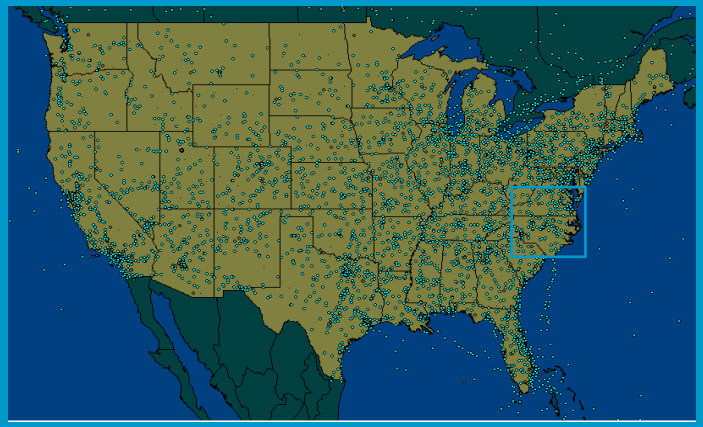
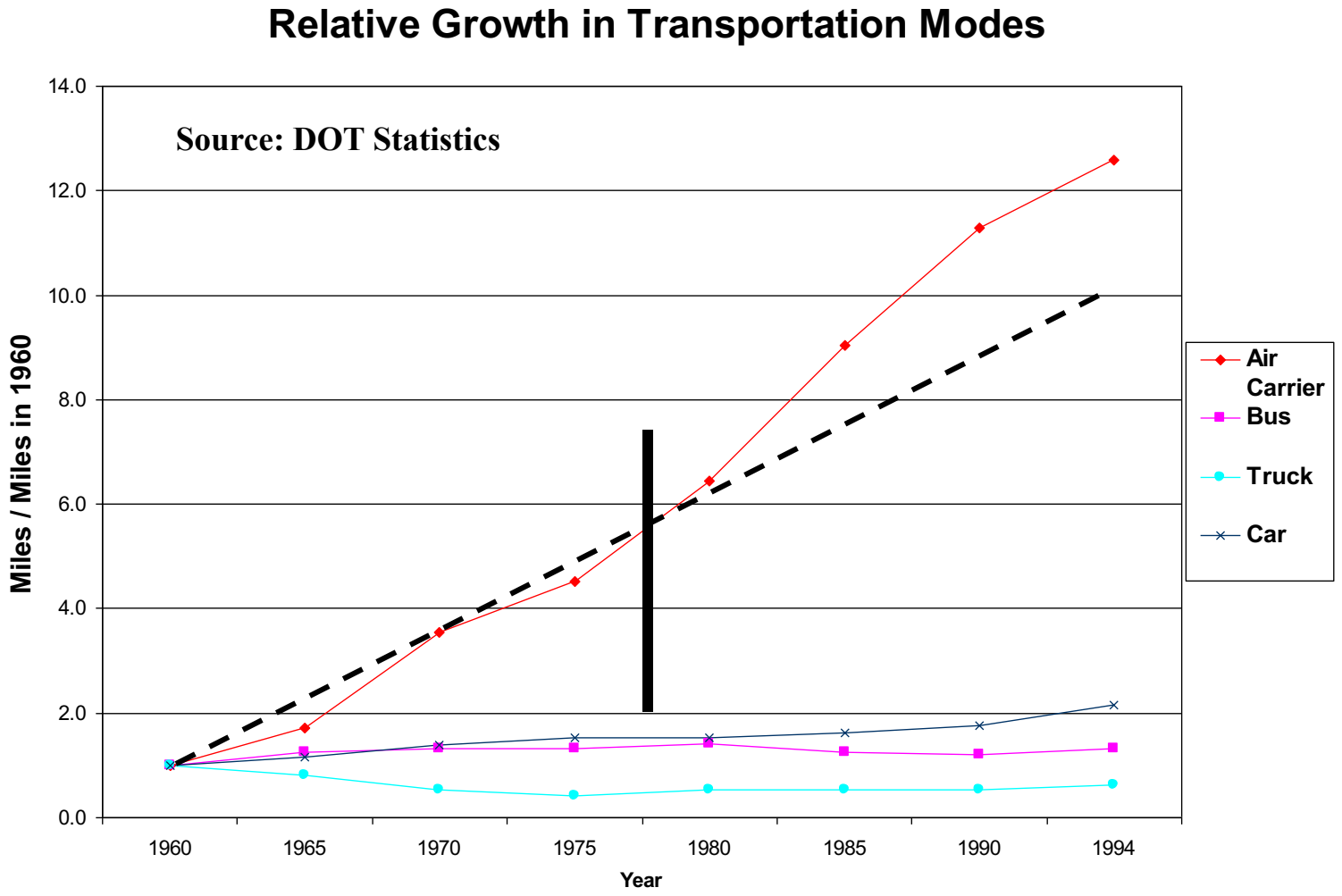
Air Transportation System Limitations, Constraints and Trends



George L. Donohue

March 19-20, Wye Woods Conference Center

Demand has grown Faster than National Infrastructure



Initial Observations and an Hypothesis

- **FACTS:**
  - Airspace above Airport Runway Thresholds (Operational Capacity) is a Limited, Nationally Allocateable Commodity
  - National Airport and Airspace Management Infrastructure growth has seriously lagged behind Growth in Air Transportation Demand
  - Utilization of this Capacity Commodity is Constrained by Airline Schedule Conflicts, Delay Tolerance, FAA Ground Delay Programs and Aircraft Safety (i.e. Aircraft Spacing)
- **HYPOTHESIS:**
  - A DoT Supervised Auction System may be Required to Efficiently allocate Airport Capacity within Delay and Safety constraints

Incentives for Operational Improvements and Modernization

Key Decision Points

- **DP 1** NATCA Contract Negotiations and Controller Mass Retirement Threat (Avg. Age=50 + Service=25) ~2007
- **DP 2** Termination of Slot Controls - 2007
- **DP 3** Sector Congestion and limits of Radio Frequency Spectrum Availability ~ 2010
- **Transition Barriers**
  - Ground Based Infrastructure L----**M**----H
  - Airborne Equipment L----M----**H**
  - Labor Issues L----M----**H**
  - Regulation L----M----**H**
  - Required Culture Change L----M----**H**
  - Communication Bandwidth L----**M**----H
  - LACK OF INCENTIVES TO CHANGE !!!!

Outline

- **Limitations on Air Transportation Capacity** ←
- **Safety, Capacity and Delay**
- **System Network Effects**
- **Future Security Effects**
- **Observations**
- **Future Vision**

Operational Capacity is a Limited Commodity

- $C_{MAX} = 2\ C_{AR\ MAX}\ S\ \Sigma_i\ (XG)_i\ R_i$ {*Airports*}
  $-\Sigma_K\ A_K(t)$ {*Airspace Management Intervention*}
  - $S = f$ (Safety, τ_{ATC} , Wake Vortex, etc.) ~ 0.6
- $A_K(t) = (A/C_{REQUEST} - A/C_{ACCEPT}) \sim [\ 0$ to $>1{,}000]$
  - $A_K(t) = f$ (GDP:Weather, Sector Workload Constraints)
- $C_{AR\ MAX}$ ~ 64 Arrivals/Hour (set by Runway Occupancy Time)
- R_i = Number of Runways at i^{th} Airport
- XG_i = Airport Configuration Factor at i^{th} Airport
- i = 1 to N, where N is approximately 60 Airports
- K = 1 to M, where M is typically much less than 100 Sectors

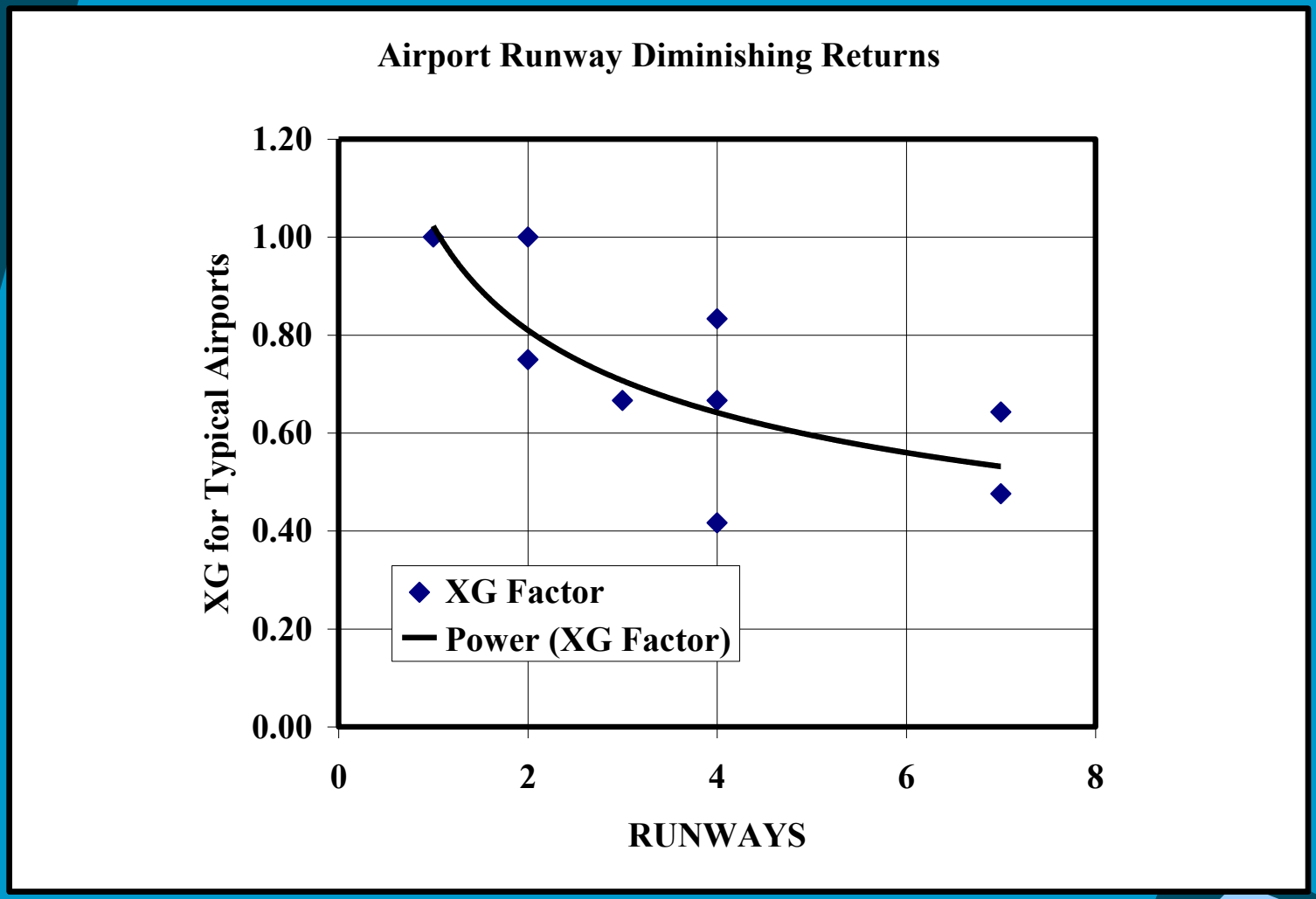
Regional Distribution of Airport Infrastructure is Uneven

TABLE 1 Regional Air Transportation Capacity Fraction For (57) Major Airports

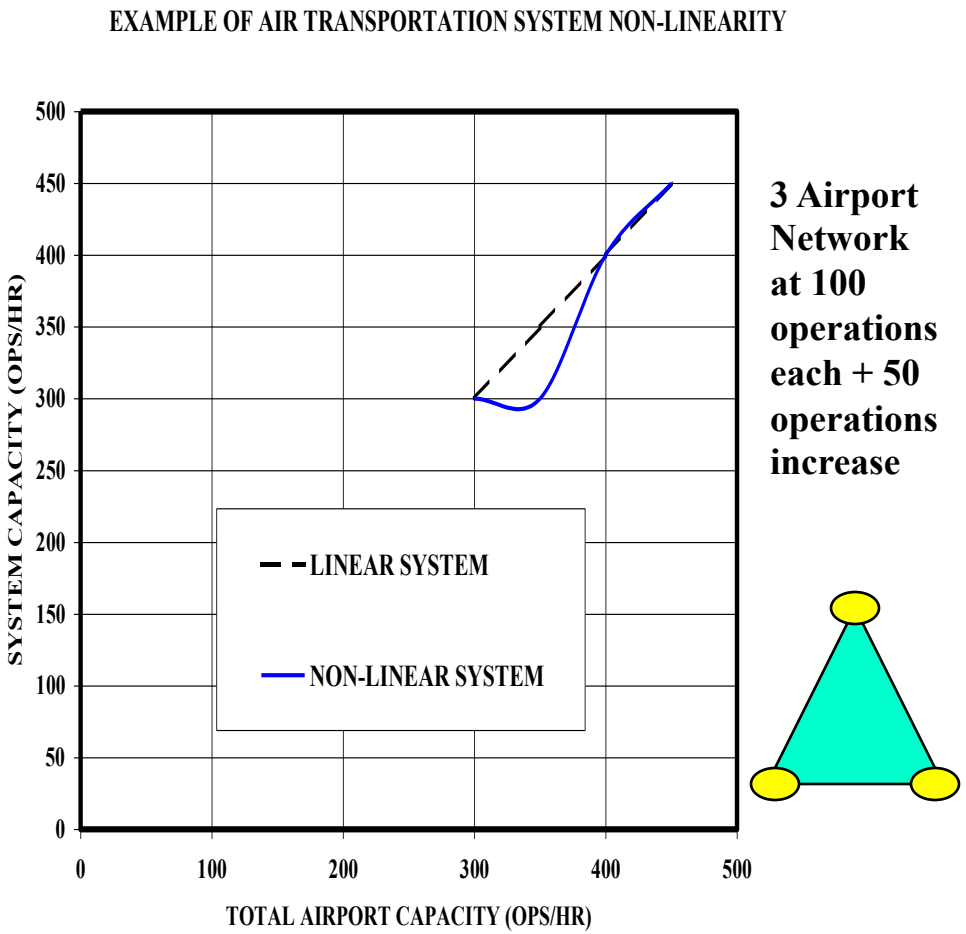
REGION	NUMBER HUB R/W	Estimated # A/C TURN POINTS	Number Ops/Hr MODEL	Number Ops/Hr 1997	% Cap97/ CapMAX	Avg 8 yr Growth Rate %	TAF 1997 ENP X10E6	OPERATIONS 2012	OPERATIONS 1997
NORTH EAST	14	420	348	294	**84**	9	54	1,950,000	1,645,786
PACIFIC SOUTHWEST	9	262	403	298	**74**	10	43	2,205,000	1,670,280
PACIFIC NORTHWEST	22	353	693	455	**66**	8	62	3,364,000	2,549,603
NOTHERN MIDWEST	42	773	1090	684	**63**	32	99	5,522,000	4,040,088
ATLANTIC COAST	13	269	438	241	**55**	8	31	1,701,000	1,347,458
CENTRAL MIDWEST	12	205	237	131	**55**	3	19	1,496,000	1,114,207
WEST	22	415	758	405	**53**	9	62	3,180,000	2,270,307
SOUTHEAST	21	424	776	391	**50**	-2	54	2,704,000	2,190,557
FLORIDA & LATIN AM	14	322	602	287	**48**	18	48	2,114,000	1,608,673
SOUTH SOUTHWEST	27	380	892	433	**48**	16	59	3,468,000	2,424,105
TOTAL	**196**	**3823**	**6239**	**3620**	**58**	**11**	**532**	**27,704,000**	**20,861,064**
% NATIONAL TOTAL							**89**	**78**	**77**

Donohue and Shaver, TRB 2000

Airport Diseconomies of Scale

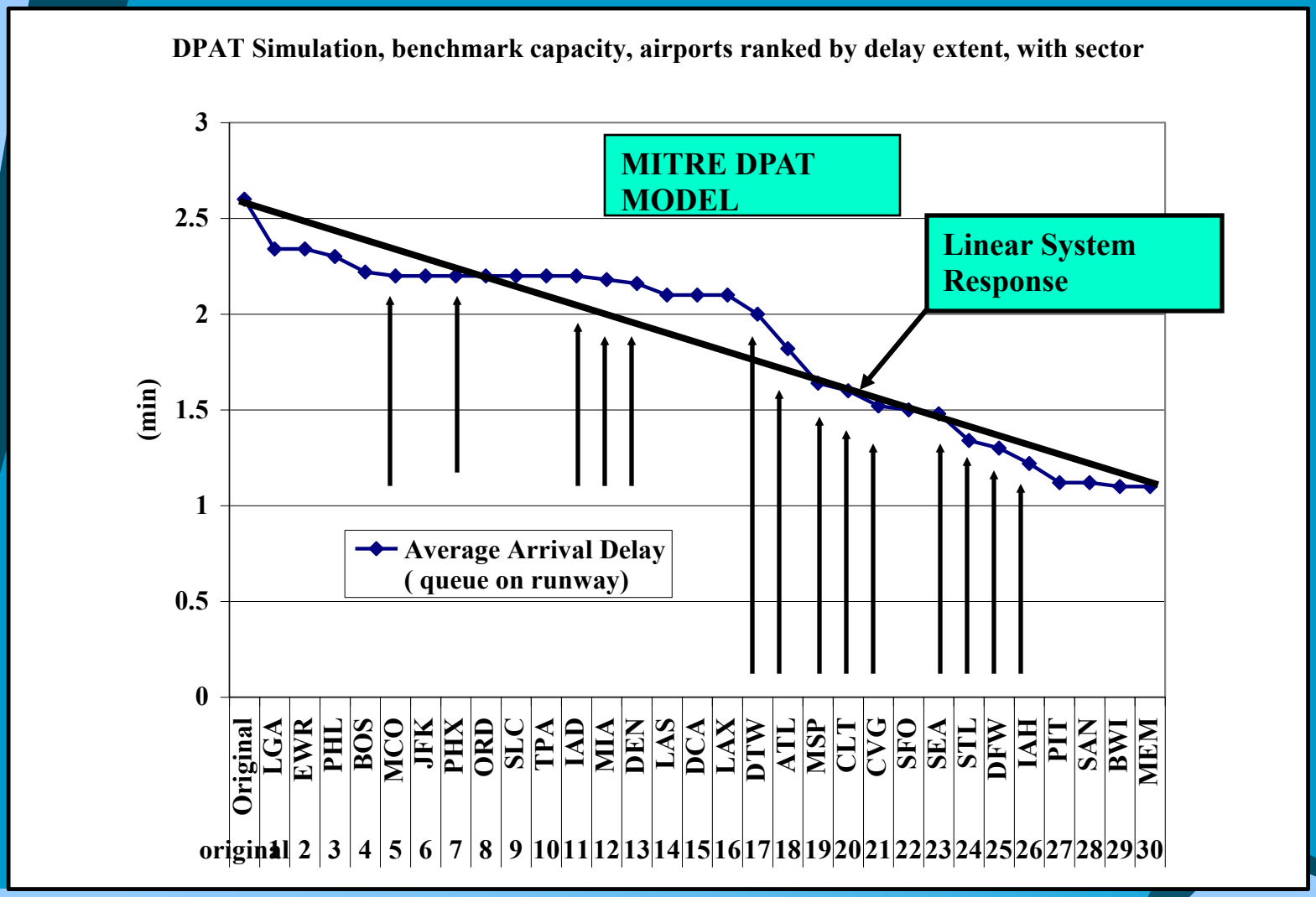


Non-Linear Network Characteristics



- NAS is a Highly Non-Linear, Adaptive System
  - Controller-in-the-Loop
  - AOC-in-the-Loop
  - Independent Network Schedules
- Stochastic In Nature
- May exhibit Chaotic Behavior under Some Conditions
- Additive Improvements DO NOT result in Additive Increases in NAS Capacity
  - ie. pFAST, Runways, etc.

Airline Schedule has a Strong Effect on Network Performance – Model Prediction to 20% Airport Capacity Increase



Outline

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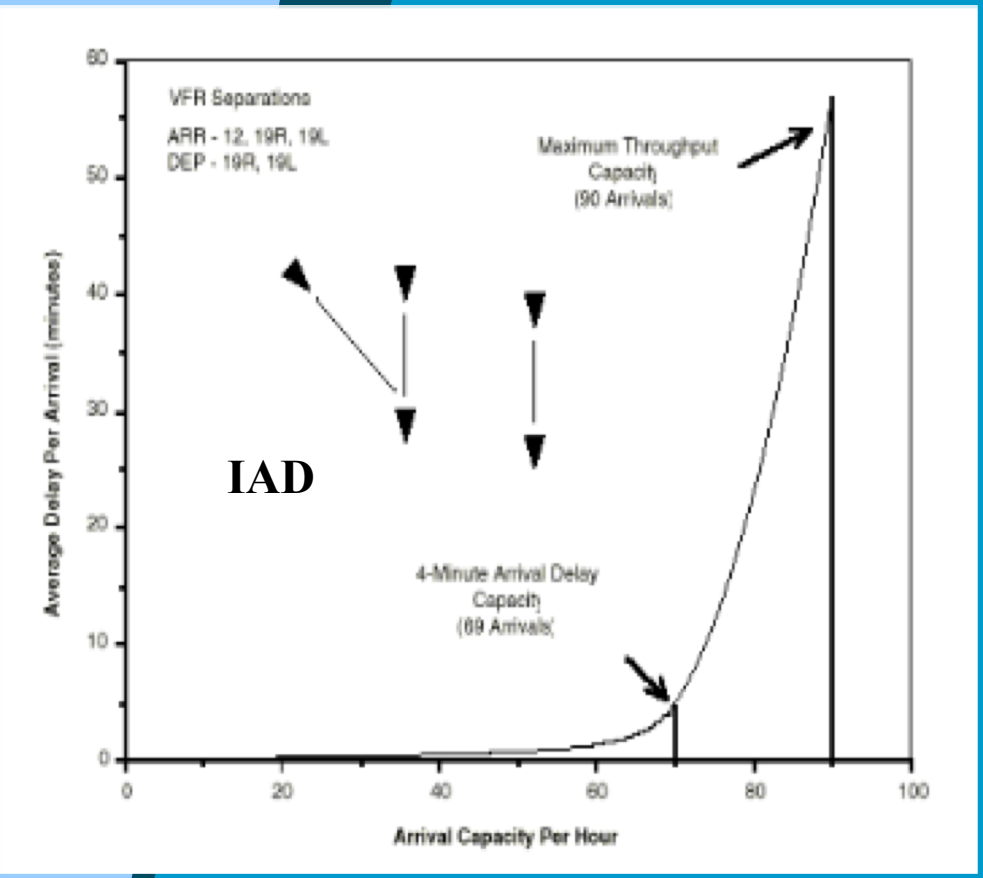
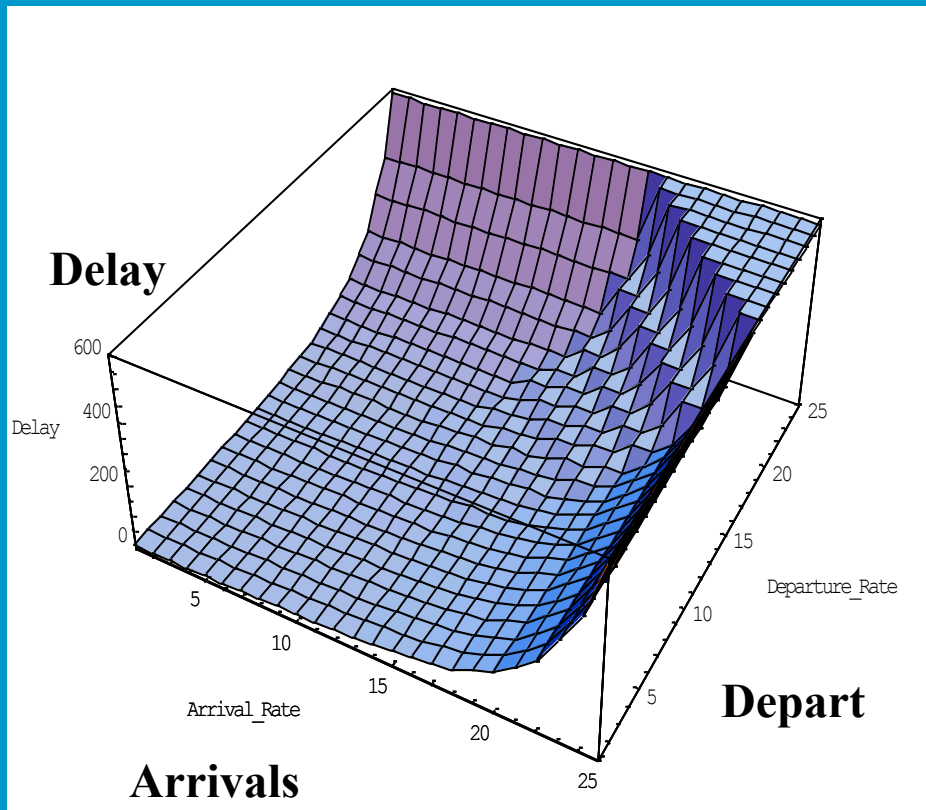
Capacity vs. Delay Penalty

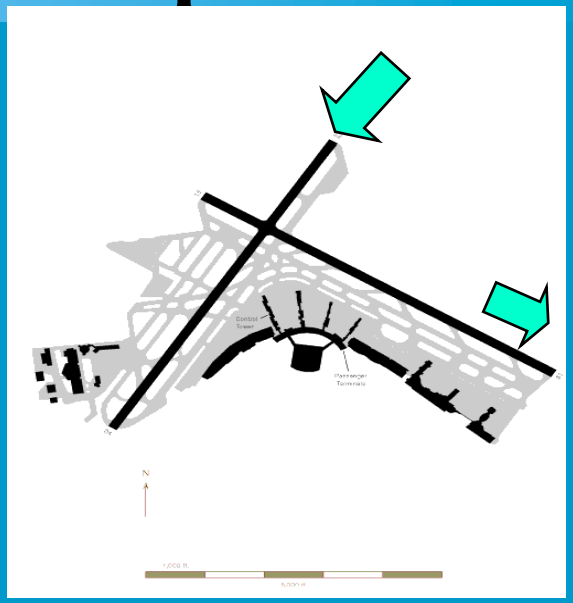


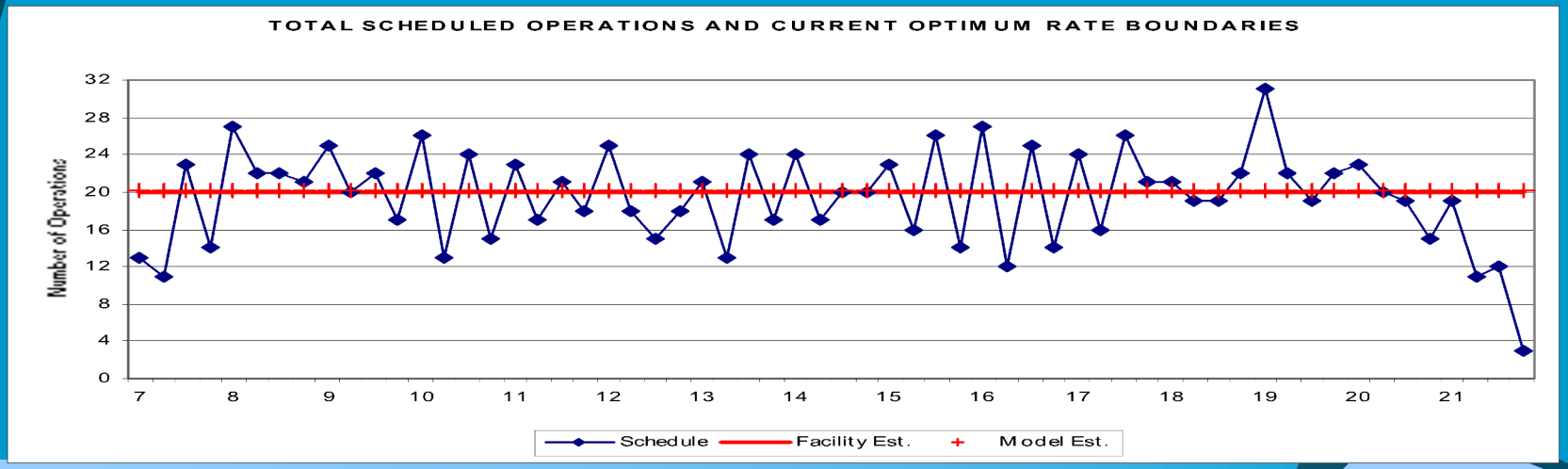


[3] "ACE 1999 Plan," CD-ROM. Federal Aviation Administration – Office of system capacity.

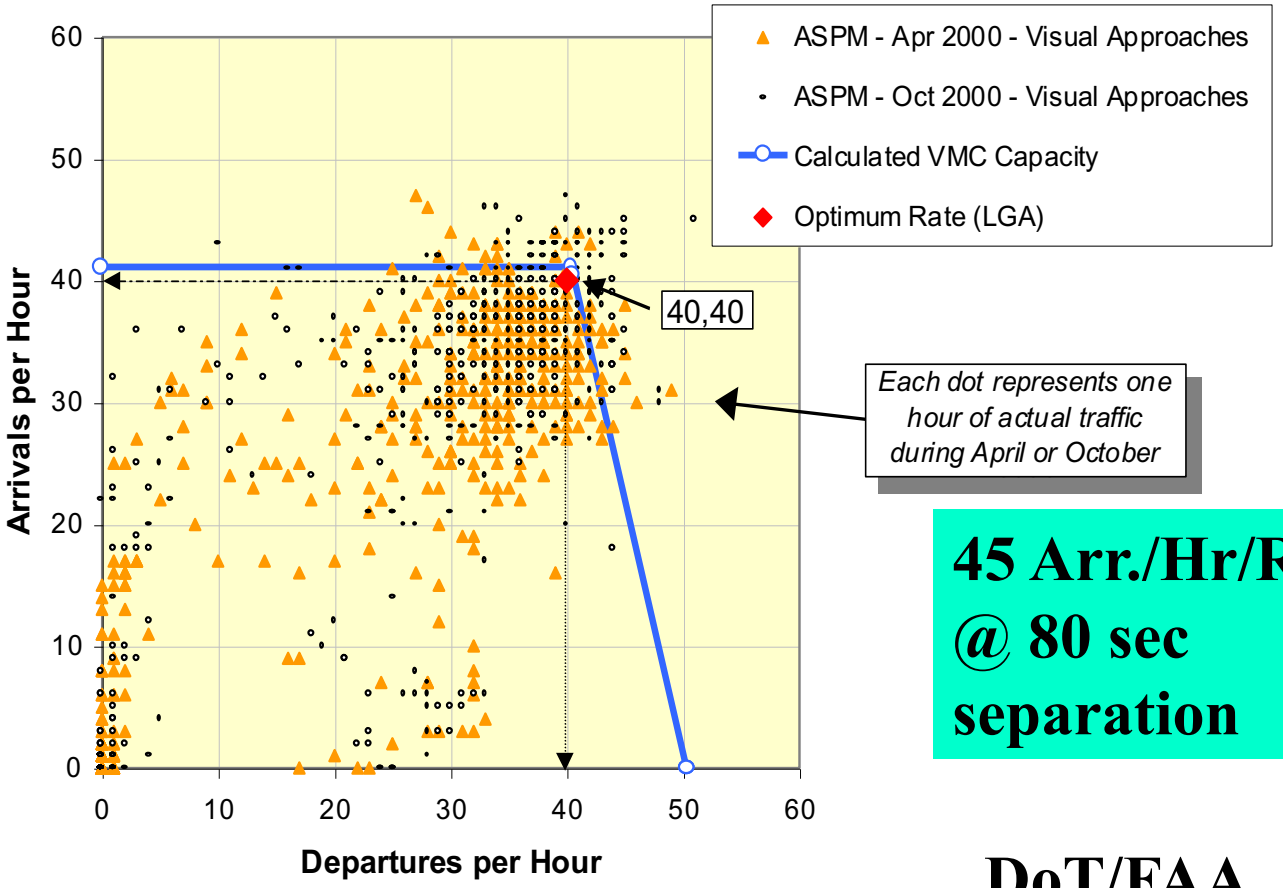
NY LaGuardia: A non-Hub Maximum Capacity Airport

- 1 Arrival Runway
- 1 Departure Runway
- 45 Arrivals/Hr (Max)
- 80 Seconds Between Arrivals
- 11.3 minute Average Delay
- 77 Delays/1000 Operations
- 40 min./Delay





New York LaGuardia Airport Arrival- Departure Spacing VMC

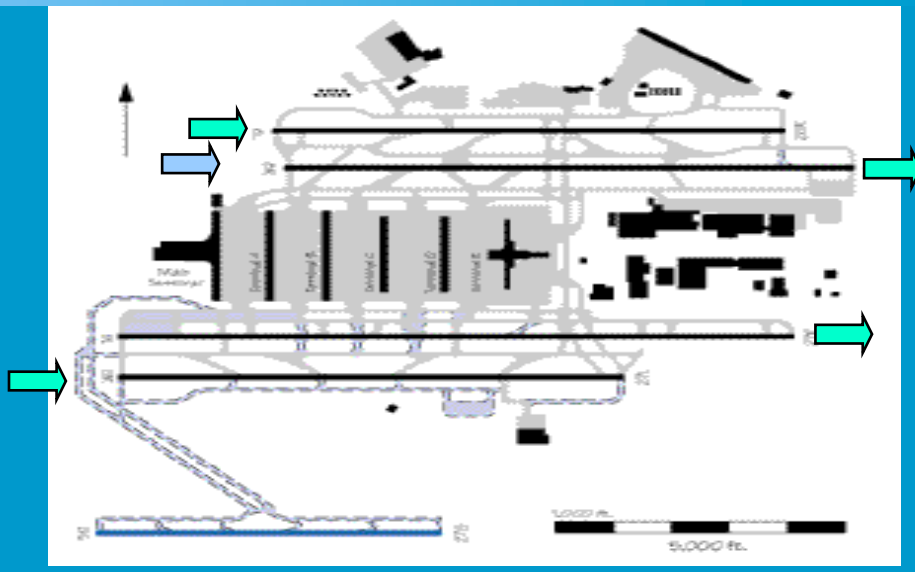


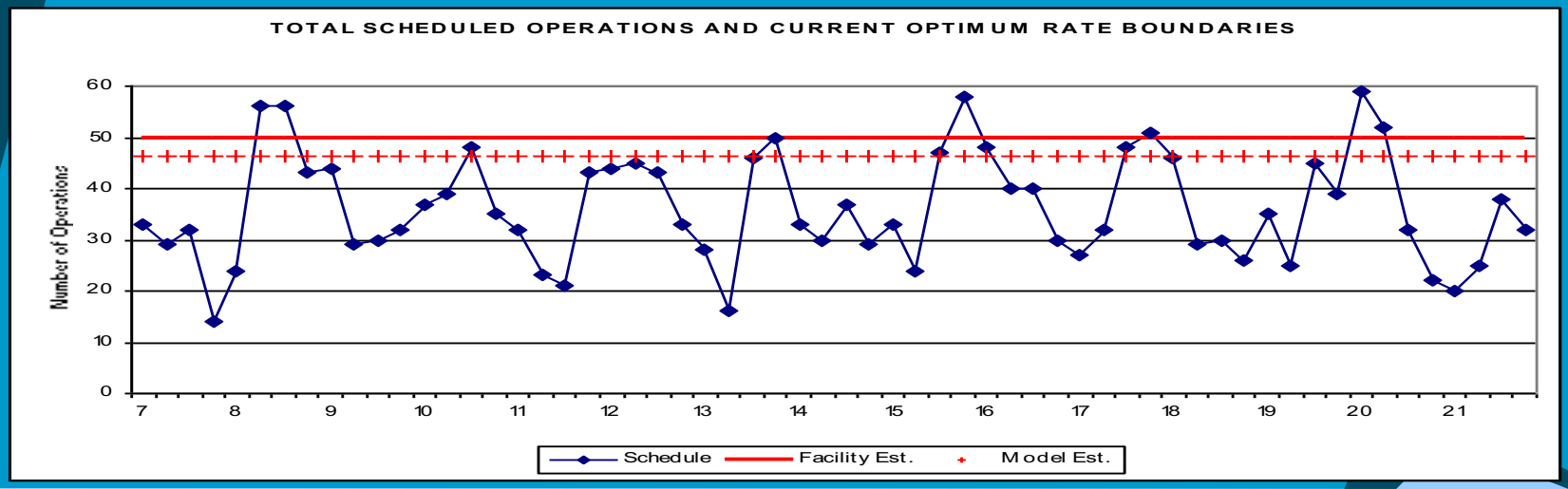
45 Arr./Hr/RW @ 80 sec separation

DoT/FAA

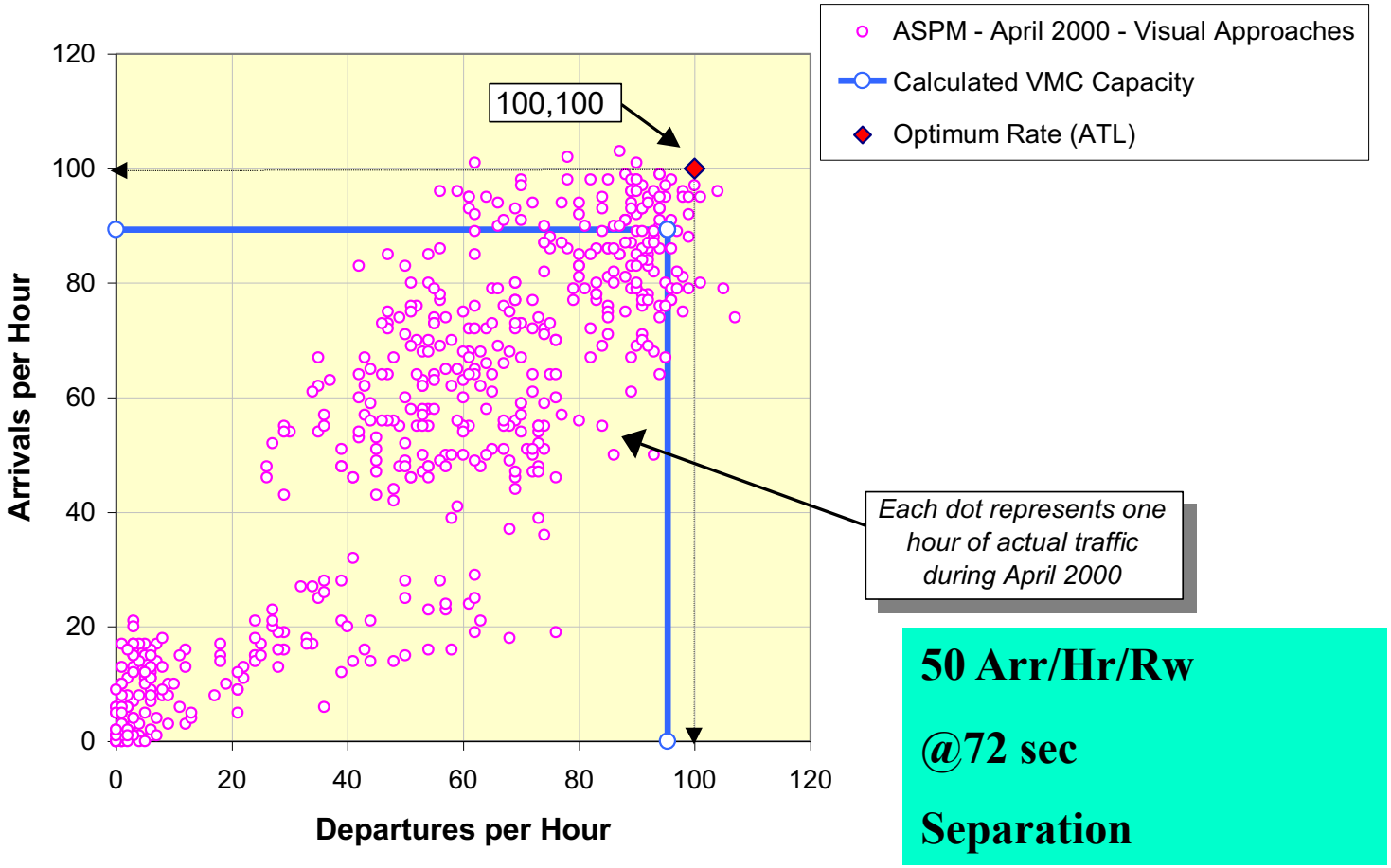
Atlanta: A Maximum Capacity Fortress Hub Airport

- 2 Runways – Arrivals
- 2 Runways – Departures
- 50 Arrivals/Hr/RW – Max
- 72 Seconds Between Arrivals
- 8.5 minutes Average Delay
- 36 Delays/1000 Operations
- 38 min./delay





Atlanta Airport
Arrival-Departure Spacing VMC



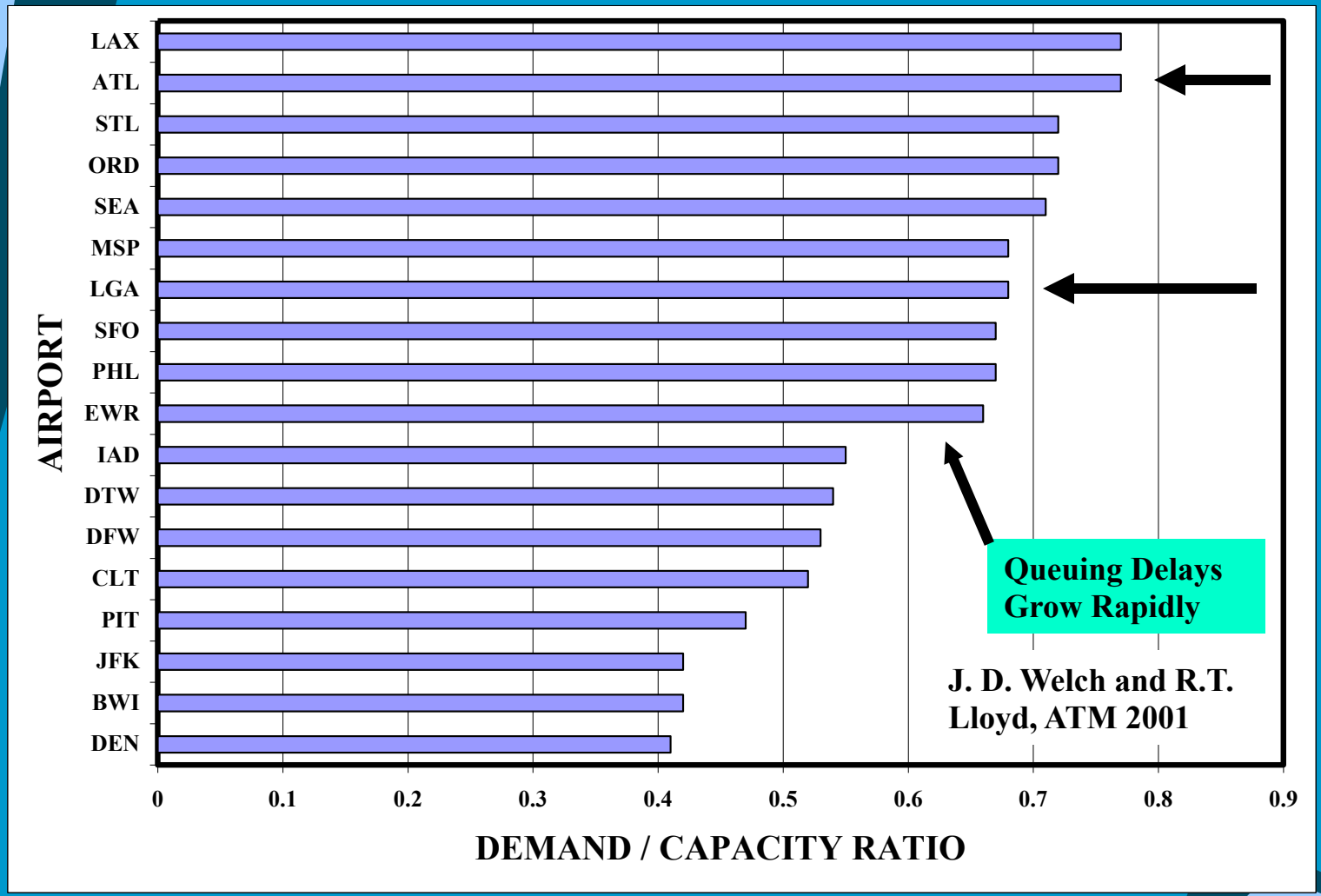
50 Arr/Hr/Rw

@72 sec

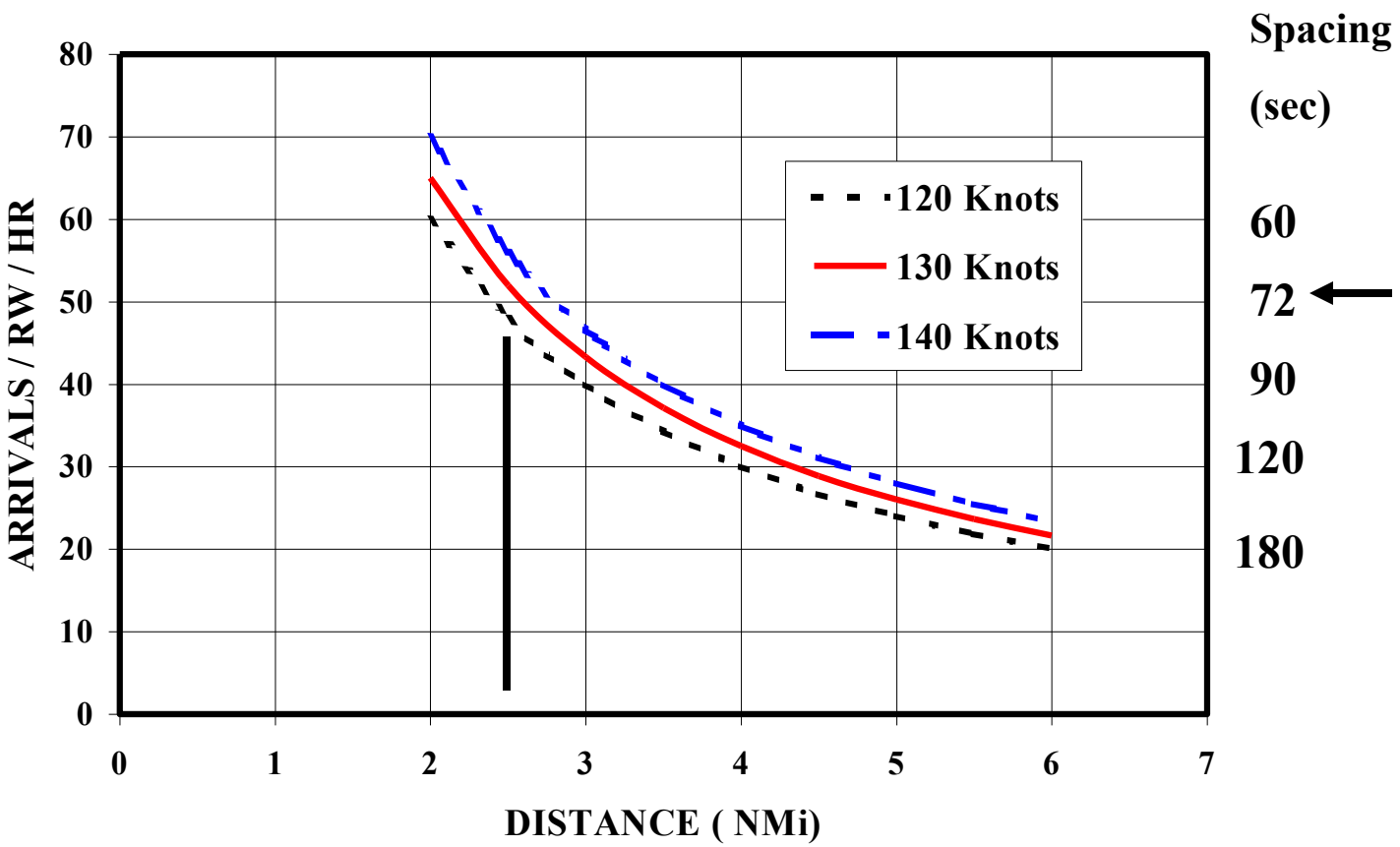
Separation

DoT/FAA

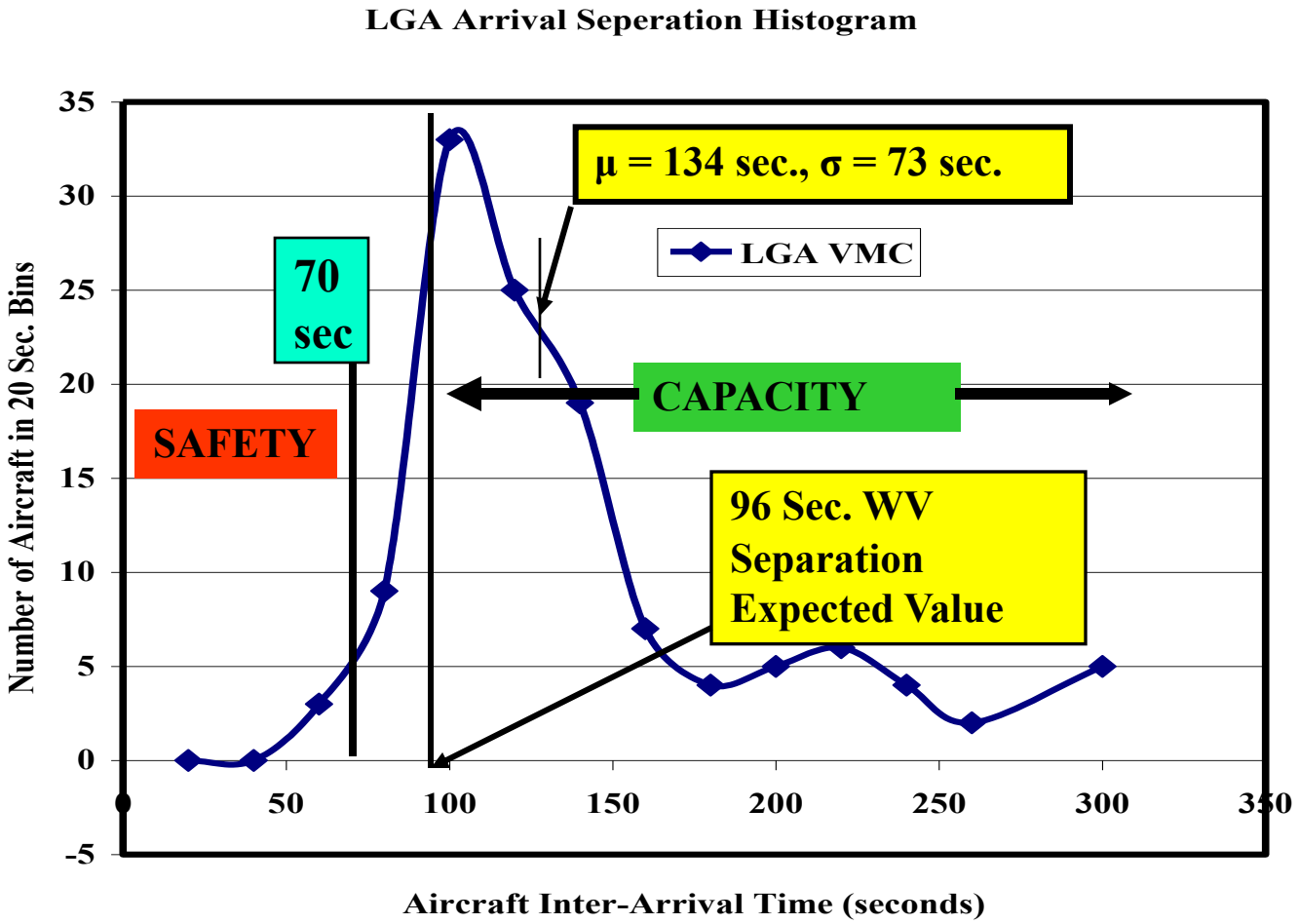
Major US Airport Congestion



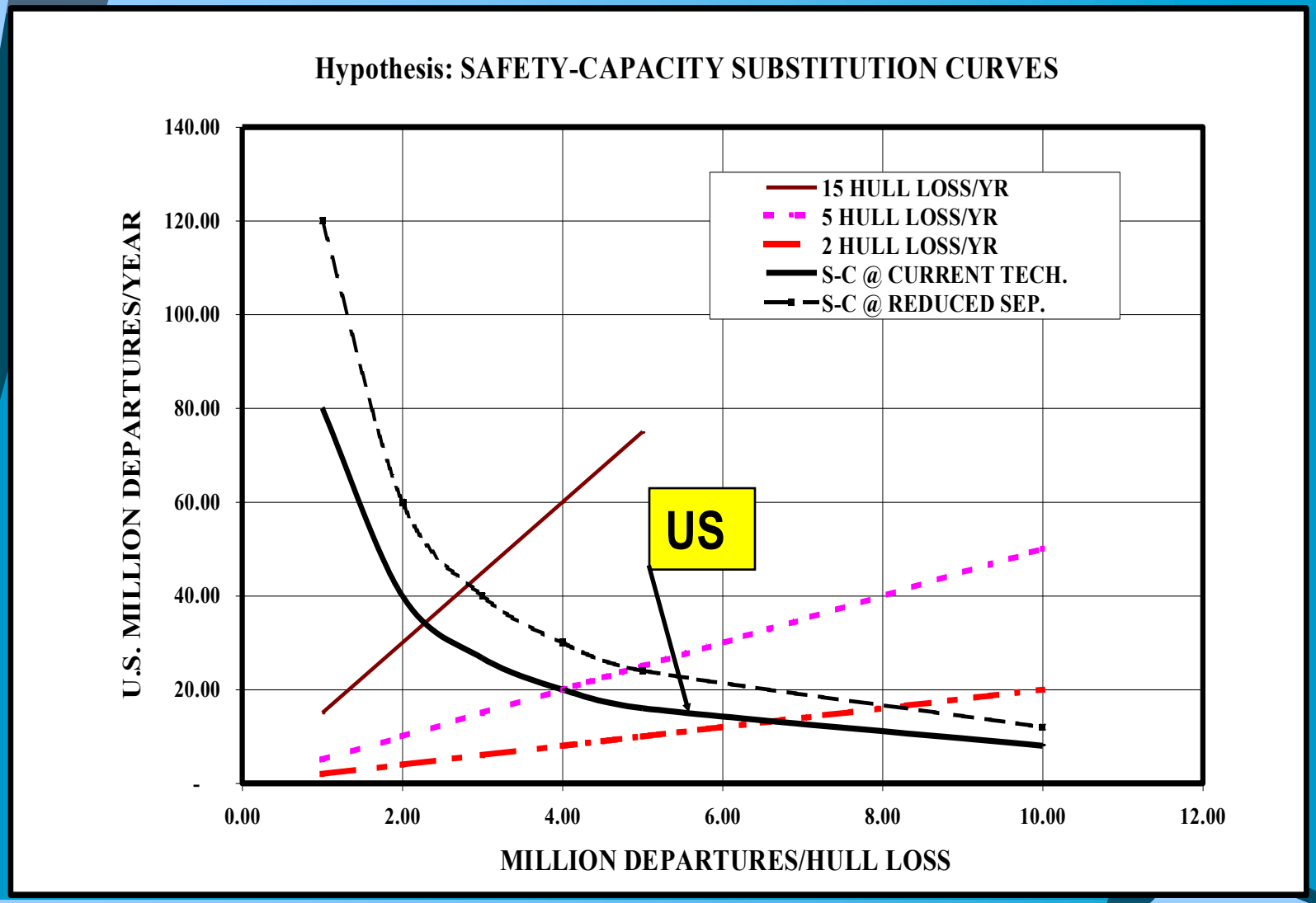
Aircraft Arrival Rate: Distance-Time Relationship



LGA Aircraft Inter-Arrival Time Distribution



Possible Relationship Between Safety and Capacity: ATM Technology Effect



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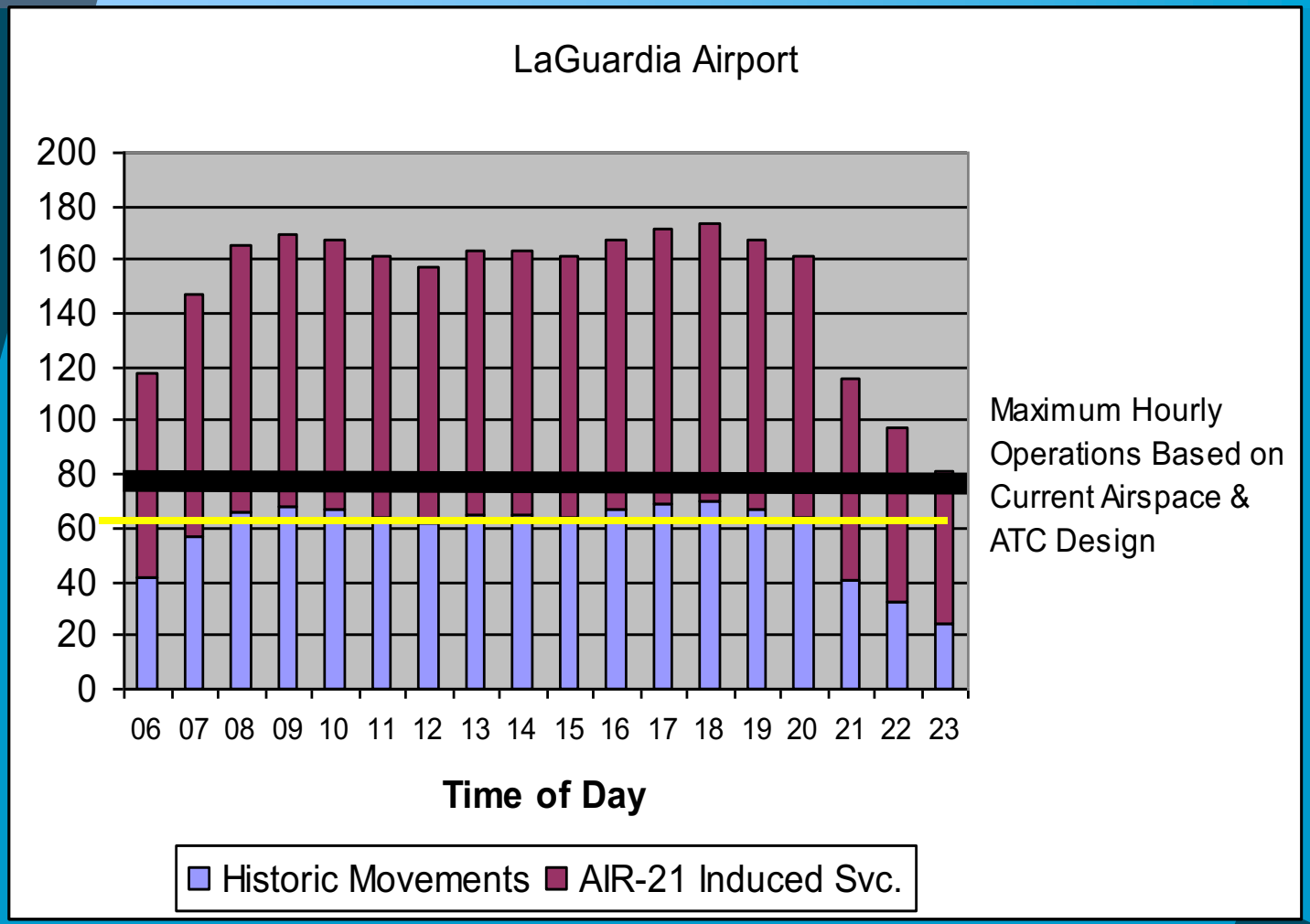
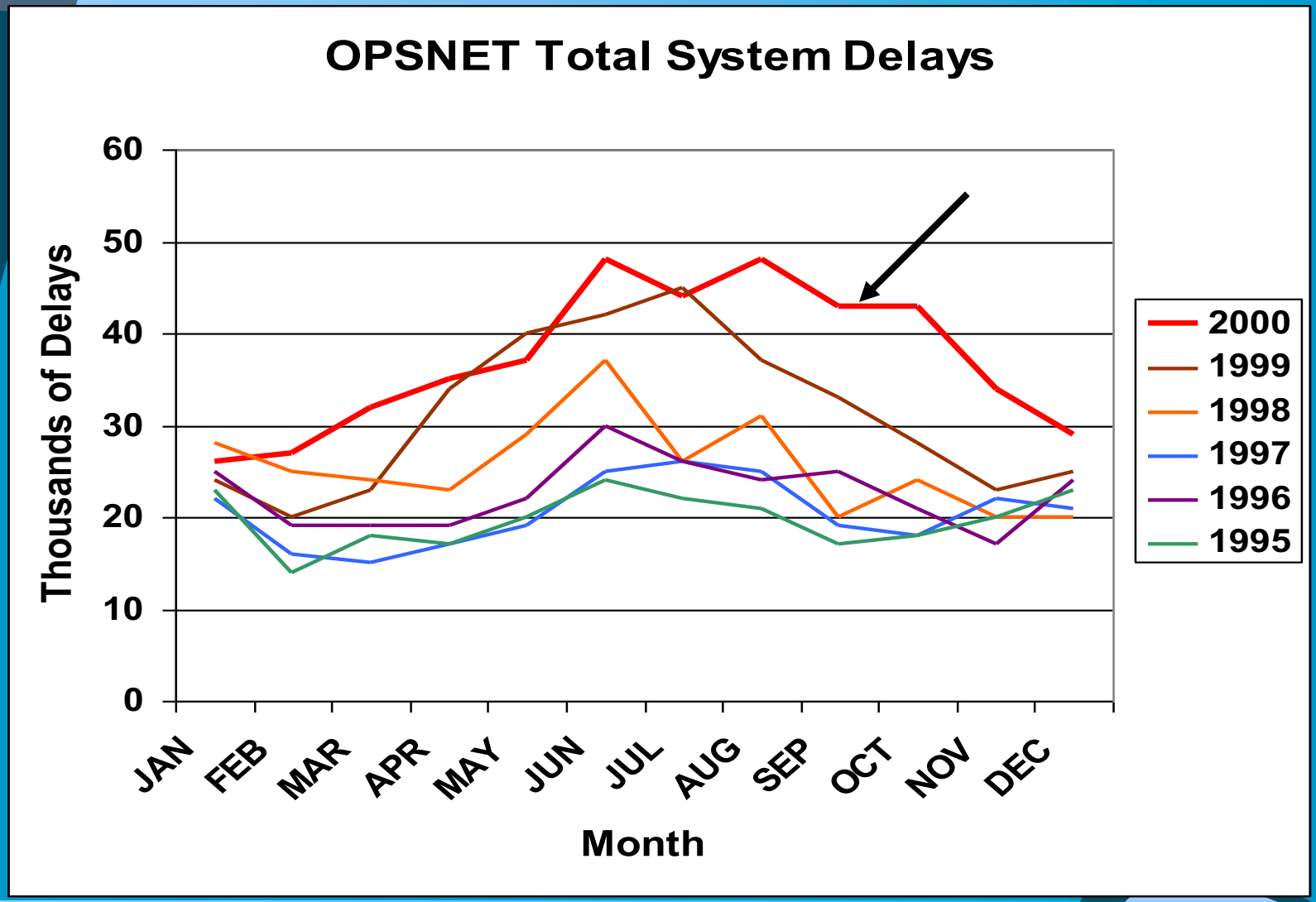
The Semi-Regulated Market Does Not Act to Minimize Delay: LGA Air 21 Impact



Source: William DeCota, Port Authority of New York

Annual and Seasonal Delay Trends
(Note Possible Effect of Air 21 on LGA & System)



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Observations

- Approximately 10 of the Top US Hub Airports are Operating close to Maximum Safe Capacity
- Demand / Capacity Ratio's Greater than 0.7 lead to Very Rapid Increase in Arrival and Departure Delays
  - Higher Delays Lead to ***Loss of Schedule Integrity***
  - 25 New Runways ***Not*** a Solution
- Airline Hub and Spoke Network System Produces a Highly Non-Linear, Connected System
  - Weather, Security or Terminal Delays ***Propagate System Wide***
  - ***Airline Schedules*** are part of the Problem & Solution
- ATC Sector Controller Workloads and Weather also Produce Network Choke-Points that Produce Capacity Constraints

Observations (cont.)

- 100% EDS Baggage Screening will either Increase Delays or Travel Block Times for Commercial Ops
- Current Regulations on Airlines and Airports do not provide Incentives for either Safe or Efficient Operations
  - Airlines are over-scheduling Major Airports
  - ATC is spacing Aircraft at the limits of current technology leading to growing safety concerns
  - Airlines are moving to Smaller aircraft to increase frequency of operations and profitability, leading to increased congestion and delays
  - Airlines are resisting modernizing their aircraft with the technology required to decrease spacing and increase capacity
    - Incentives are to be last to equip

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Vision: Incentives for Operational Improvements and Modernization

Brief Summary of Vision:

Major Hub Airports will Allocate Slots by DoT Auctions:

- **Both Strategic, Near Term and Spot Auctions**
- **Peak runway loading will be reduced to Government Established Safety and Capacity optimized schedules**
- **Aircraft Size will be driven by a combination of airline profits and maximum enplanement opportunities**

Business travel will migrate to Travel on Demand via air-taxi or private aircraft ownership and operation

Increased En-route Traffic density will be accommodated by Aircraft Self Separation-Technology-Equipped Flight Corridors

Auctions will provide incentives for aircraft technology insertion and a government contract to provide enhanced benefits

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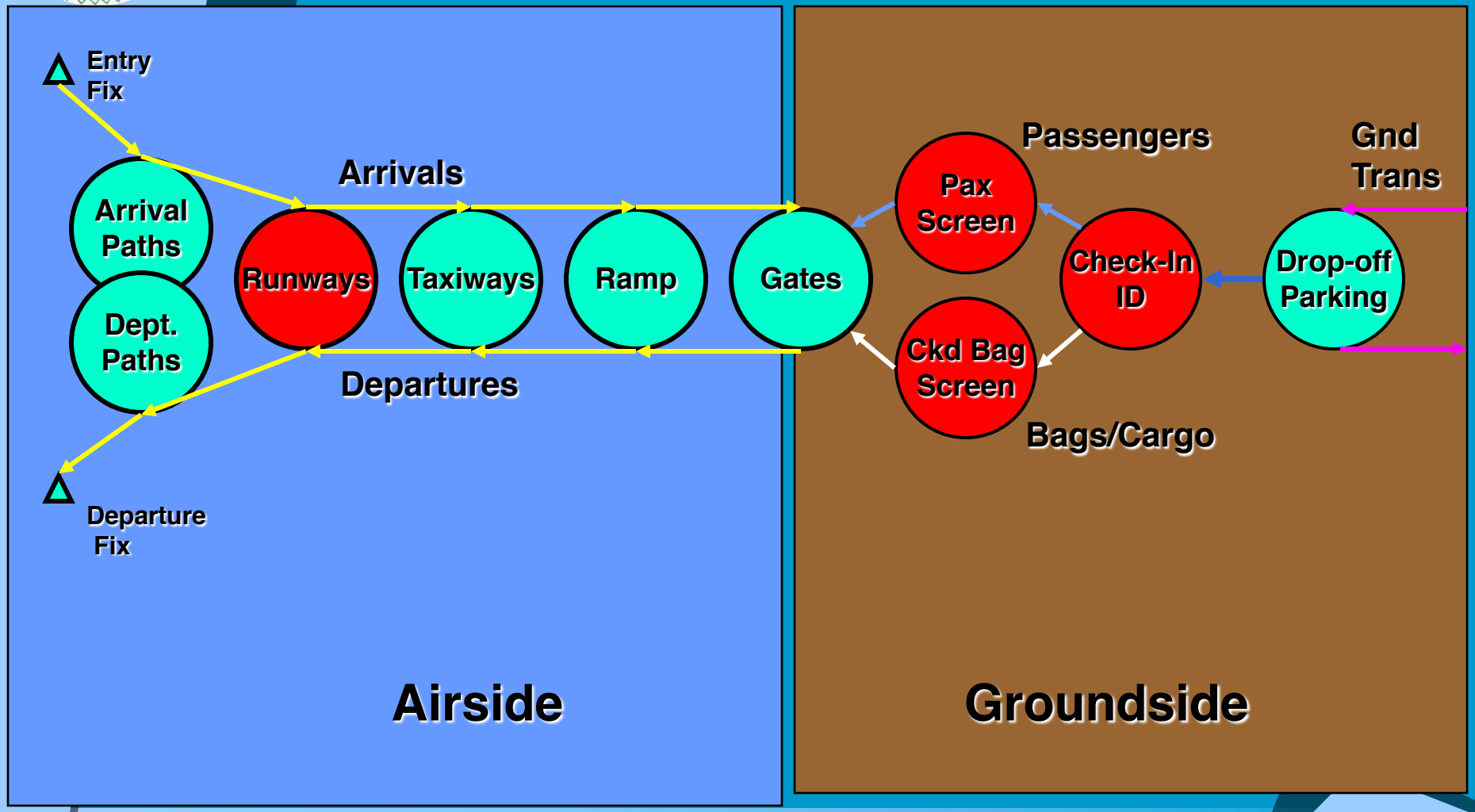
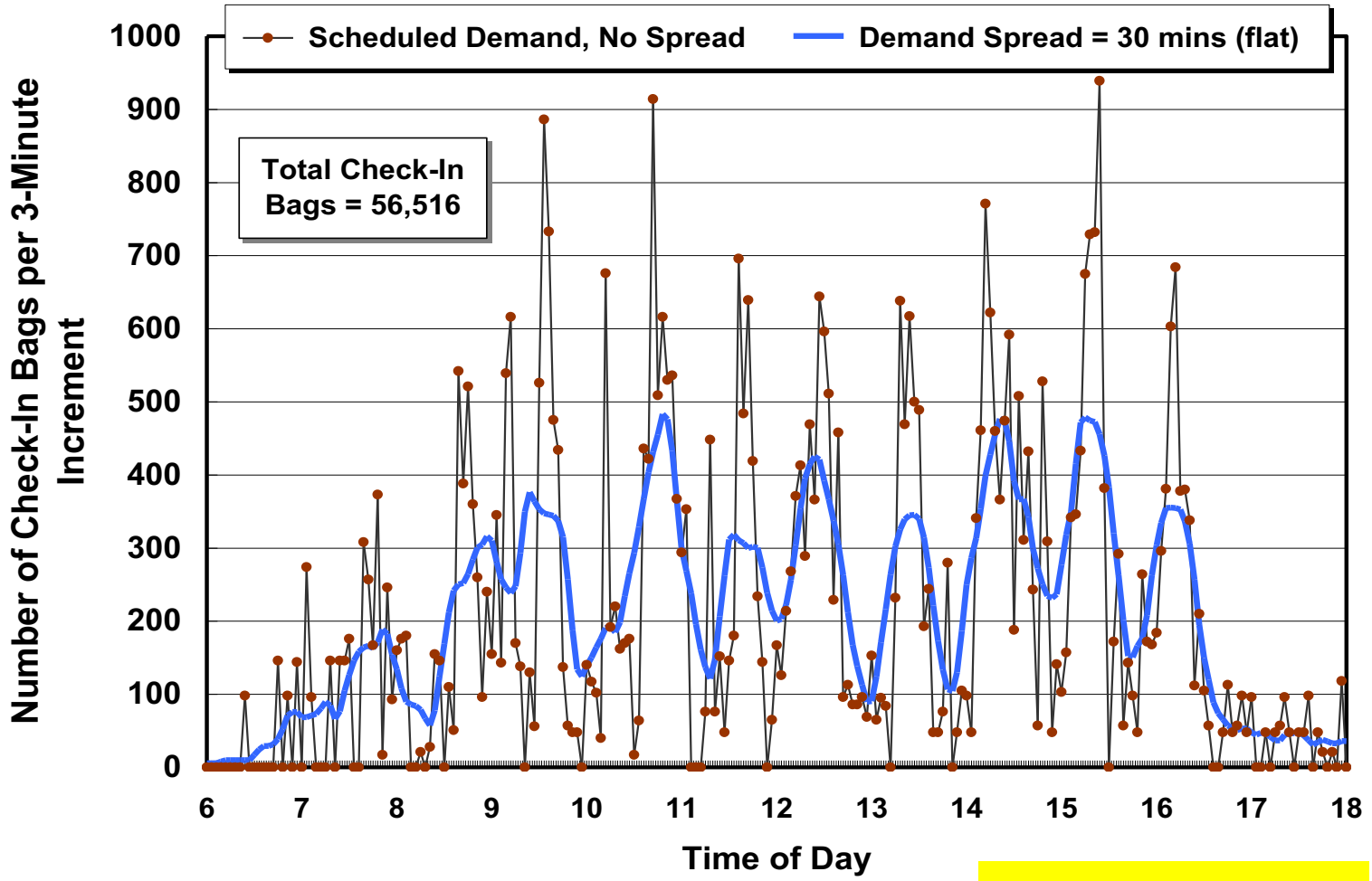
Key Airport System Flows
MIT Queuing Model



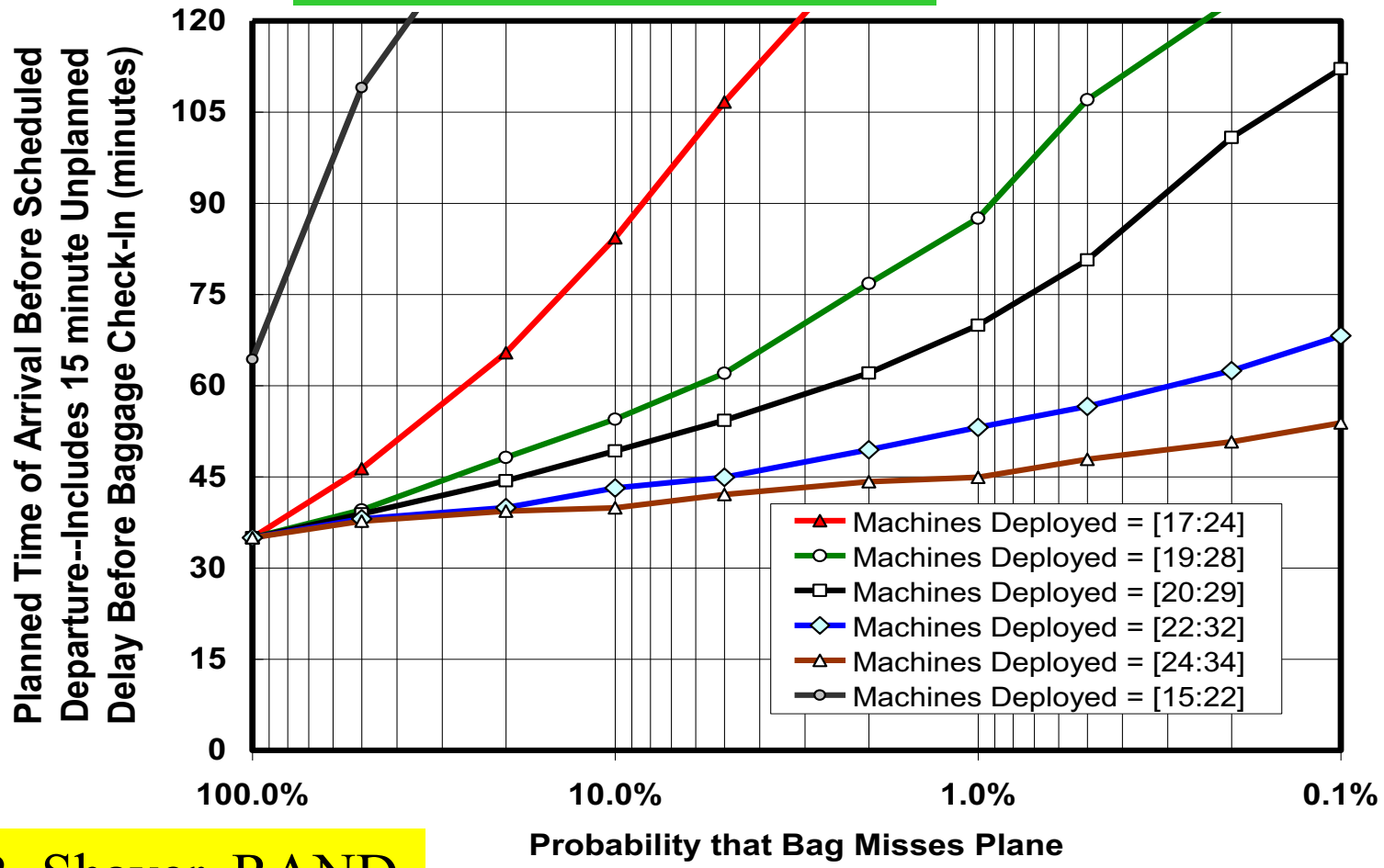
Baggage: Actual and Spread Demand for 1998 DFW Case (RAND Study)



Dr. R. Shaver

Planned Time of Arrival According to Passenger Propensity to Accept Risk

"The Passenger's View"



R. Shaver, RAND