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

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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
• 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
• 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
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!
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
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?
• 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 Approx. 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

Calculated IMC Capacity: 84,90
ATL and LGA Inter-Arrival Time in IMC and VMC: 32 - 39 Ar/Rw/Hr

LGA & ATL Arrival Histograms

Aircraft / RW / Hr (20 Sec. Bins)

LGA in VMC N=168
LGA in IMC N=124
ATL IN VMC N=114
ATL in VMC N=323
LTI: Landing Time Interval; ROT: Runway Occupancy Time

<table>
<thead>
<tr>
<th>Observation Simulation Result</th>
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<td>Time (seconds)</td>
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**ROST**

**LTI**

**Probability**

LTI: Landing Time Interval; 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
• 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
• 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

Number of < WVSS Incidents Expected in 15 Minutes

Percent of Capacity Used in 15 Minutes

BWI  LGA  Quadratic Model

Haynie, GMU 2002
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

Haynie, GMU 2002
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

Queuing Delays Grow Rapidly

J. D. Welch and R.T. Lloyd, ATM 2001
The Semi-Regulated Market Does Not Act to Minimize Delay: LGA Air 21 Impact

LaGuardia Airport

Maximum Hourly Operations Based on Current Airspace & ATC Design

Source: William DeCota, Port Authority of New York