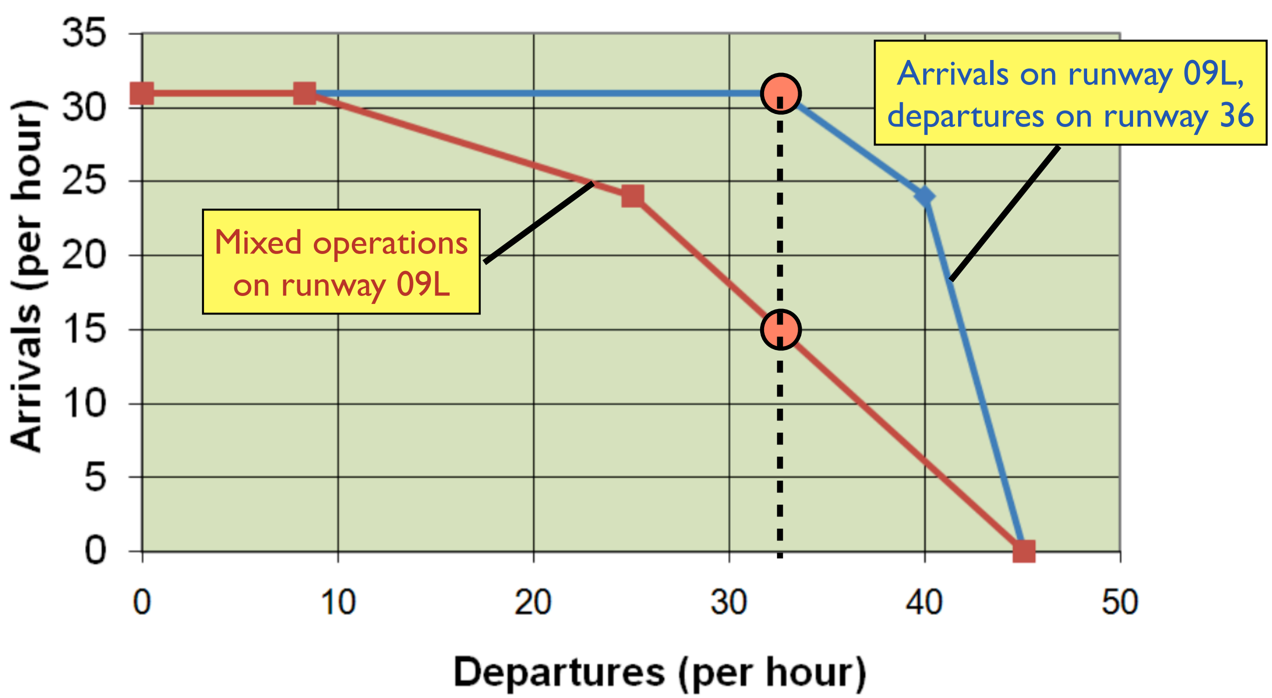
IFR Capacity Pareto Diagram (Runways 09L and 36 as Coupled Pair)

Saturation capacity for two runways operated with dependent operations. Arrivals on runway 09L, departures on runway 36.



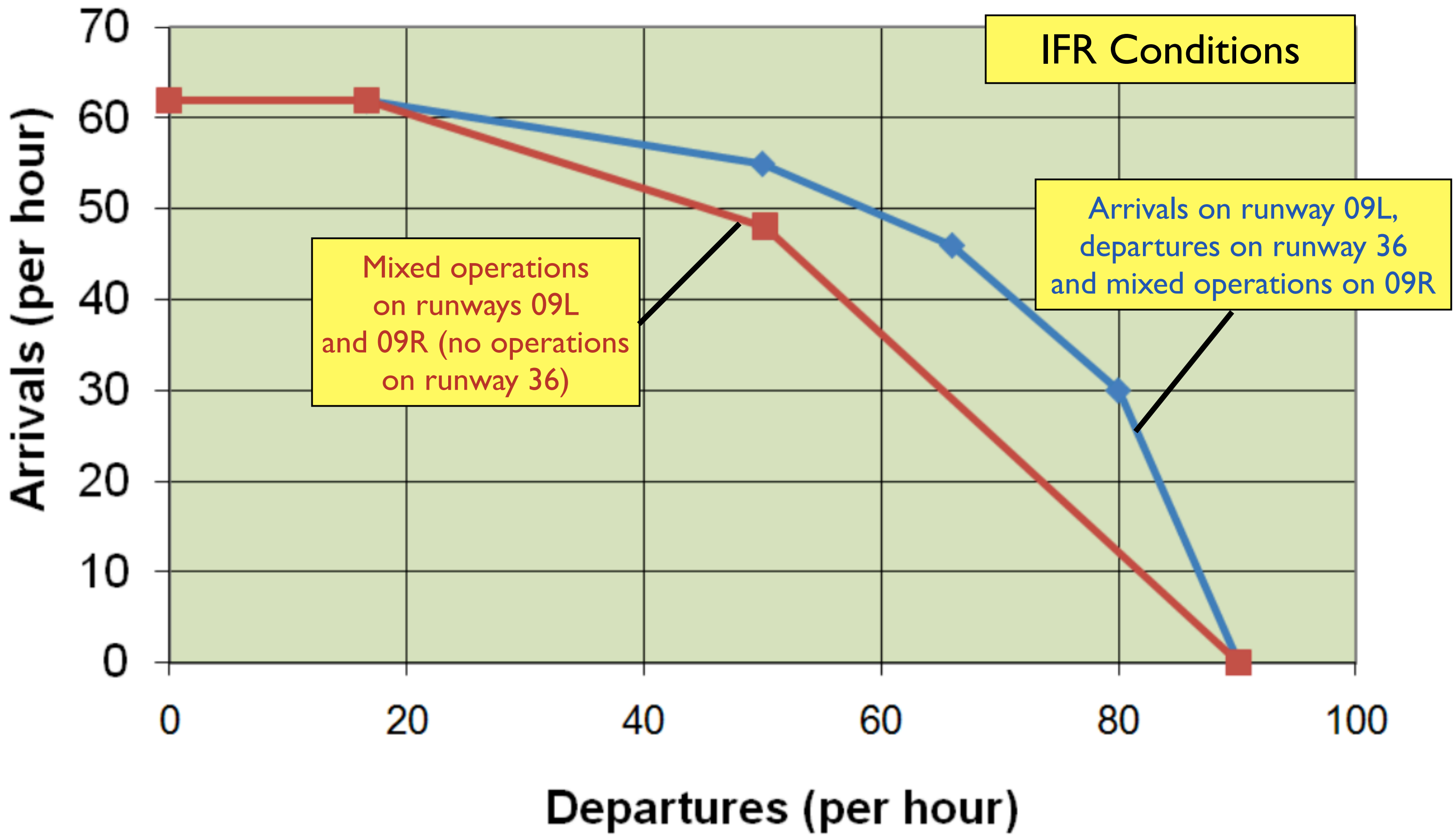
Capacity Benefits

- It is clear that an expansion of the Pareto diagram is a benefit to the capacity of the airport
- Consider an operating point where the coupled runway pair handles 33 departures and 31 arrivals, the single runway 09L in mixed operations can only process 33 departures and and 15 arrivals



IFR Capacity Pareto Diagram (Coupled Runway Pair 09L / 36 + Runway 09R)

Saturation capacity for three runways (coupled pair + single runway). Arrivals on runway 09L and 09R, departures on runway 36 and 09R.

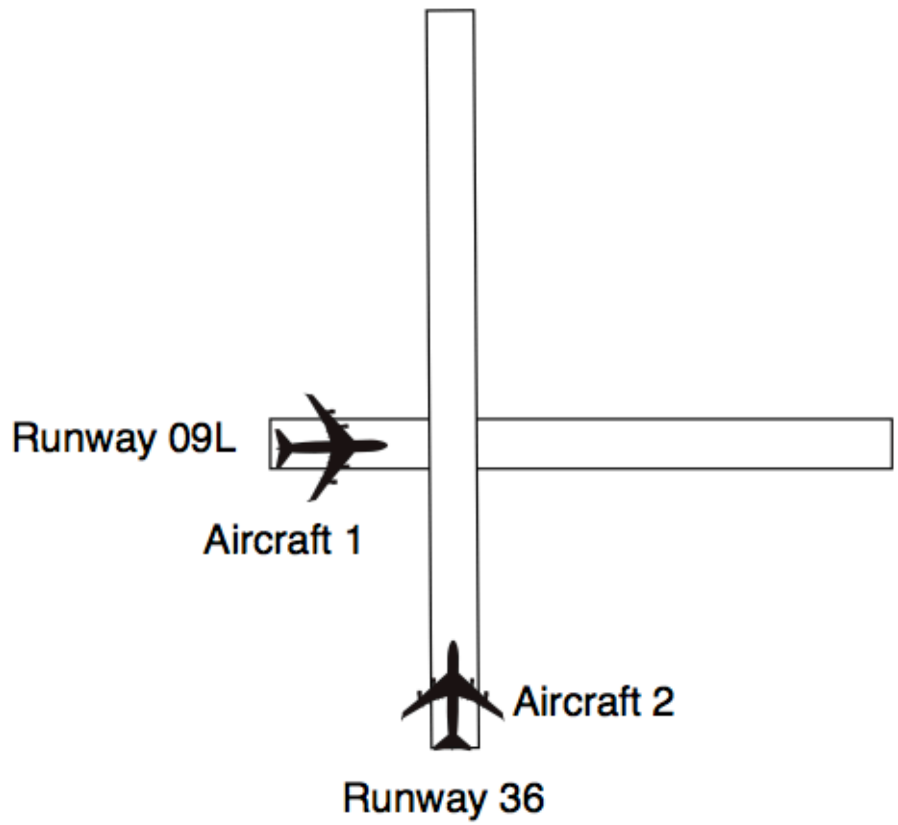


Final Twist on Departure Capacity

- As the arrivals on runway 09L are reduced to zero (allowing more departures on runway 36 during departure rush periods) it is clear that substantial departure capacity gains are possible operating the coupled pair with sequenced departures (as shown)

- You can show that the departure saturation capacity of the coupled pair is ~80 per hour

- This in the end increases the departure capacity of the airfield to 125 per hour



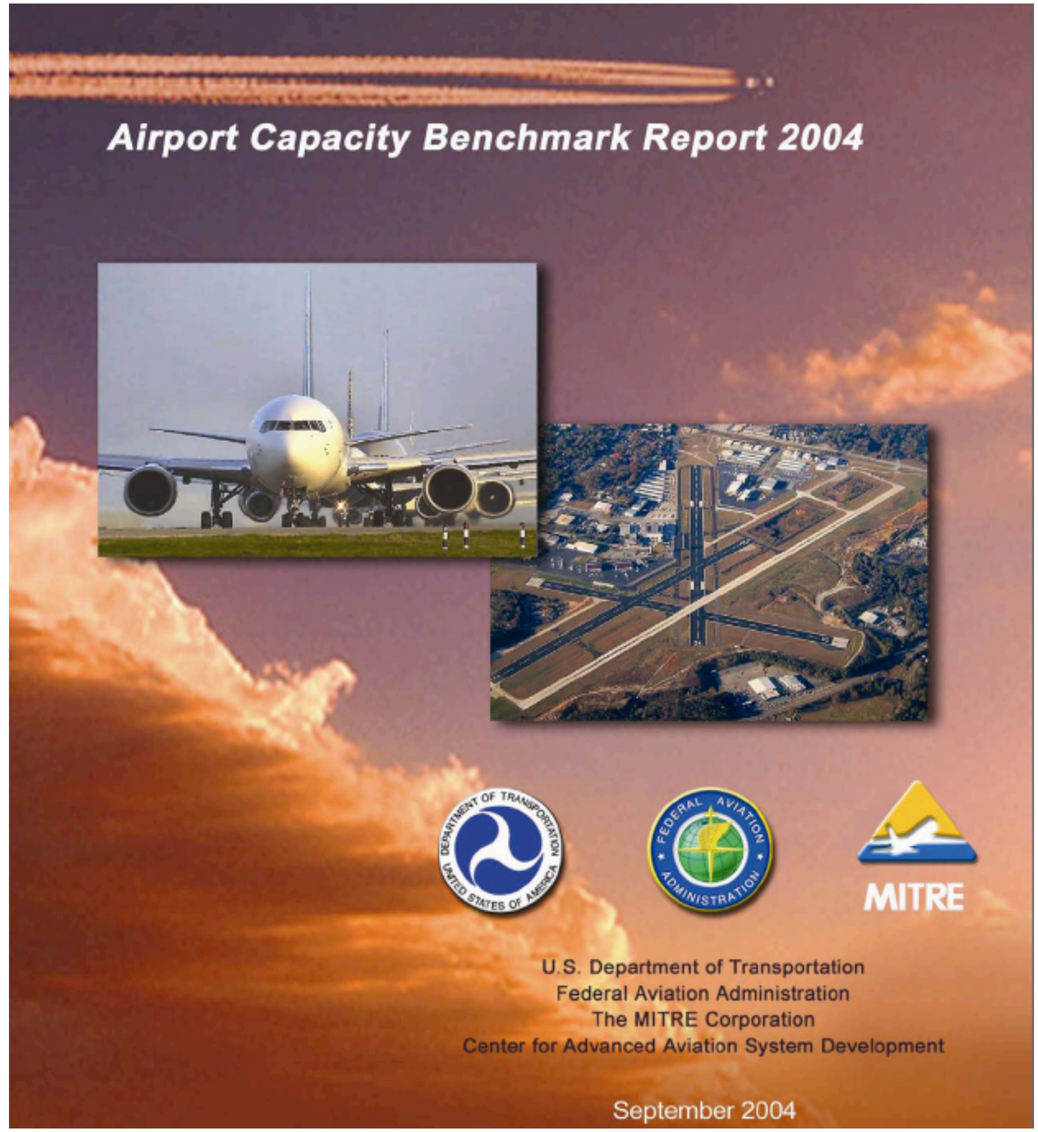
Capacity Diagrams for Various Airports

CEE 5614
Analysis of Air Transportation Systems

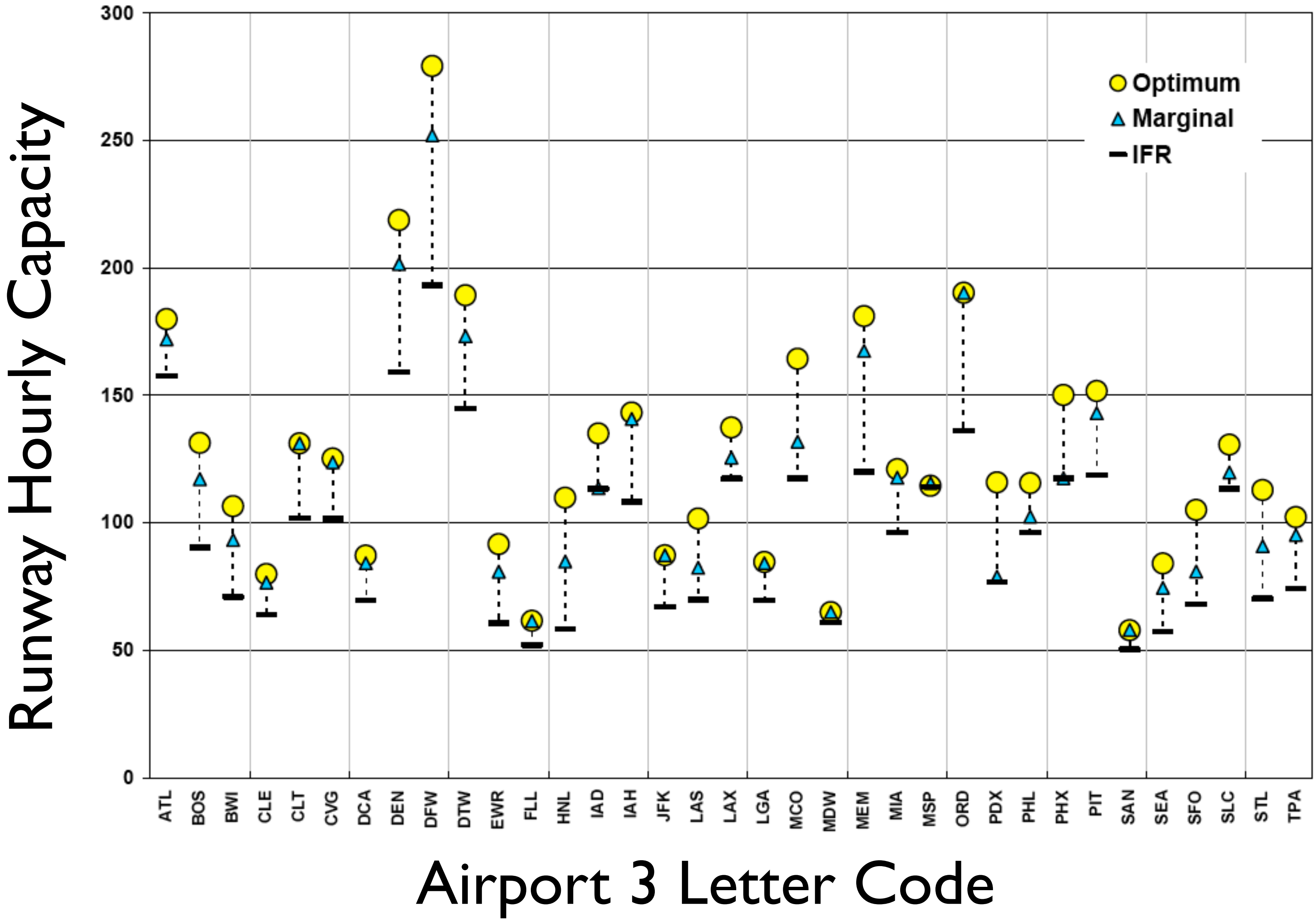
Dr. Antonio A. Trani
Professor

FAA Airport Capacity Benchmarks

- The FAA has conducted detailed capacity studies for the 31 most important airports to determine their VFR and IFR hour capacities
- The details are included in the FAA Airport Capacity benchmark document
- Document: http://www.faa.gov/about/office_org/headquarters_offices/ato/publications/bench/



Summary of Top 31 Airports

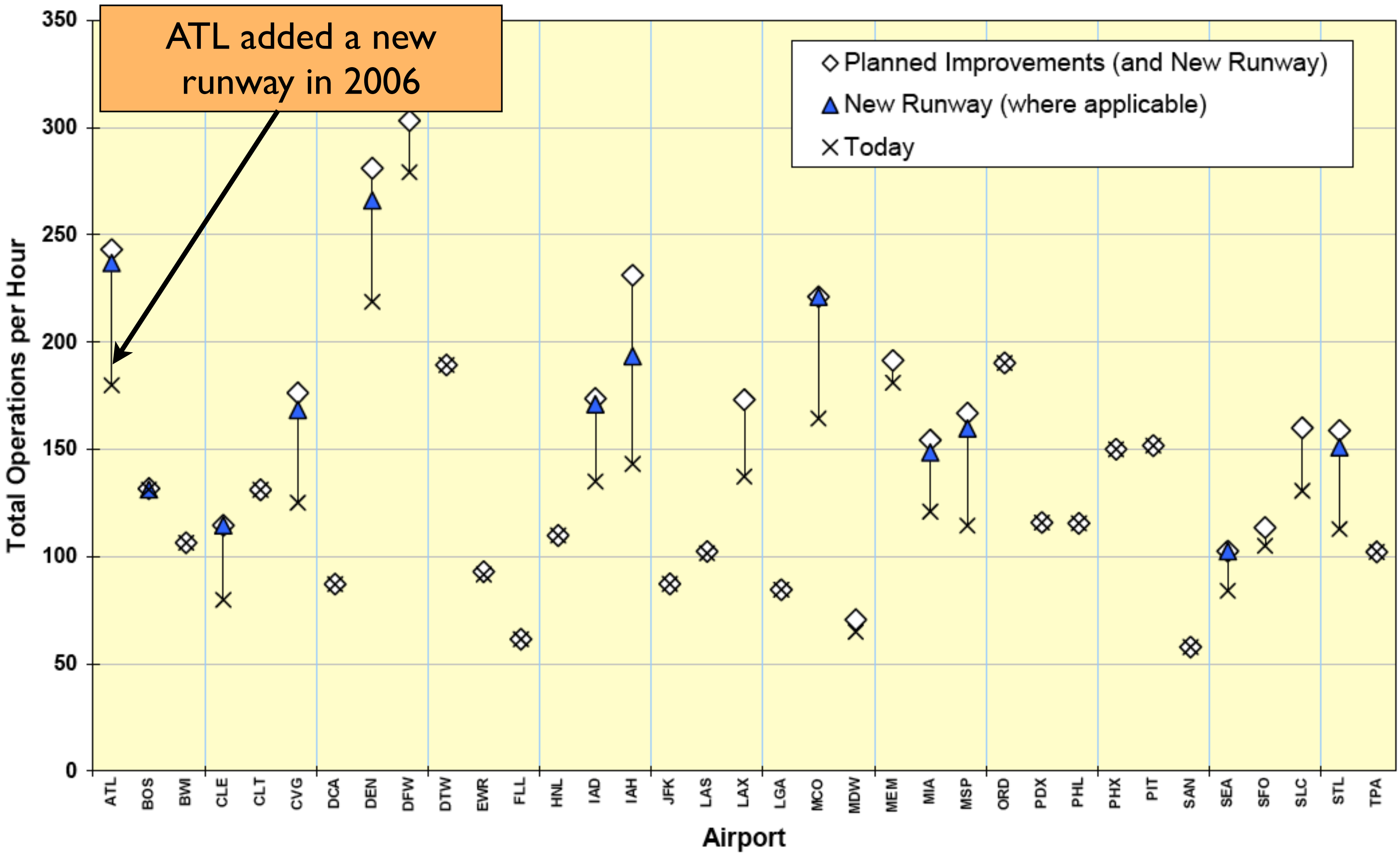


Observations

- Airports with largest margins between VFR (Optimal) and IFR capacities are DFW (Dallas Forth Worth), DEN (Denver) and ORD (Chicago)
- These airports have multiple parallel runways that benefit from VFR rules
- Few airports such as San Diego (SAN), La Guardia (LGA), Chicago Midway (MDW) and Fort Lauderdale (FLL) have IFR capacities close to those for VFR
- Capacity is affected by:
  - Runway configuration
  - Weather
  - Aircraft fleet mix

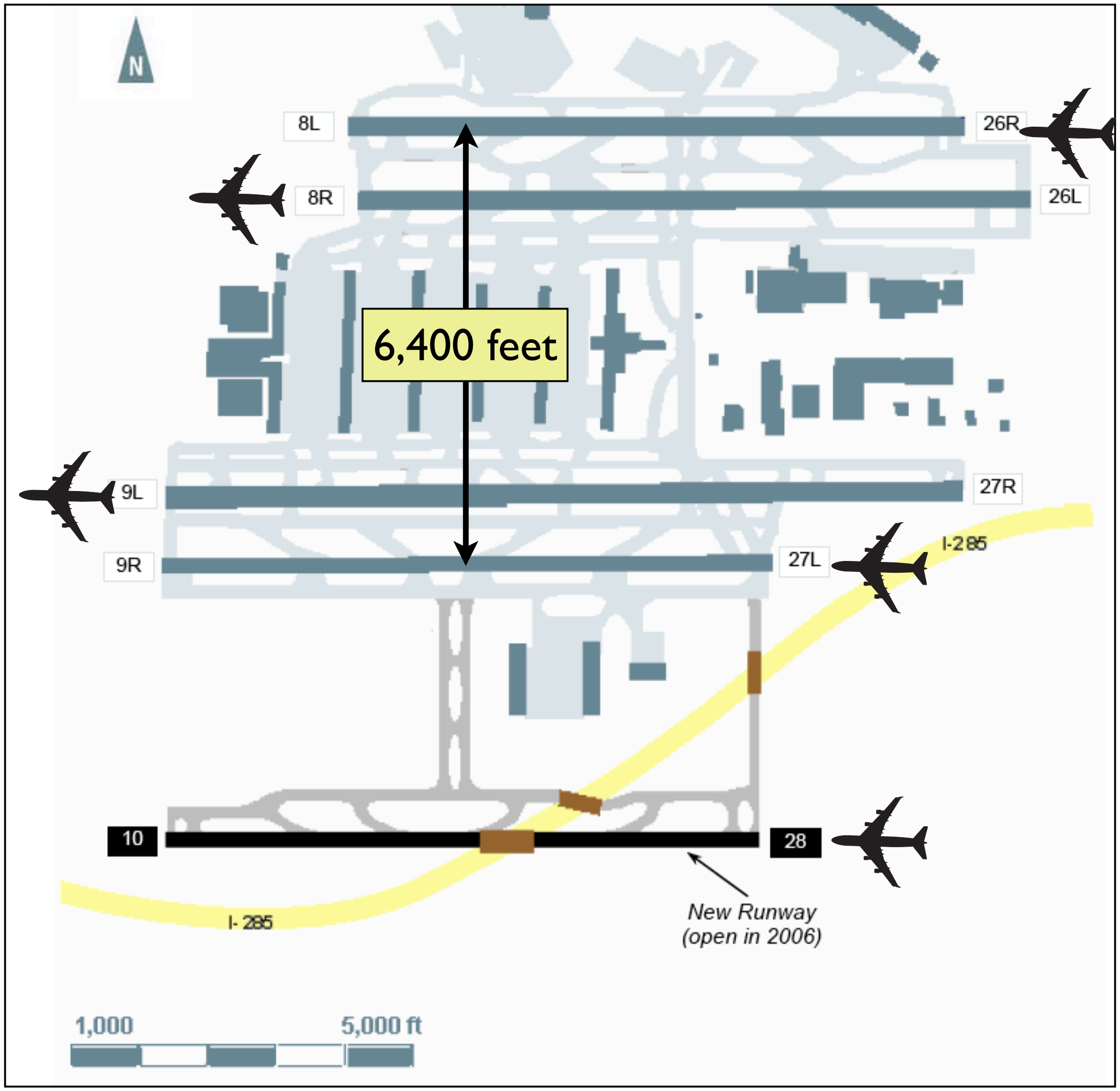
Planned Improvements (VFR Weather)

- Airport authorities and the FAA have planned some improvements to the top 31 airports



Airport # 1: Atlanta Hartsfield

- One of the busiest airports in the World

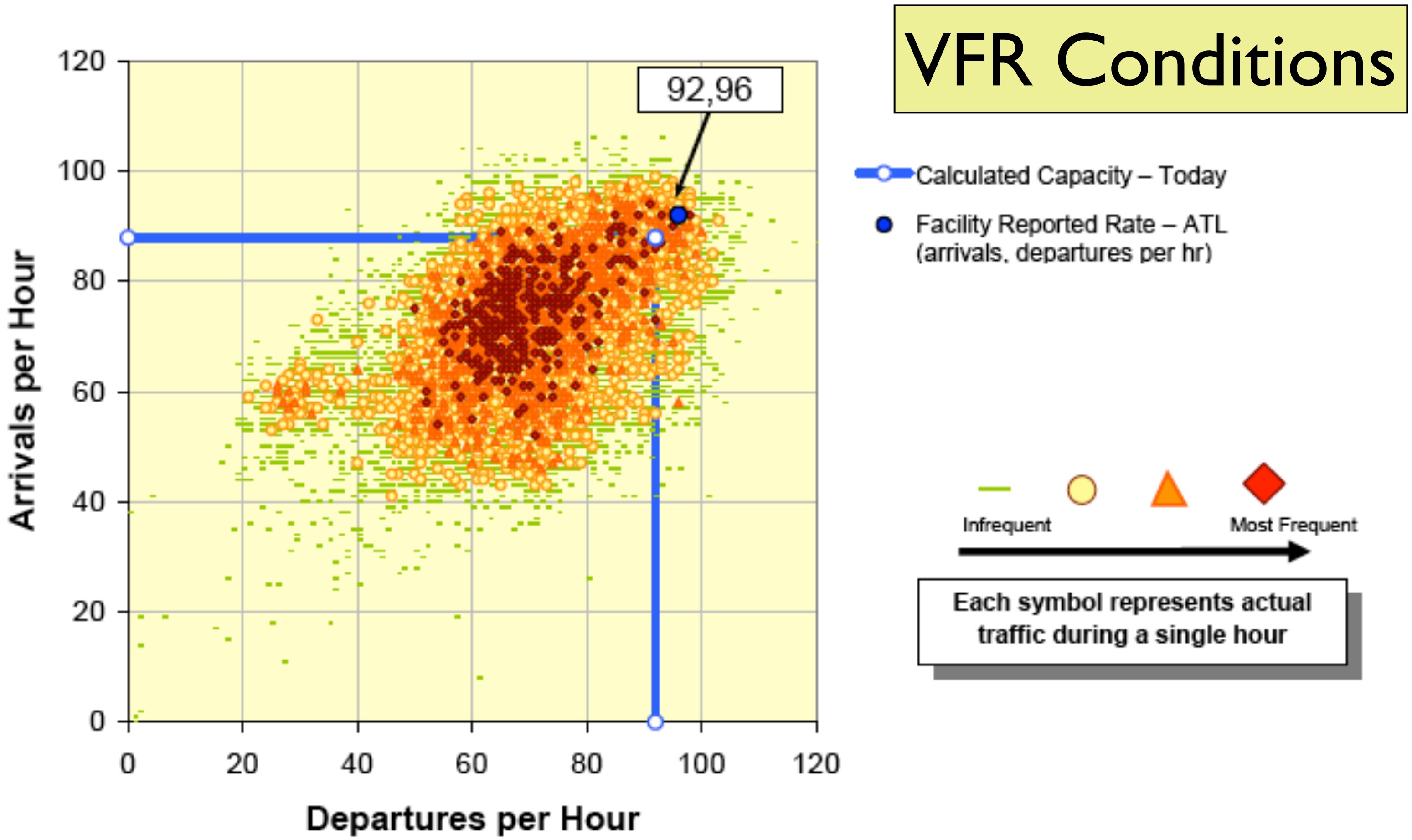


Aircraft Class	% Mix
Small	2.3
Large	78.5
B757	12.0
Heavy	7.4

Condition	Hourly Capacity
VFR	180-188
Marginal VFR	172-174
IFR	158-162

Airport # 1: Atlanta Hartsfield

- With **4 runways** the hourly capacities of the airport are: **VFR=180, MVFR =172 and IFR=158 per hour**

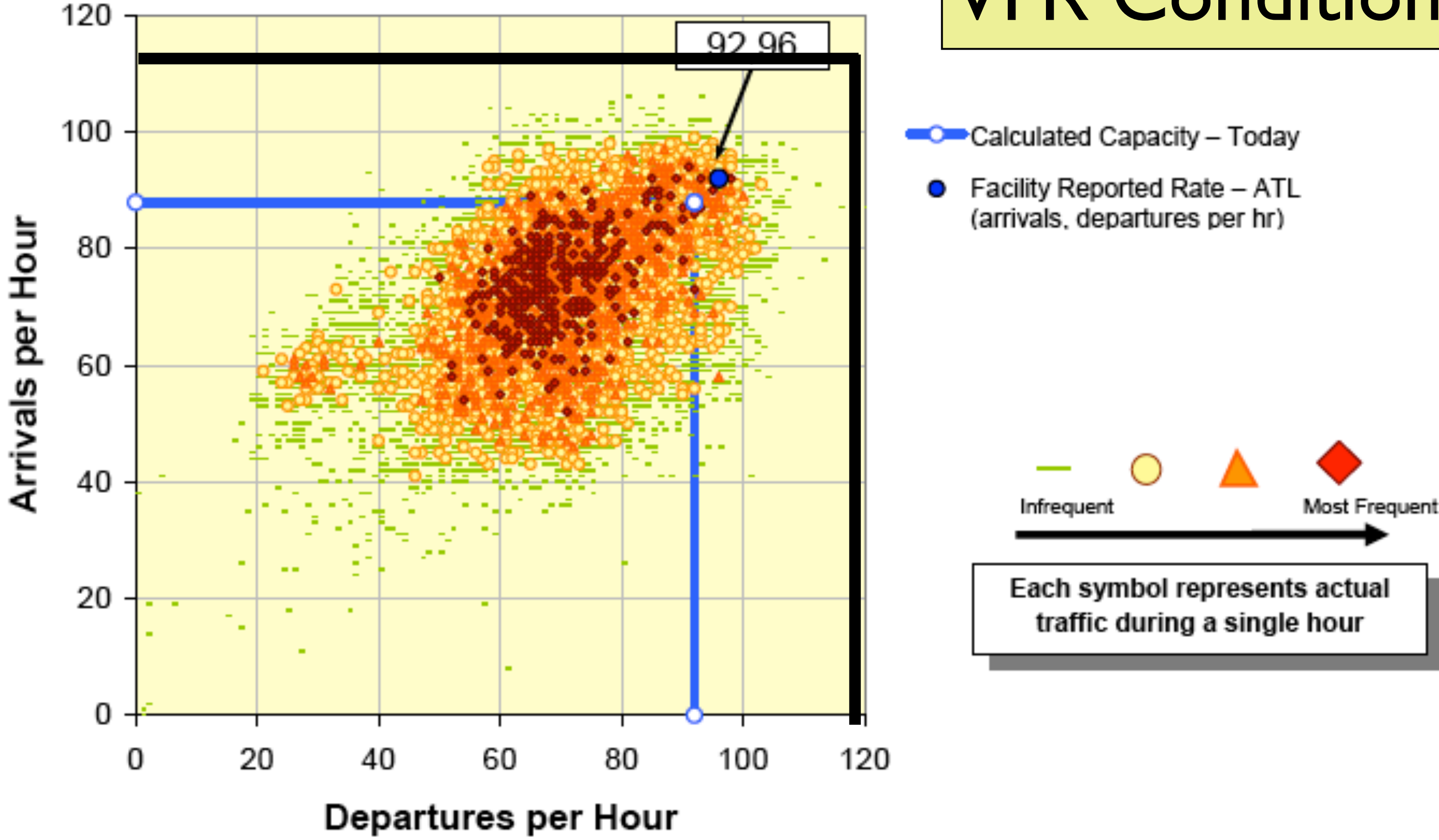


source: FAA Airport Capacity Benchmarks

Airport # 1: Atlanta Hartsfield

- With 5 runways the hourly capacities of the airport are: **VFR=237, MVFR =229 and IFR=202 per hour**

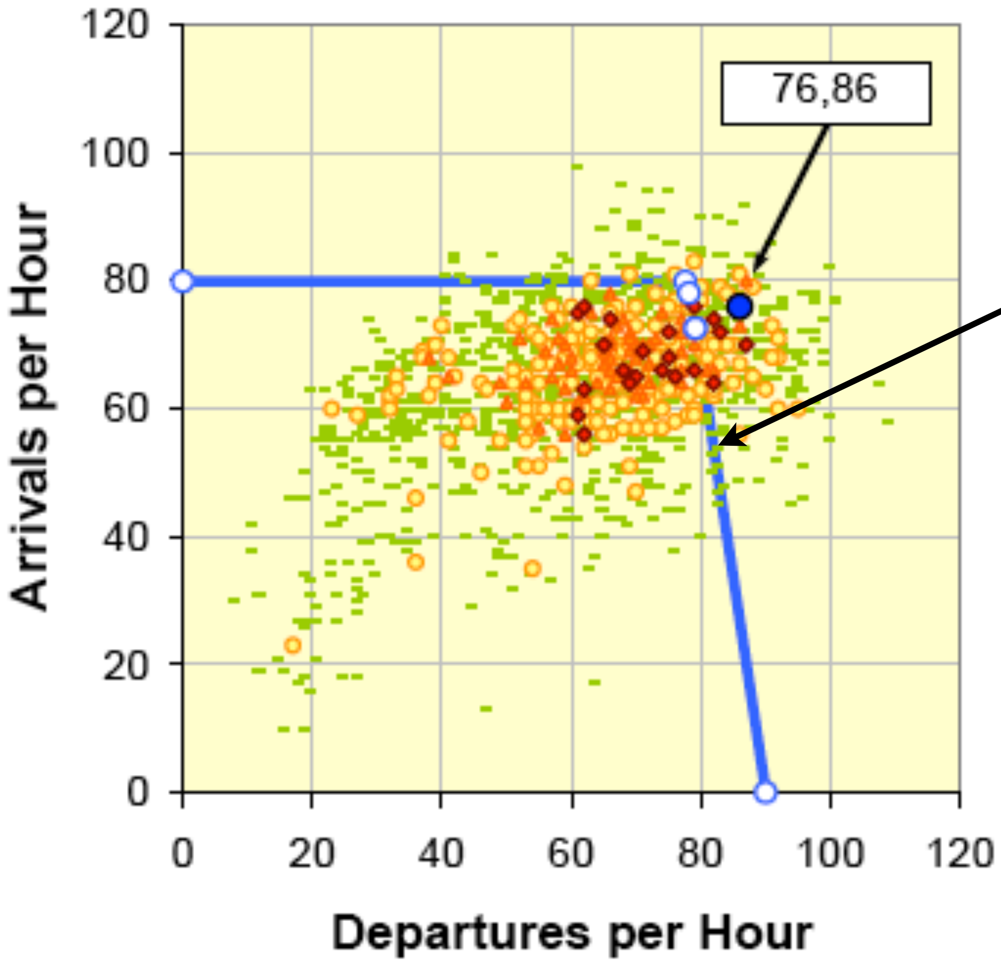
VFR Conditions



source: FAA Airport Capacity Benchmarks

Airport # 1: Atlanta Hartsfield

- 4-runway Pareto diagram

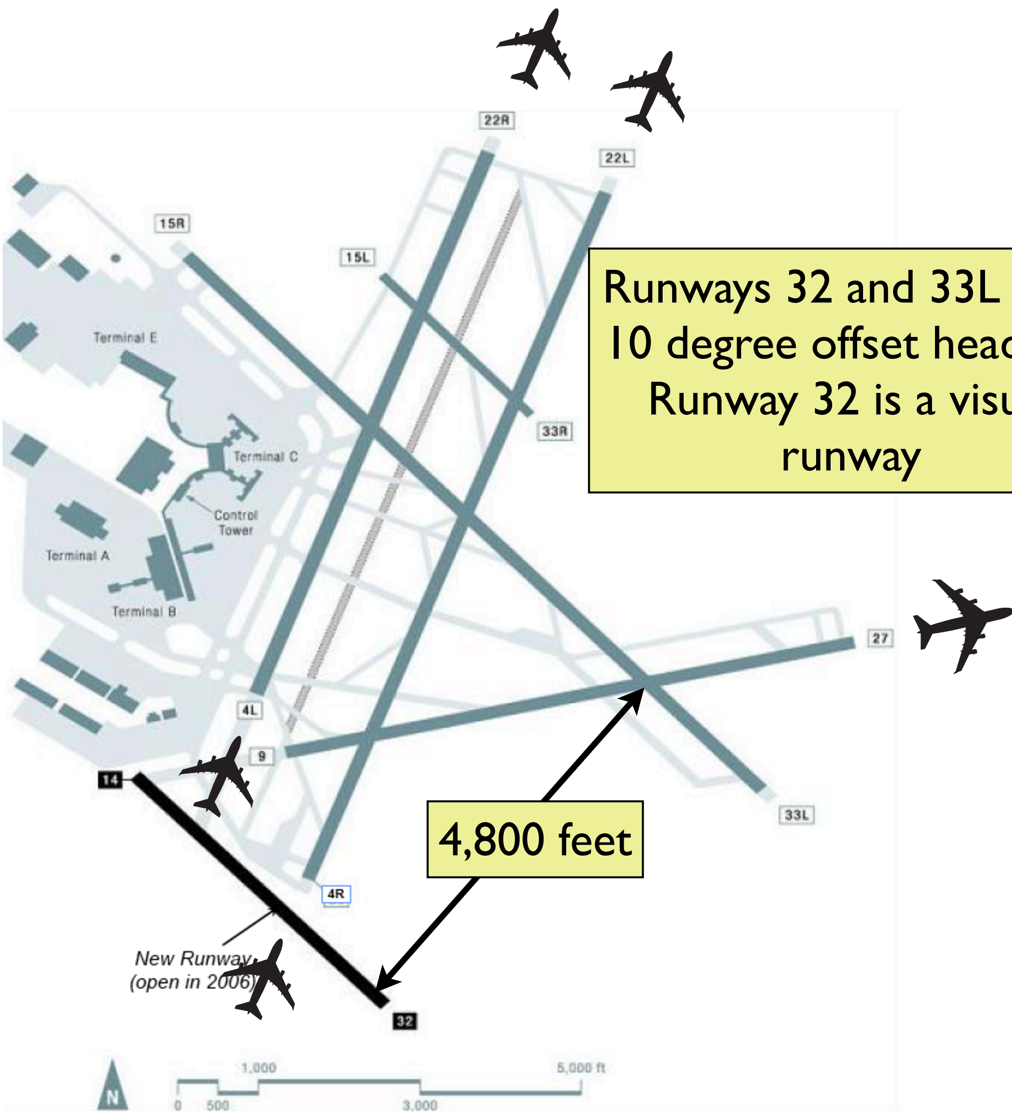


IFR Conditions

- Note a small reduction in the number of departures under IFR conditions
- Departures wait for arrivals to cross threshold

source: FAA Airport Capacity Benchmarks

Airport # 2: Boston Logan

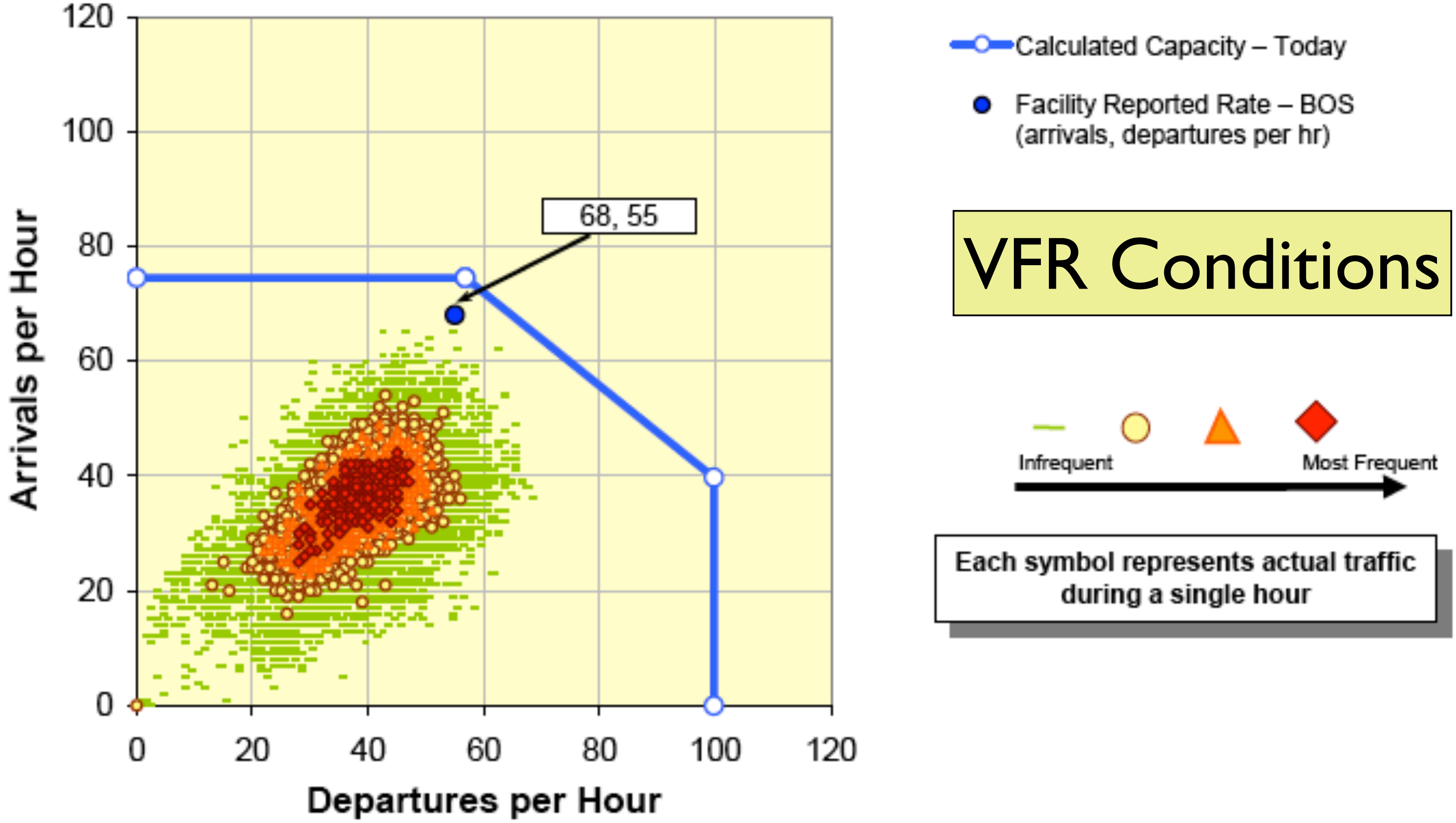


Aircraft Class	% Mix
Small	15.2
Large	70.0
B757	10.3
Heavy	4.5

Condition	Hourly Capacity
VFR	123-131
Marginal VFR	112-117
IFR	90-93

Airport # 2: Boston Logan

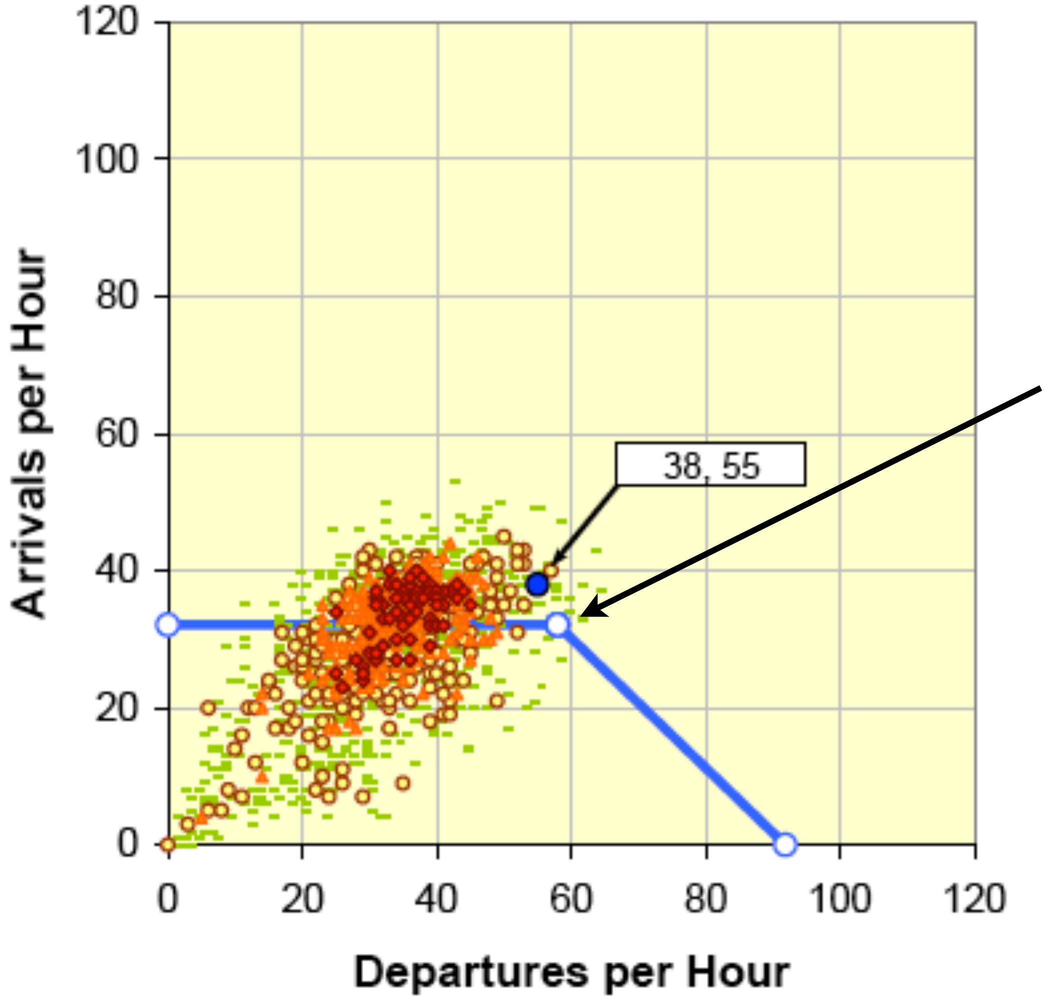
- With 4 runways the hourly capacities of the airport are: **VFR=123, MVFR =112 and IFR=90 per hour**



source: FAA Airport Capacity Benchmarks

Airport # 2: Boston Logan

- Pareto diagram (Arrivals on Runway 4R, Departures on runways 4R, 4L and 9)



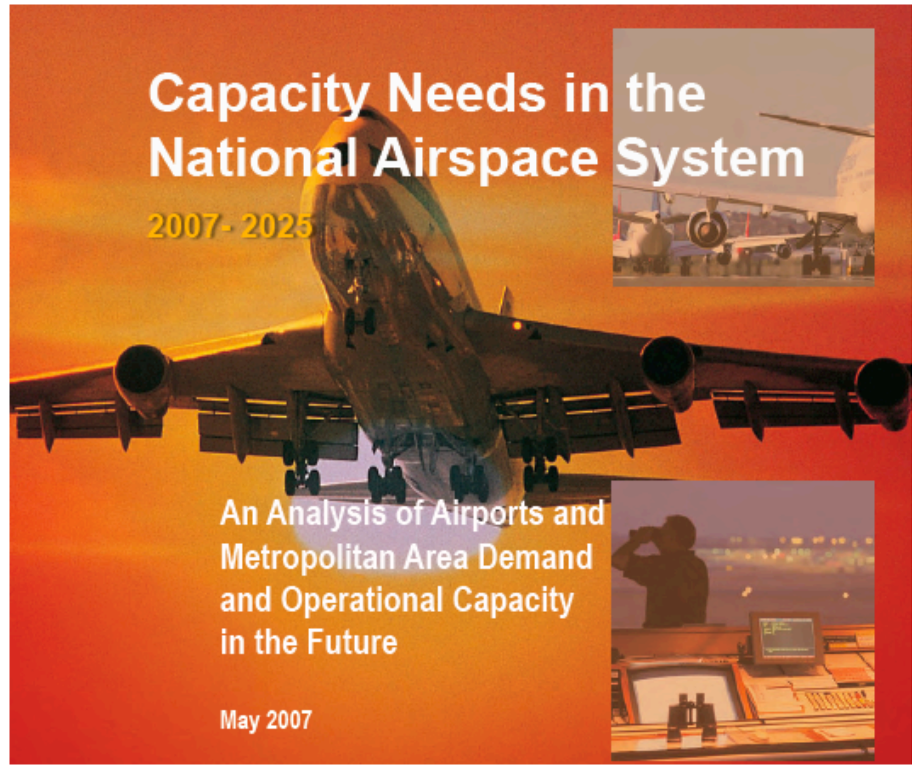
IFR Conditions

- Note airport has an equivalent of one arrival runway in IFR conditions
- Good departure rate

source: FAA Airport Capacity Benchmarks

Capacity Needs

- This section presents some sample Pareto diagrams for some of the best known airports in the country
- This section provides some ideas on how these Pareto diagrams may have been derived
- An important study is the Capacity Needs in the National Airspace System (FAA, 2007)



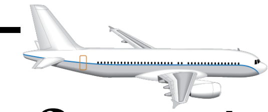
Airports and Metro Areas With Capacity Needs in 2025

Figure 6 Airports and Metropolitan Areas Needing Capacity in 2025 if Planned Improvements Do Not Occur

27 airports that need additional capacity in 2025

15 metro areas that need additional capacity in 2025

Source: Capacity Needs in the National Airspace System



How is the FAA Trying to Improve the System?

- Next Generation Air Transportation System (NextGen)

Figure C1 - Capacity Assumptions–OEP Airports: Detailed Improvements Modeled in 2015 and 2025

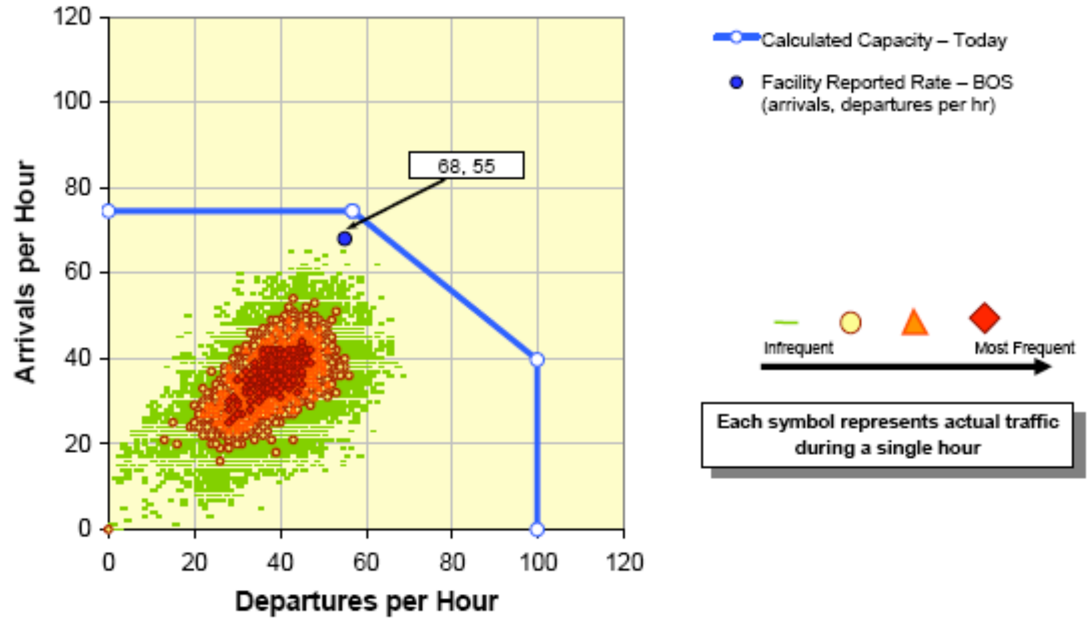
	ATL	BOS	BWI	CLE	CLT	CVG	DCA	DEN	DFW	DTW	EWR	FLL	HNL	IAD	IAH	JFK	LAS	LAX	LGA	MCO	MDW	MEM	MIA	MSP	ORD	PDX	PHL	PHX	PIT	SAN	SEA	SFO	SLC	STL	TPA
Reduced Separation Standards -- use visual separation in MMC -- use 2/3/4/5 NM in IMC	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x*	x	x	x	x	◊* x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Improved threshold delivery accuracy	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊
1.5 NM Departure/Arrival separation (IMC) -- spacing < 2500 ft or same runway	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Independent parallel approaches (IMC) -- spacing 2500-4299 ft												x												▲		x		x			x			▲	
Triple indep. parallel approaches (IMC)	▲					▲		▲	▲	x				◊	▲					◊					◊								x		
"Mixed triple" independent/dependent parallel approaches (IMC)					x																														
Paired approaches, e.g. SOIA -- MMC (spacing 700-2499 ft)	x	◊		▲							◊						x	x					x			◊					◊	▲			
-- IMC (spacing 1200-2499 ft)		x																																	
Dependent Approaches -- MMC/IMC (700-2500 ft spacing) -- 1.5 NM diagonal behind Small, Large -- wake vortex sep behind B757/Heavy											x							x		x			x									x		◊	x
LAHSO (all weather) if >7000 ft to intersection		▲											x				x						x												
Simultaneous Converging Approaches (IMC)																	x							x											
Standard Departure/Departure separations (no departure constraints)		x										x				◊	x									x				x		x	x		
Independent parallel departures (IMC) -- no wake vortex separation behind Small/Large (700-2500 ft spacing)											x						x			x			x									x		◊	x
New/extended runways (since 2002)	▲	◊	x	▲	x	▲		▲ x	▲ x			◊		◊ x	▲ x					▲			▲	▲	◊		◊				◊			▲	x

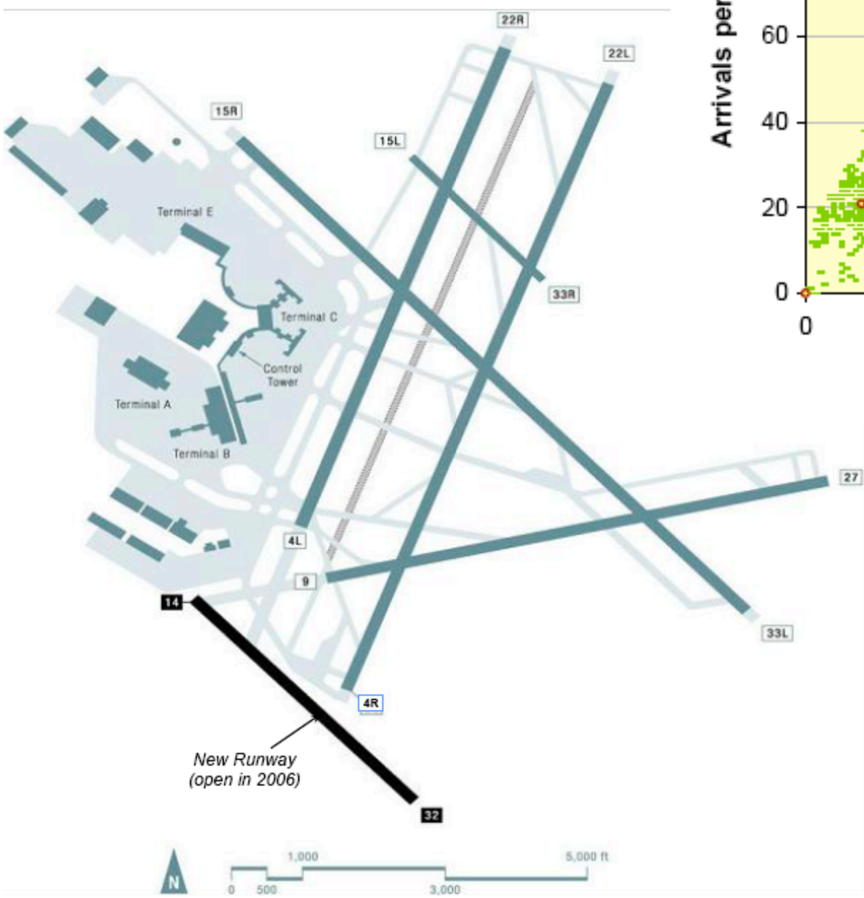
▲ Included in 2006 capacity
◊ 2015 capacity improvement
x 2025 capacity improvement

x* Visual separations applied in VMC and MMC (2025)
◊* Visual separations applied in VMC (2015)

Source: Capacity Needs in the National Airspace System

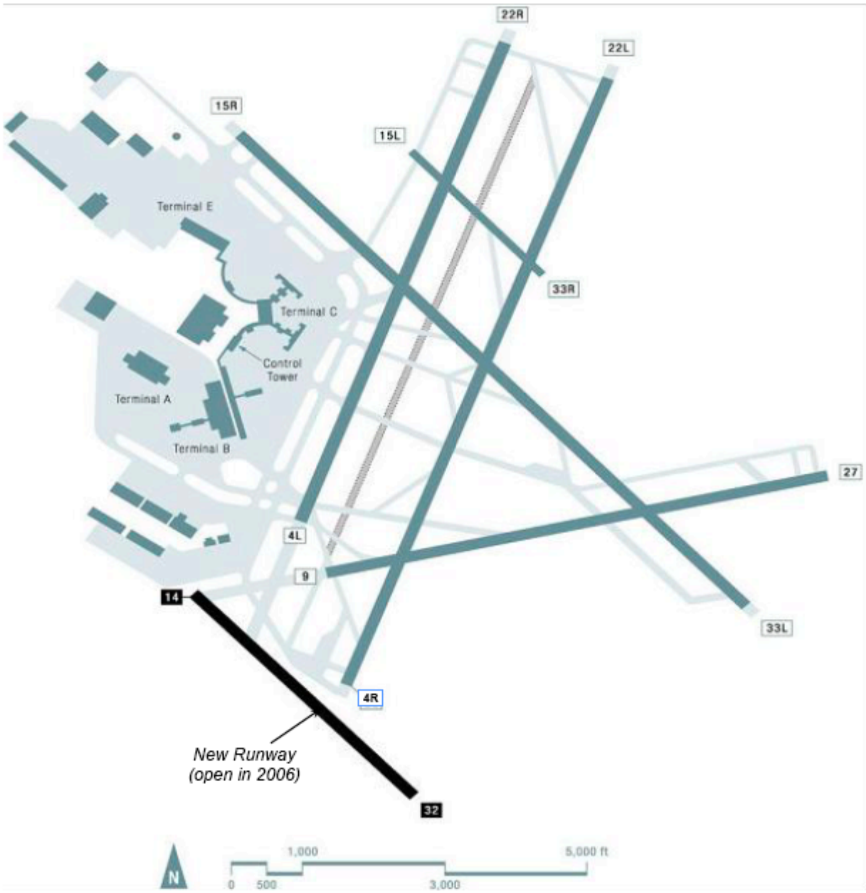
Boston Logan Airport (VMC)





- Arrivals on Runways 4L, 4R
- Departures on 9, 4L, 4R
- *Frequency of Use: 24%*

Boston Logan Airport (IFR)



- Arrivals on Runways 4R
- Departures on 9, 4L, 4R
- *Frequency of Use: 45% in IFR conditions*