



Air Transportation Infrastructure and Technology: Do We have Enough and Is this the Problem?

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1 April, 2004

**NEXTOR-MIT Symposium on the Economic and
Social Value of Air Transportation**

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My Definition of Air Transportation Infrastructure

- **ATC Telecommunications System**
- **ATC Command and Control Computer Systems**
- **ATC Surveillance Systems**
- **ATC Navigation and Landing Systems**
- **Airport Runways, Taxiways, Ramps, Gates, Parking, etc.**



Bottom Line: Key ATC Services Must be Outsourced

- **FAA has Insufficient Financial and Technical Personnel Resources to Maintain the Current Centralized Computer network, Surveillance System and a modern, Secure Digital Telecommunications system**
 - **Newest Installed Center Computers (1997-98) reach the end of their economic service life this year : No Funding to Upgrade**
 - **Keystone of Productivity Increasing Software is a Digital Data-Link : Program Delayed Indefinitely, Lack of Technical Expertise and Funding Recourses**
 - **Mode S Secondary Radars (1990's) technically obsolete**
- **Oceanic and Class A Airspace Services Need to be Outsourced to Provide the necessary financial capital and technical expertise**
 - **The Technology already Exists**



Technology and Funding Availability only Part of the Problem

- **Future Capacity Growth is Primarily dependent on new technologies and procedures that transfer aircraft separation authority to the aircraft flight deck**
 - **Requires Airline Investment and Government Policy Changes**
- **DoT/FAA Policy Change is Required to provide Economic Incentives for Airlines to Equip and Modify Schedules to use Underutilized Available Network Runway Capacity**



Transition Problem: CAS do NOT Transition Linearly

- **The NAS IS A Complex Adaptive System (CAS)**
- **CAS Systems are Highly Non-Linear and the benefits of any given Sub-System are NOT Additive!**
- **This CAS has STRONG Economic, Multi-Actor, and Safety Regulatory Properties**
- **Flight DELAYS are not Compelling Enough to Significantly FIX a Transportation Network that is in DECLINE!**
- **The System Adapts to WHAT is Measured**
- **Delays are being Managed by DECREASING SAFETY MARGINS**



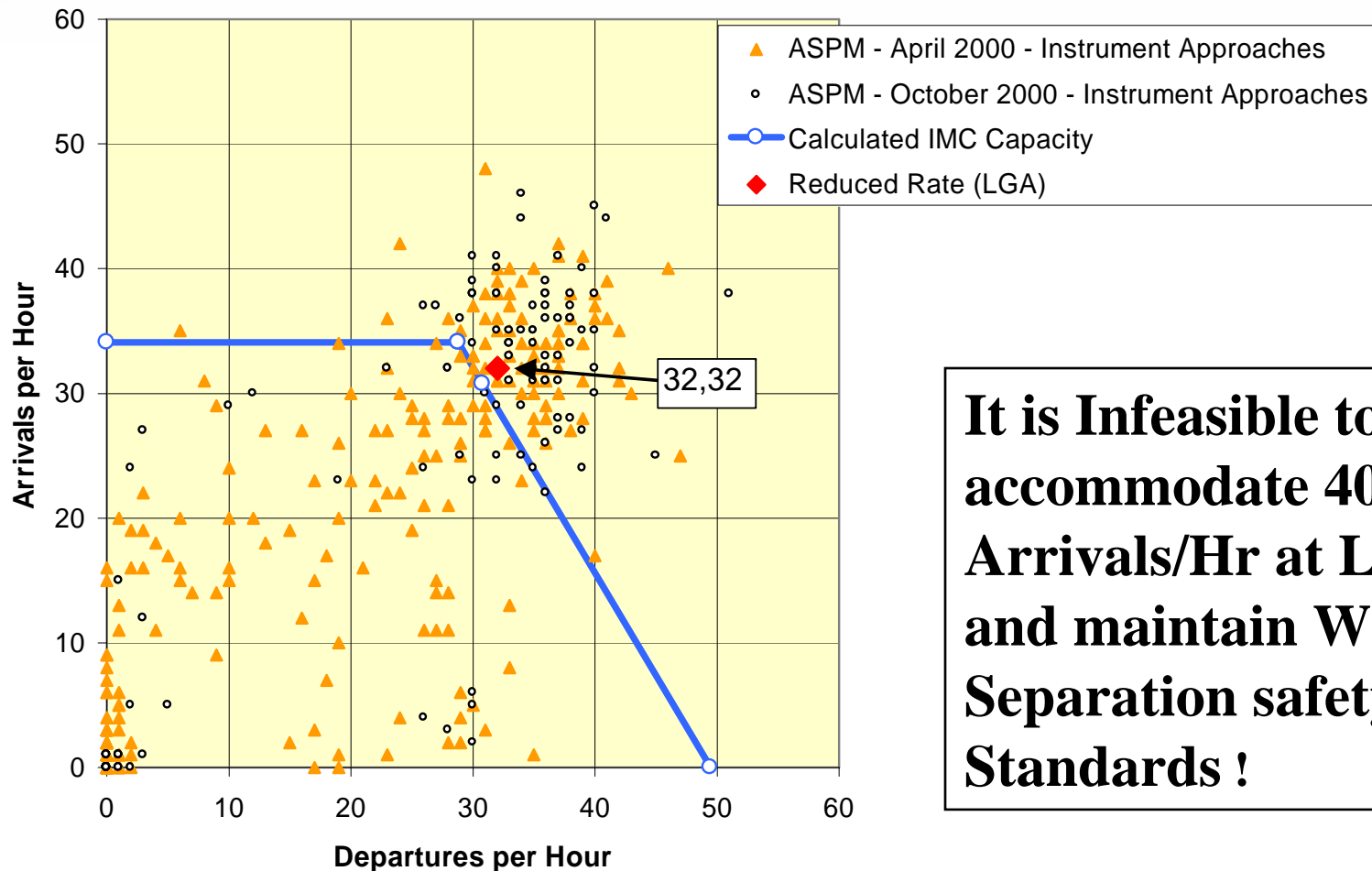
Capacity and Safety are Critically Related

Preliminary Analysis indicates that a 50% Increase in Operations at Capacitated Airports (e.g. ATL, ORD, LGA) may lead to an 8 fold Decrease in Safety!





LGA Arrival - Departure IMC



It is Infeasible to accommodate 40 IFR Arrivals/Hr at LGA and maintain WV Separation safety Standards !



New Regulations, Technology

- **Safety is the ONLY Compelling Reason to Transform the NAS with New Tech Infrastructure and Procedures**
- **Most of the Capacity, Productivity and Safety Gains come from**
 - **Installation and Regulatory Benefits of Flight Deck Equipment**
 - **Properly Dealing with Uncertainty in Traffic Flow Management**
- **A New Regulatory Environment MUST be Coordinated with the Insertion of Universal Data-Links and Aircraft Self-Separation in Closely Spaced Airspace**
- **High-Capacity Airports MUST Provide an Economically Efficient means for SAFE Congestion Management**
- **Strategic Network Controls Must be Developed and Implemented (i.e. Network Scheduling by Auctions)**



FAA Investment Analysis Primarily focus on Capacity and Delay

- **OMB requirement to have a B/C ratio > 1 leads to a modernization emphasis on Decreasing Delay**
- **In an Asynchronous Transportation Network operating near it's capacity margin, Delay is Inevitable**
- **Delay Costs Airlines Money and is an Annoyance to Passengers BUT**
 - **is Usually Politically and Socially Acceptable**



Central Research Questions

- **Both Safety and Efficiency Concerns lead us to the conclusion that the network should be operated as a Synchronous System**
- **Central Research Questions:**
 - **How Synchronous and Efficient Can We Make this Multi-User Network Schedule?**
 - **How does TFM/CDM Best Deal with UNCERTAINTY in Schedule Perturbations?**



A Potentially New Framework for National Air Transportation Management

- **Time Window, Combinatorial-Auctions at Airport Arrival Metering Fixes may provide the Economic Incentives Necessary to Maximize Network Enplanement Capacity at Acceptable Levels of Safety**
 - **Revenue Available to Airports, Traffic Management Service Provider, and Airlines for Needed Capital Investments**
 - **Safety Caps at Capacitated Hub Airports will encourage Airlines to expand to non-OD Hubs and up-gage Fleets**
- **Clearly Define Stake holder's Network Property Rights**
 - **Ensure Equity and Competition**
- **Enhanced TFM/CDM Day-of-Operations Slot Market Exchange Mechanisms to Optimally Deal with Inherent System Uncertainty**



Conclusions

- **Runway Capacity Increases are (in general) NOT POSSIBLE in Major Metropolitan Regions**
 - **But Appox. Half Passengers Non-OD**
- **Current DOT/FAA policy CANNOT encourage use of Under-utilized National Airport Capacity**
 - **No Economic Incentive for Private Transportation Providers**
- **Current DOT/FAA policy does NOT provide Incentives for Private Sector to make Aircraft “Infrastructure” Investments Required to Improve Safety and provide Productivity Gains**
- **Public-Private Service Provider Economic Incentives ARE NOT ALIGNED for Safe Growth of the System**



- **BACKUPS**



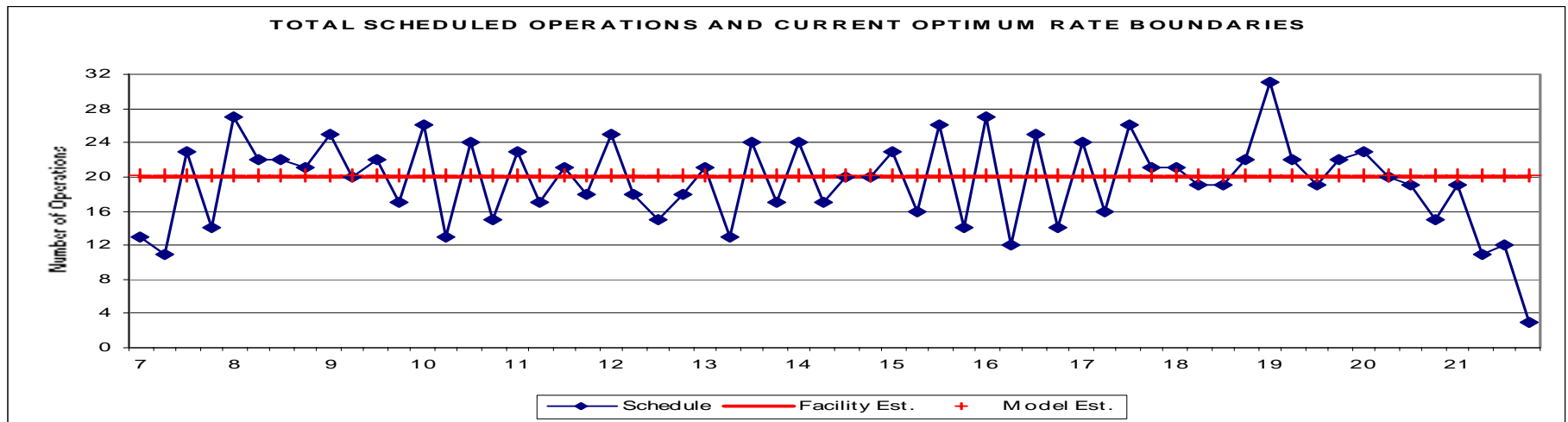
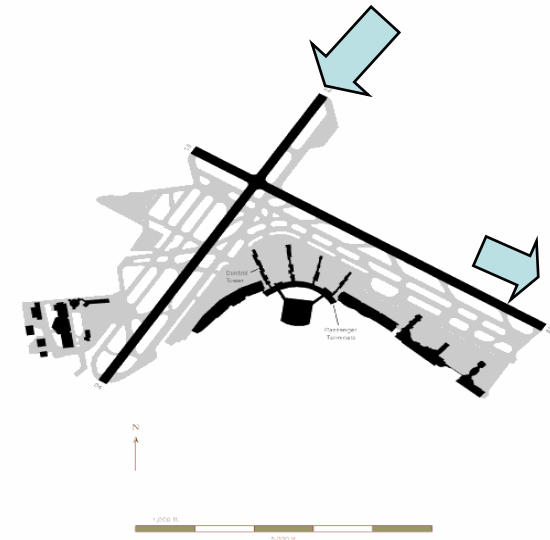
Capacity and Delay

- **System Capacity is Primarily Limited by Network Runway Availability**
- **ATC Workload is an important Secondary Limitation**
- **Runway Maximum Capacity is a function of Aircraft Landing Speed and Runway Occupancy Time (ROT)**
- **Delay is a Non-Linear function of Demand to Maximum Capacity Ratio**
 - **Stochastic FCFS System**
 - **Queuing Theory Applies**
- **Major Hub Airports are Over-Scheduled**



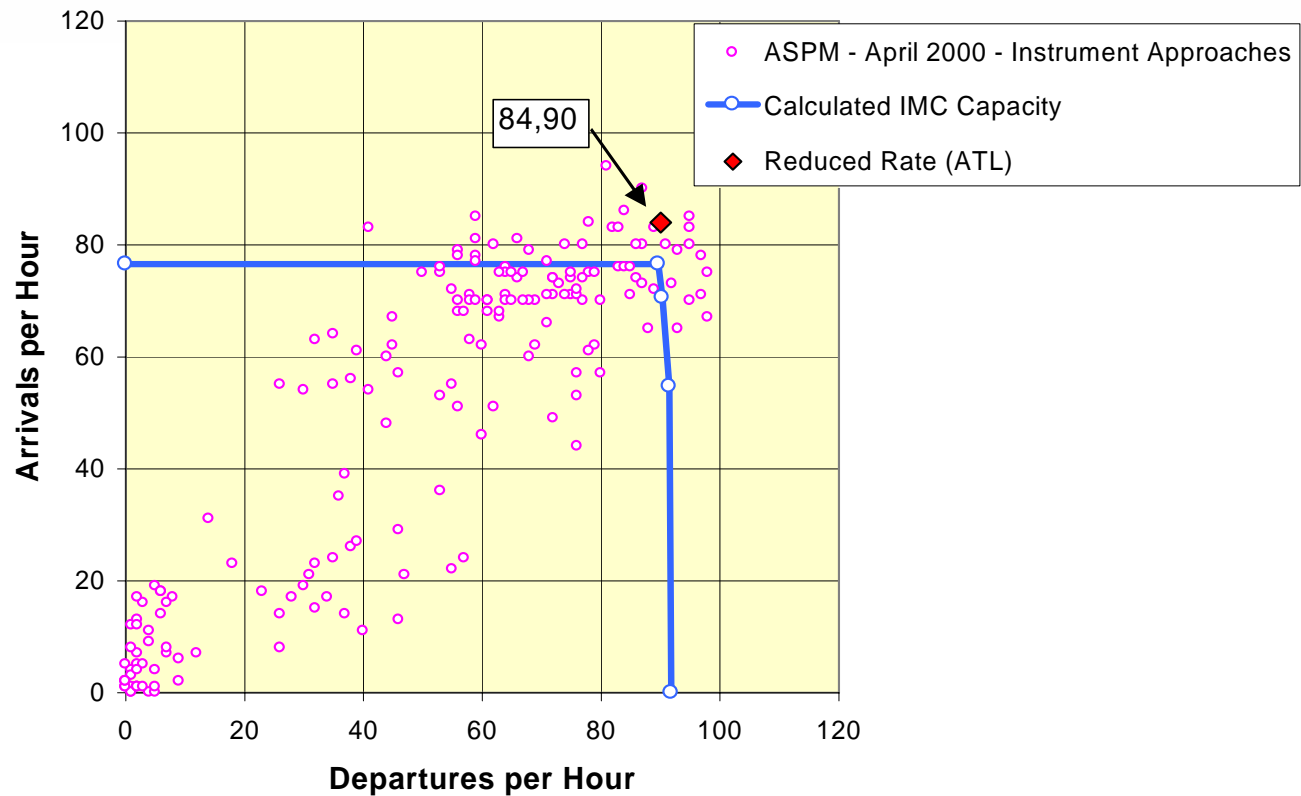
NY LaGuardia: A non-Hub Maximum Capacity Airport

- 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





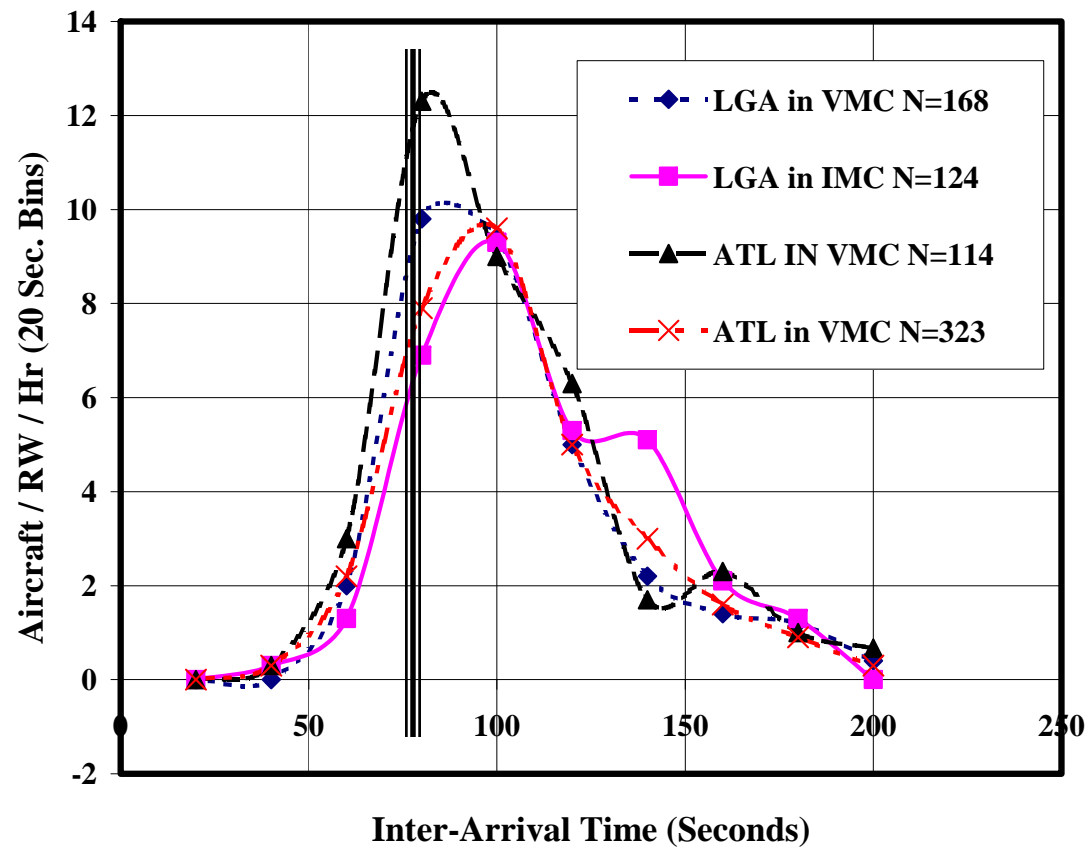
ATL Arrival - Departure IMC





ATL and LGA Inter-Arrival Time in IMC and VMC:32 - 39 Ar/Rw/Hr

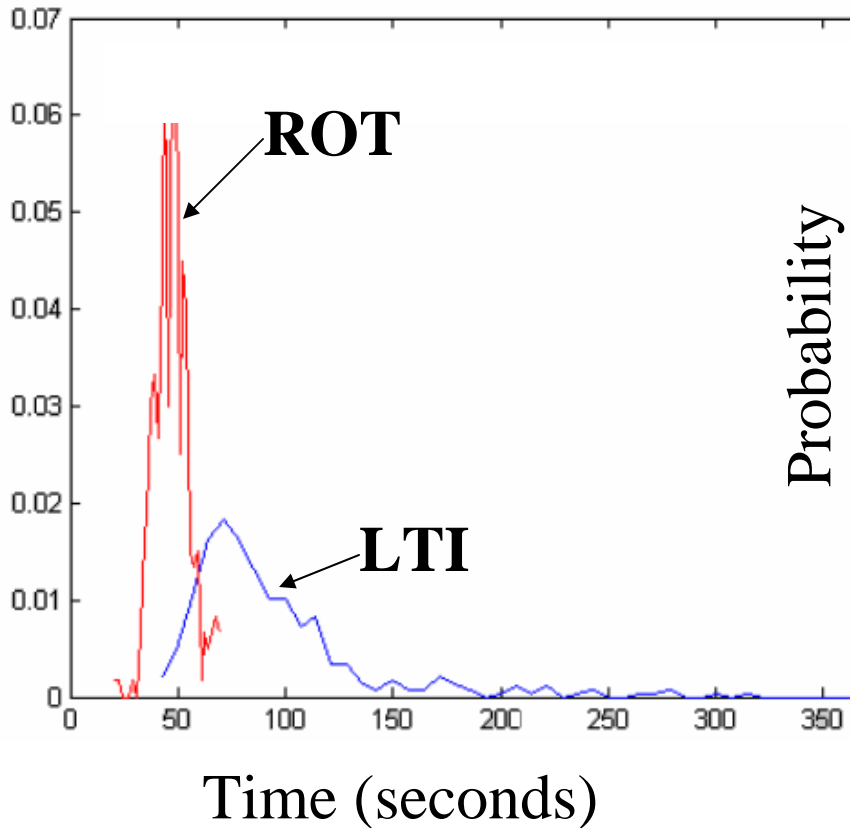
LGA & ATL Arrival Histograms





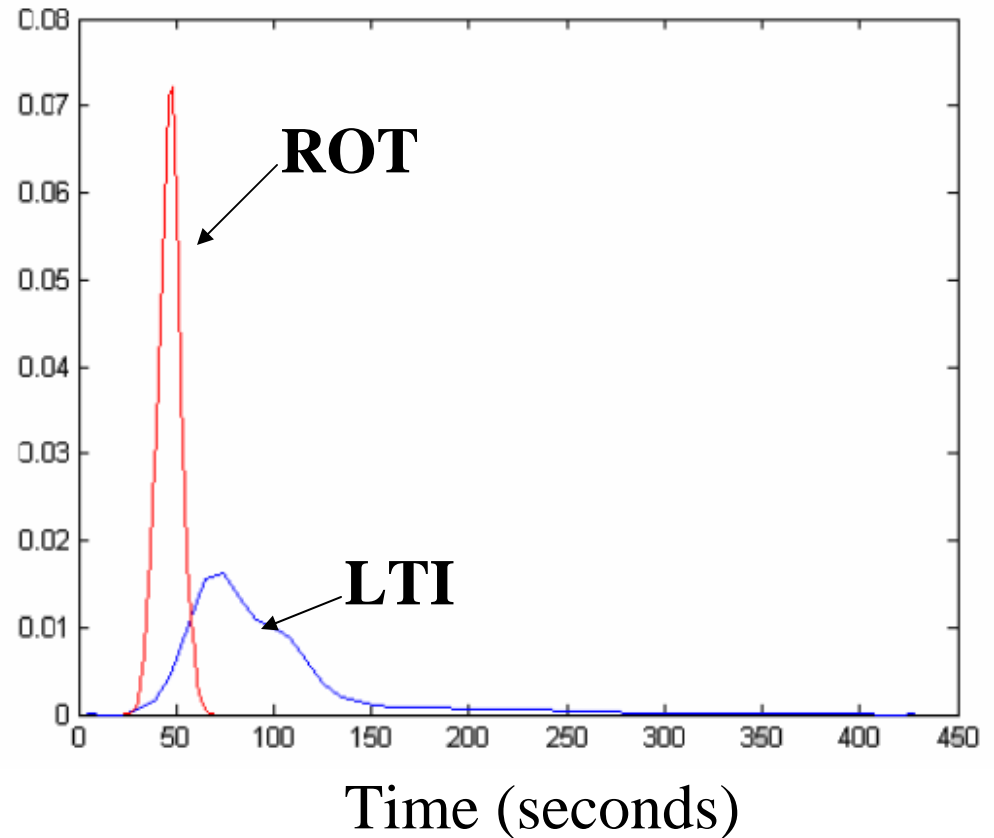
ATL Runway Occupancy and Landing Time Intervals

Observation



LTI: Landing Time Interval;

Simulation Result



ROT: Runway Occupancy Time



Hypothesis: Most Major Changes to the NAS have been due to Safety Concerns

- **1960's Mandated Introduction of Radar Separation**
- **1970's Decrease in Oceanic Separation Standards Required a Landmark Safety Analysis**
- **1970's Required A/C Transponder Equipage**
- **1970's Required A/C Ground Proximity Equipage**
- **1990's Required A/C TCAS Equipage**
- **1990's Required A/C Enhanced Ground Prox. Equipage**
- **1990's TDWR & ITWS Introduction**
- **1990's Mandated Development of GPS/WAAS**



Observations – NAS Safety

- **We are approaching the Point that the existing system may be demonstrably less safe (at current and future capacity fractions) than a new, more synchronous, aircraft FMS/ADS-B separation based system**
- **System is Safe BUT Safety Margins are Diminishing!**
- **This case has not been Analyzed nor even Suggested to date!**



Proposed Grand Experiment/OPEVAL to FOCUS Efforts

- **FY 2008 One Year of Night Operations**
 - **12pm to 8 am**
- **DAG-TM + aFAST+CDM + WV**
- **Entire US Air Cargo Fleet**
- **Inter-Agency IPT**
 - **DoT, NASA, FAA, DoD, NTSB, Boeing, CAA airlines**



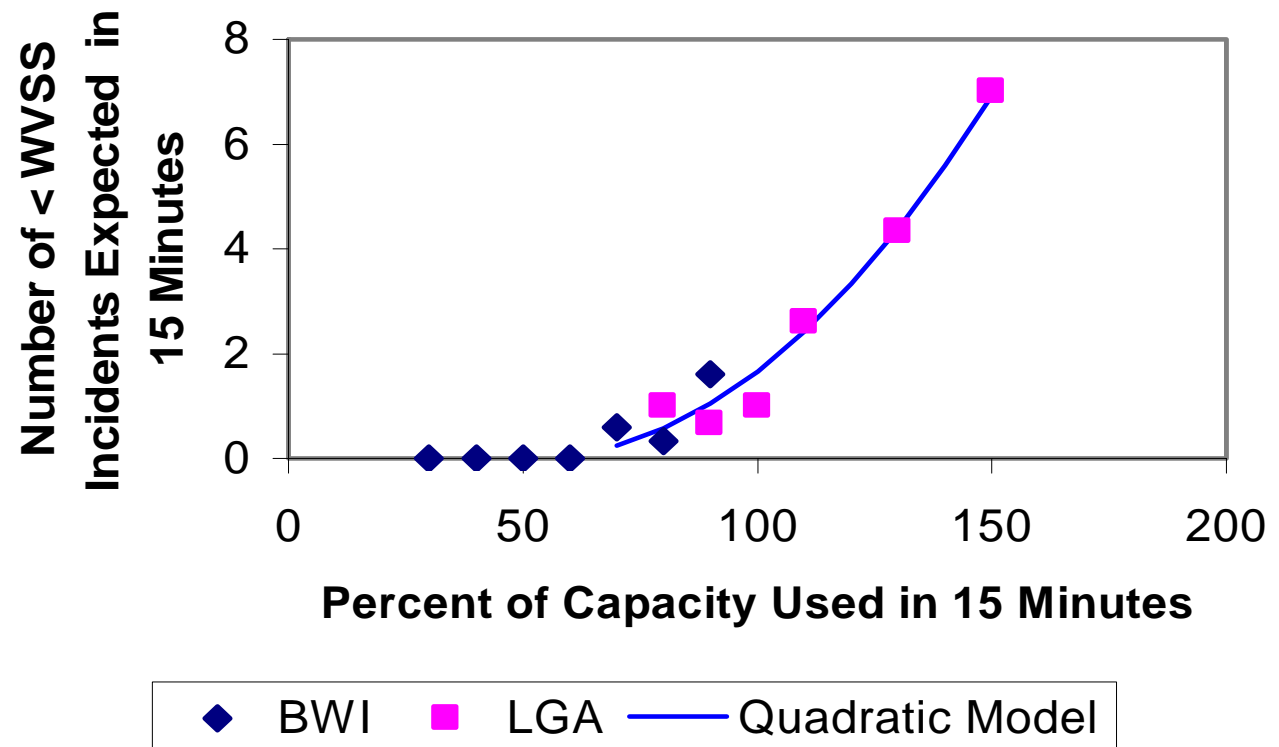
Capacity-Delay-Safety

- **ATM System Safety and Capacity are Non-Linearly Related**
- **Wake Vortex Separation sets the Current System Capacity Limit**
 - **Safety Limitation**
- **ICAO System Safety Goal is 10^{-9} / Operation**
- **Small number Statistics leads us to use Accident Precursors as Safety Indicators**
- **Safety Analysis must be Analytical**



Observed WV Separation Violations vs. Capacity Ratio

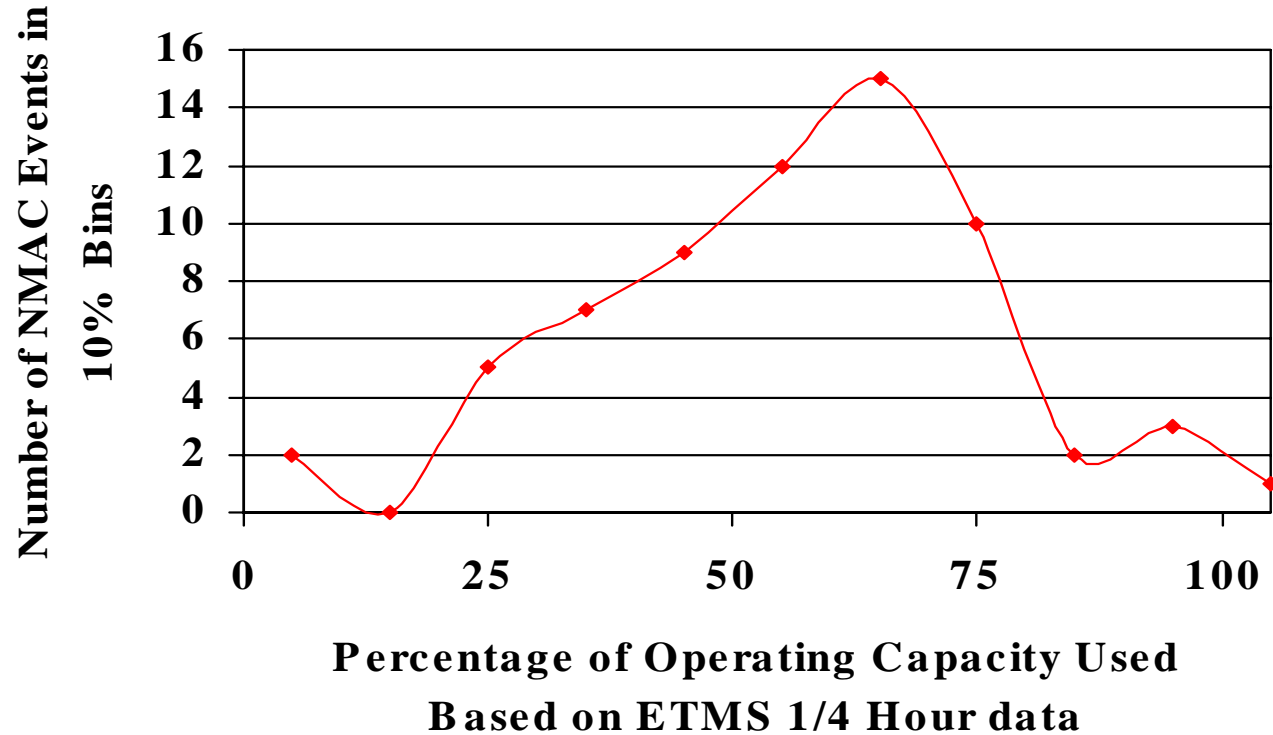
Figure 6-5
Ratio of Incidents to Capacity Used





13 Years of Near Midair Collision reports show Similar Correlation with Capacity

Figure 6-21
NMAC Events at Top 31 Airports Correlated With Capacity Used

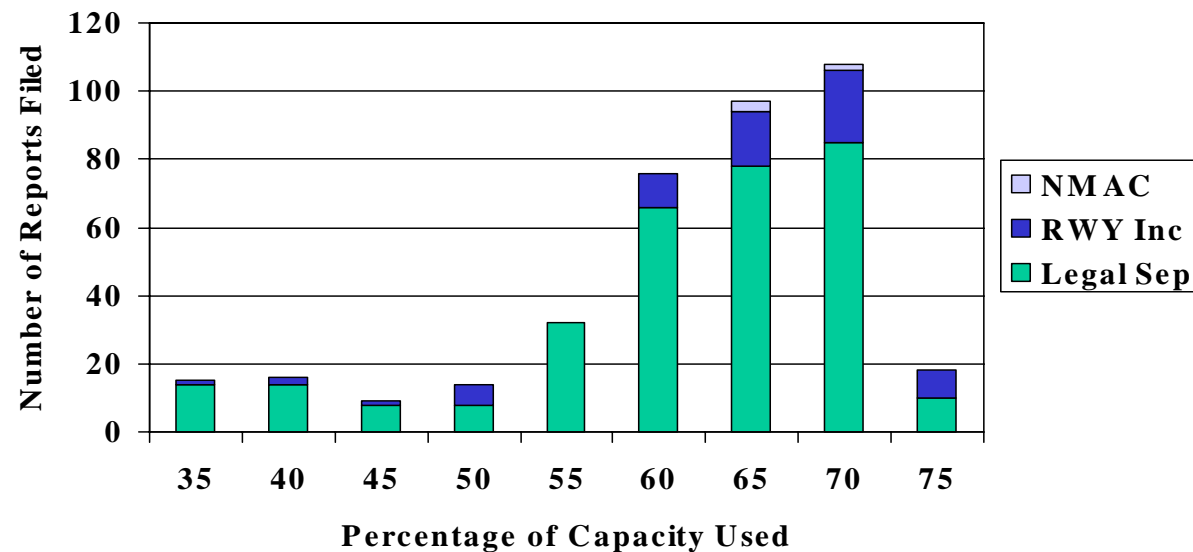


Haynie, GMU 2002



Accident Pre-Cursor Incidents seem to Indicate a Trend

Figure 6-19
ATL, BWI, DCA, & LGA Historical Reports 1988-2001
Correlated with Percentage of Capacity Used



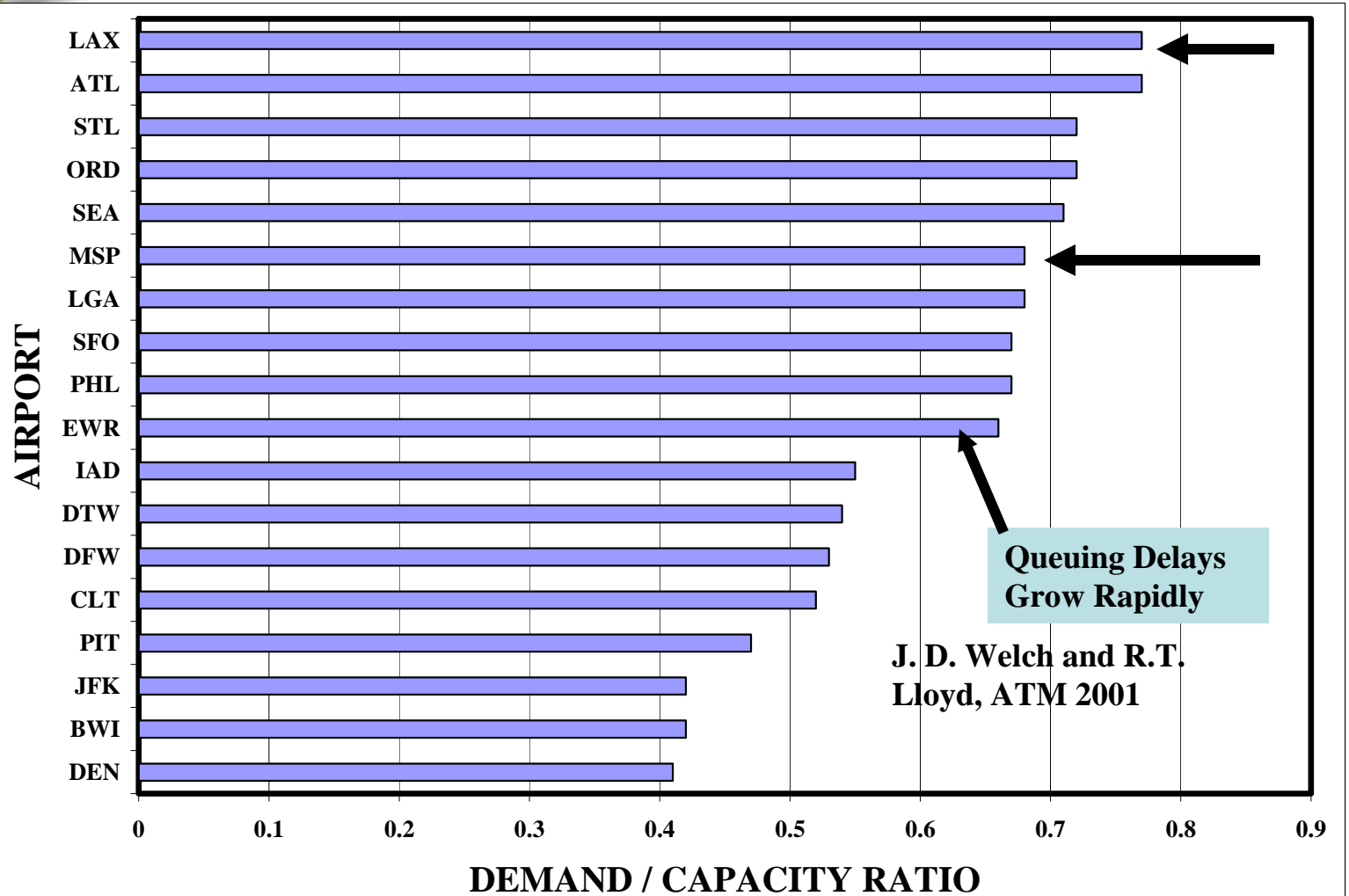


System Network Effects

- **Aprox. 10 Major Hub Airports are Operating at D/C max > 0.65**
- **Delays at these Airports spread Non-Linearly throughout the Network**
- **Runway Additions at one Airport May have Little Network Effect**
- **System-wide improvements have a Larger Effect than Individual Airport Improvements**

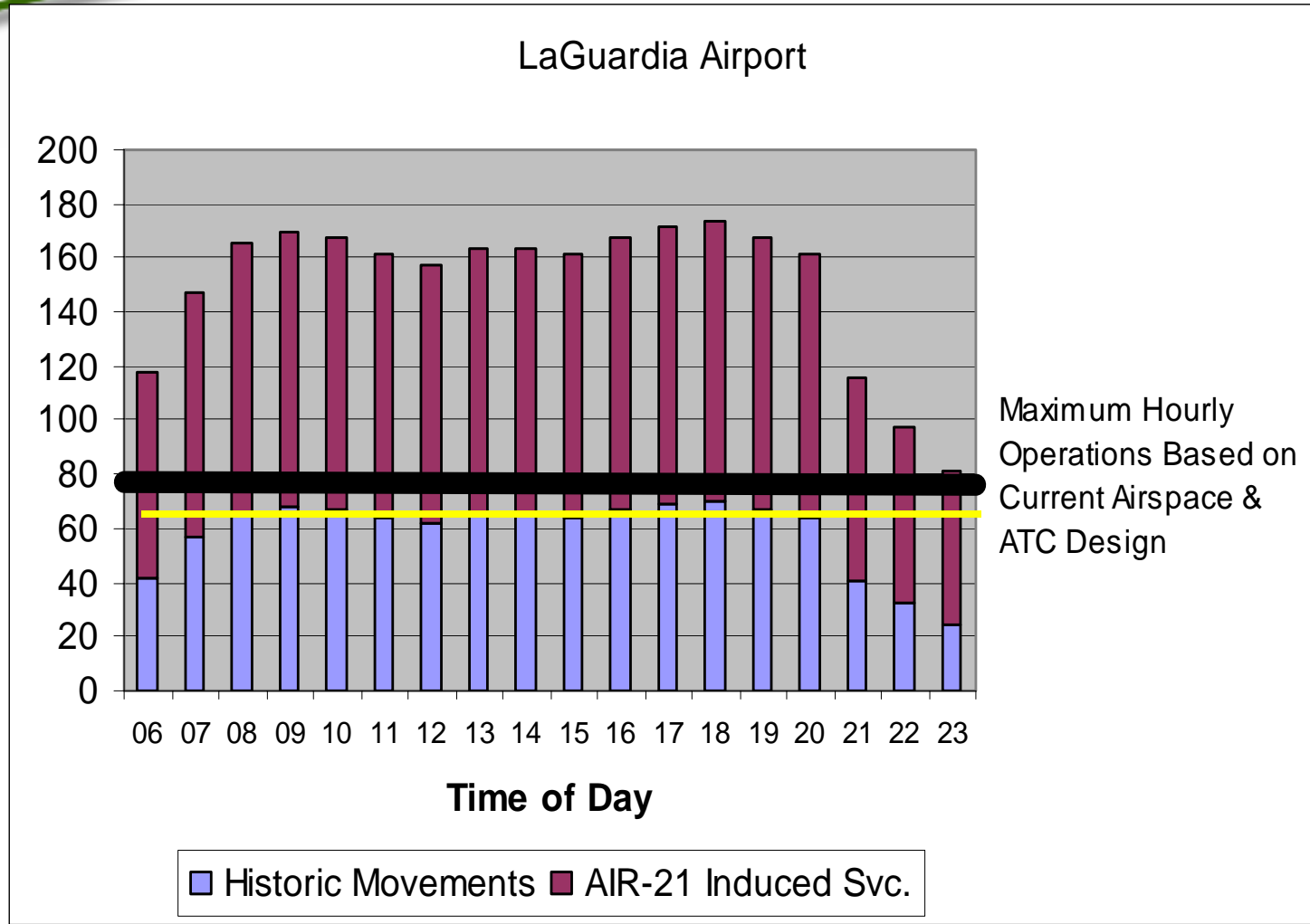


Major US Airport Congestion





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



Source: William DeCota, Port Authority of New York