Next Generation Air Traffic Management: Incentivizing Air Carrier Infrastructure Investment

David Lovell

Civil and Environmental Engineering

Institute for Systems Research

Applied Mathematics, Statistics, and Scientific Computation

Engineers Without Borders

University of Maryland, College Park

Outline

- Who is NEXTOR
- Where the Air Transportation System is going (concepts, technologies, procedures)
- What we've been working on to get it there
  - Traffic Flow Management Initiatives
  - Performance prediction and evaluation
  - New procedures for new technologies

NEXTOR Research group at UMD

- Prof. Mike Ball, BMGT/ISR
- Prof. David Lovell, CEE/ISR
- Dr. Bob Hoffman, Metron Aviation
- Current students:
  - Prem Swaroop, BMGT
  - Kleoniki Vlachou, CEE
  - James Jones, CEE
  - Cynthia Bossard, AMSC
  - Corina Wang, ISR

(L to R) Mike Ball, Nasim Vakili, Alex Tien, Andy Churchill, Bob Hoffman, Moein Ganji, Dave Lovell

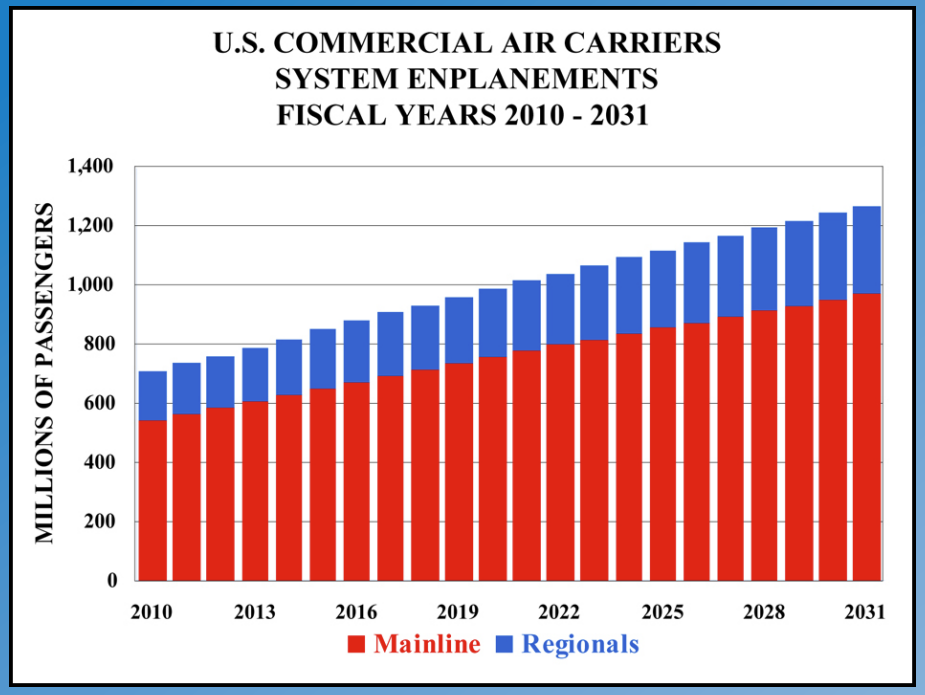
Other faculty, former students and post-docs

- Paul Schonfeld, CEE
- Mark Austin, CEE/ISR
- Peter Cramton, ECON
- Larry Ausubel, ECON
- Larry Bodin, BMGT
- Martin Dresner, BMGT
- Wolfgang Jank, BMGT

- Thomas Vossen, University of Colorado
- Tasha Inniss, Spelman College
- Avijit Mukherjee, NASA Ames
- Jasenka Rakas, U.C. Berkeley
- Jason Burke, Metron Aviation
- Bala Chandran
- Ming Zhong
- Yufeng Tu, TUI University
- Bargava Subramanian
- Nasim Vakili
- Moein Ganji, Metron Aviation
- Alex Tien, MITRE
- Andrew Churchill, Mosaic ATM
- Charles Glover, Booz-Allen
- Kennis Chan, ATAC Corporation

Aviation growth predictions

Passengers



FAA Aerospace Forecast Fiscal Years 2011–2031

Airframes

Airplanes in service 2010 and 2030

Size	2010	2030
Large	770	1,140
Twin aisle	3,640	8,570
Single aisle	12,100	27,750
Regional jets	2,900	2,070
Total	**19,410**	**39,530**

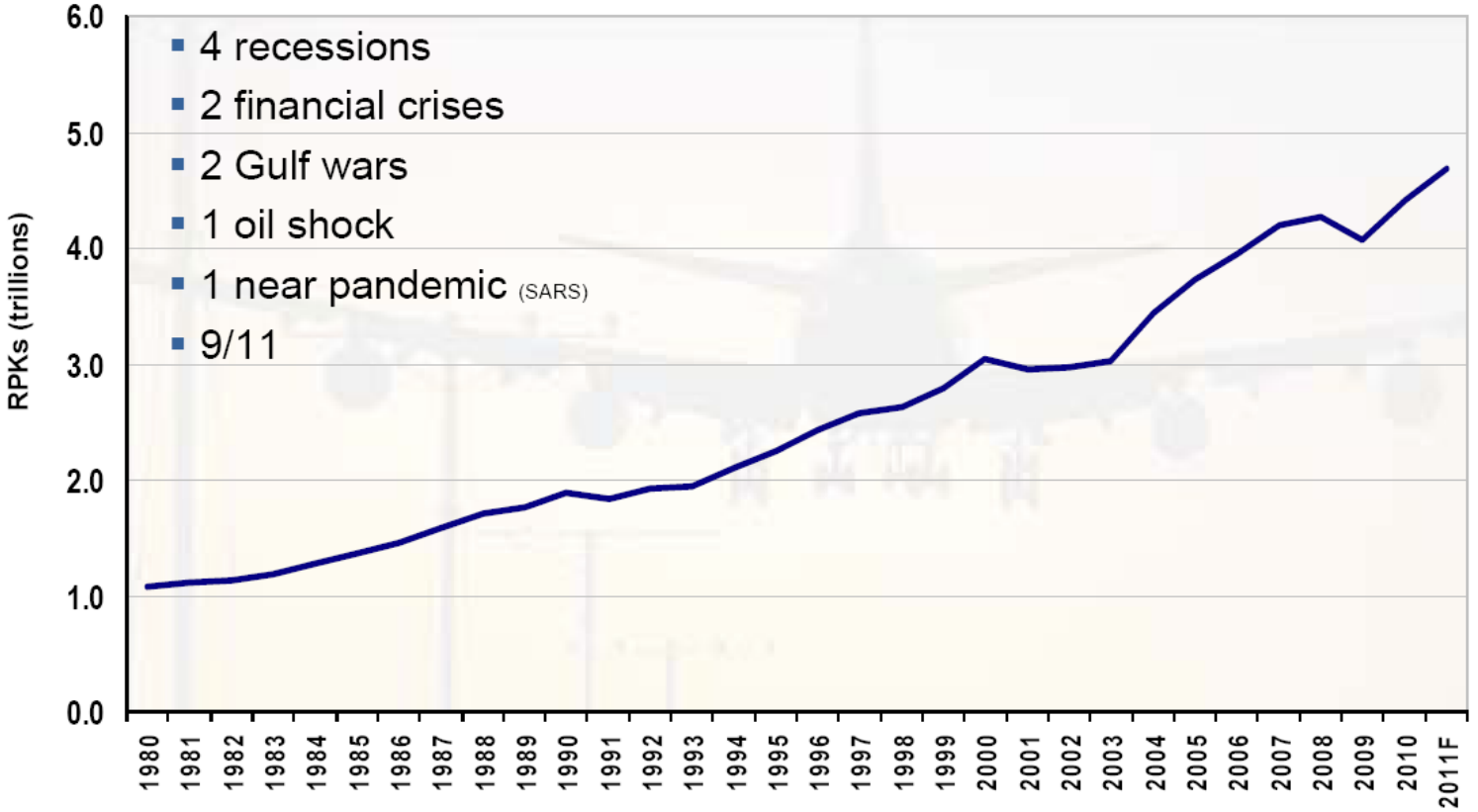
Demand by size 2011 to 2030

Size	New airplanes	Value ($B)
Large	820	270
Twin aisle	7,330	1,770
Single aisle	23,370	1,950
Regional jets	1,980	70
Total	**33,500**	**4,060**

Current Market Outlook 2011–2030

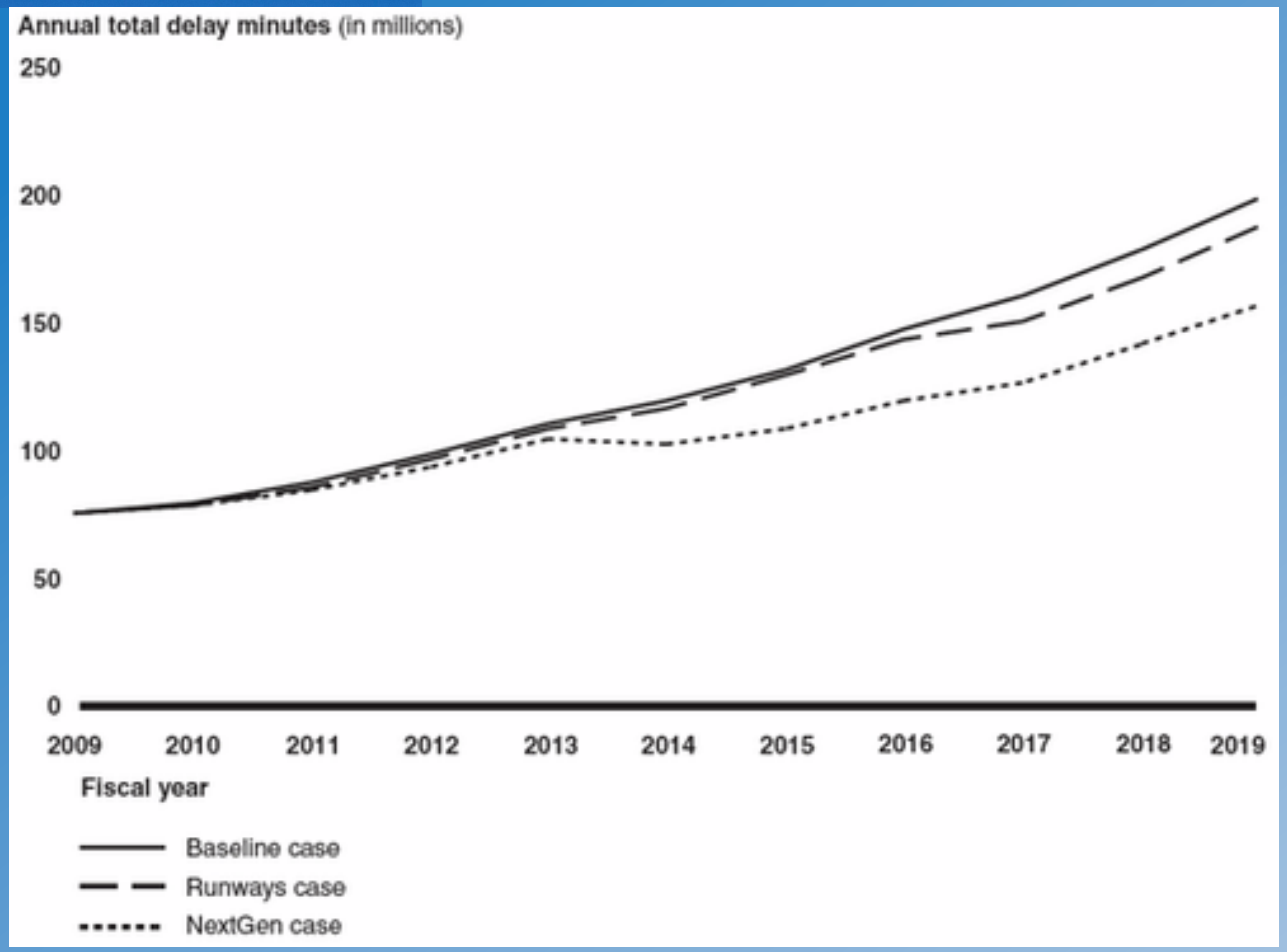
Example airframes: Large (747-8, A380), Twin aisle (787, 777, 767, A350, A340, A330), Single aisle (737, A320, MD80), RJ (Bombardier CRJ, Embraer ERJ 145)

Historic growth



RPKs = Revenue Passenger Kilometers
Sources: ICAO Scheduled Traffic

Delay forecasts



Source: US FAA

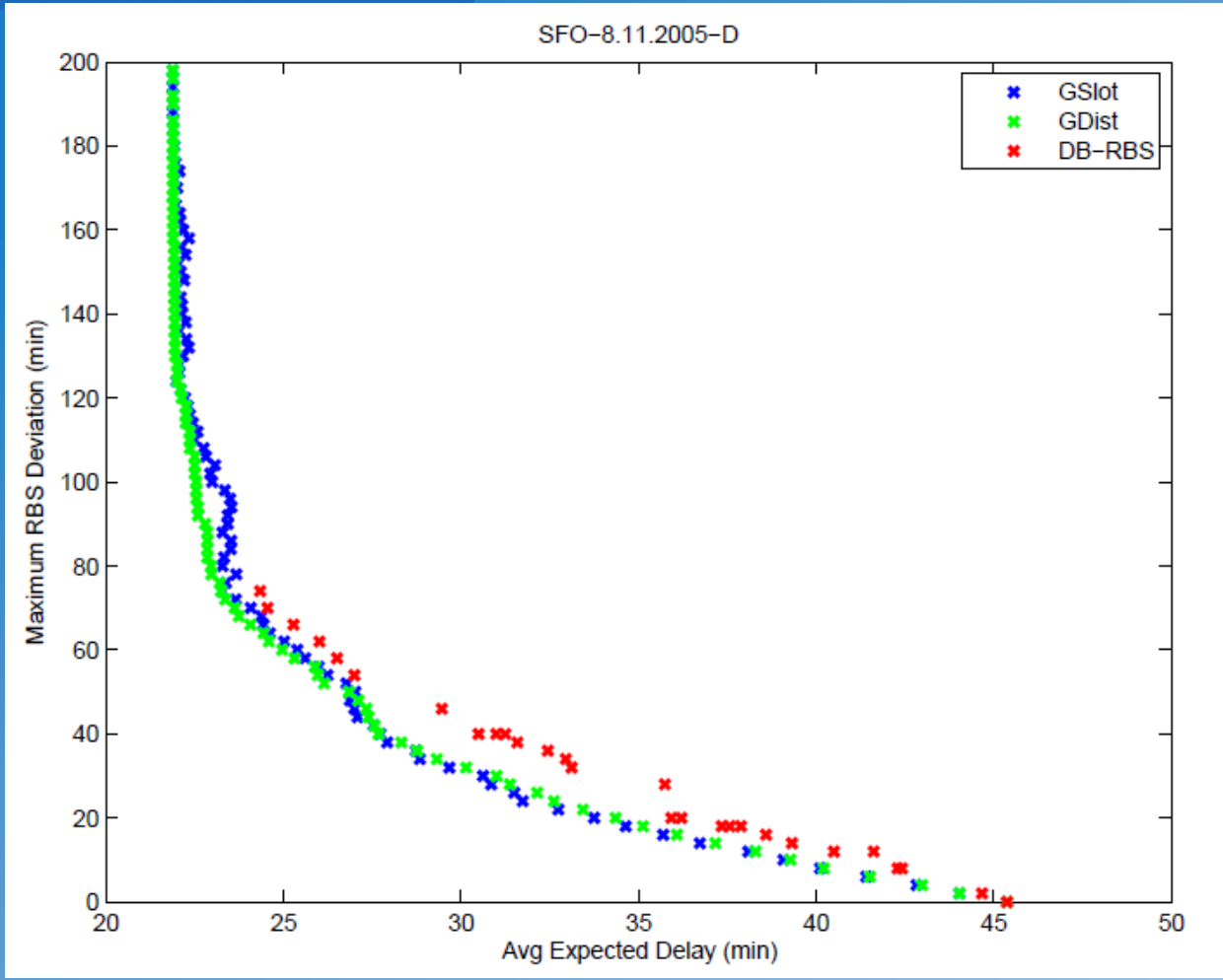
The Next Generation Air Transportation System (NextGen)

- Created in 2003 as part of the legislation VISION 100 – Century of Aviation Reauthorization Act (P.L. 108-176)
- Congress created the Joint Planning and Development Office (JPDO)
- Predicated on predictions of unsustainable air travel demand growth
- Aims to leverage existing and new technological innovations in navigation, control, and communications

UMD Contributions

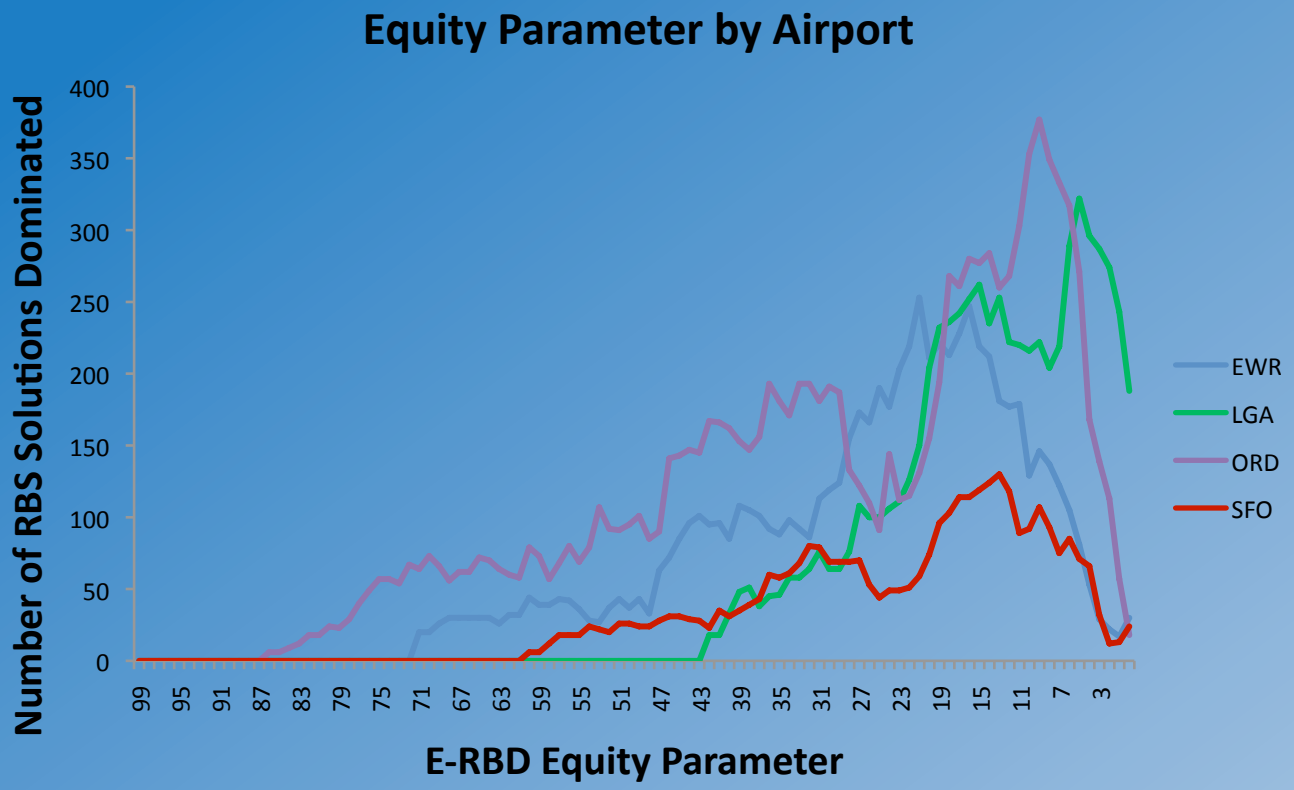
- Resource rationing mechanisms
- Performance analysis and prediction
- Large scale modeling and optimization
- Policy analysis
- Market mechanism design
- Benchmarking
- Economic impacts

Designing rationing mechanisms



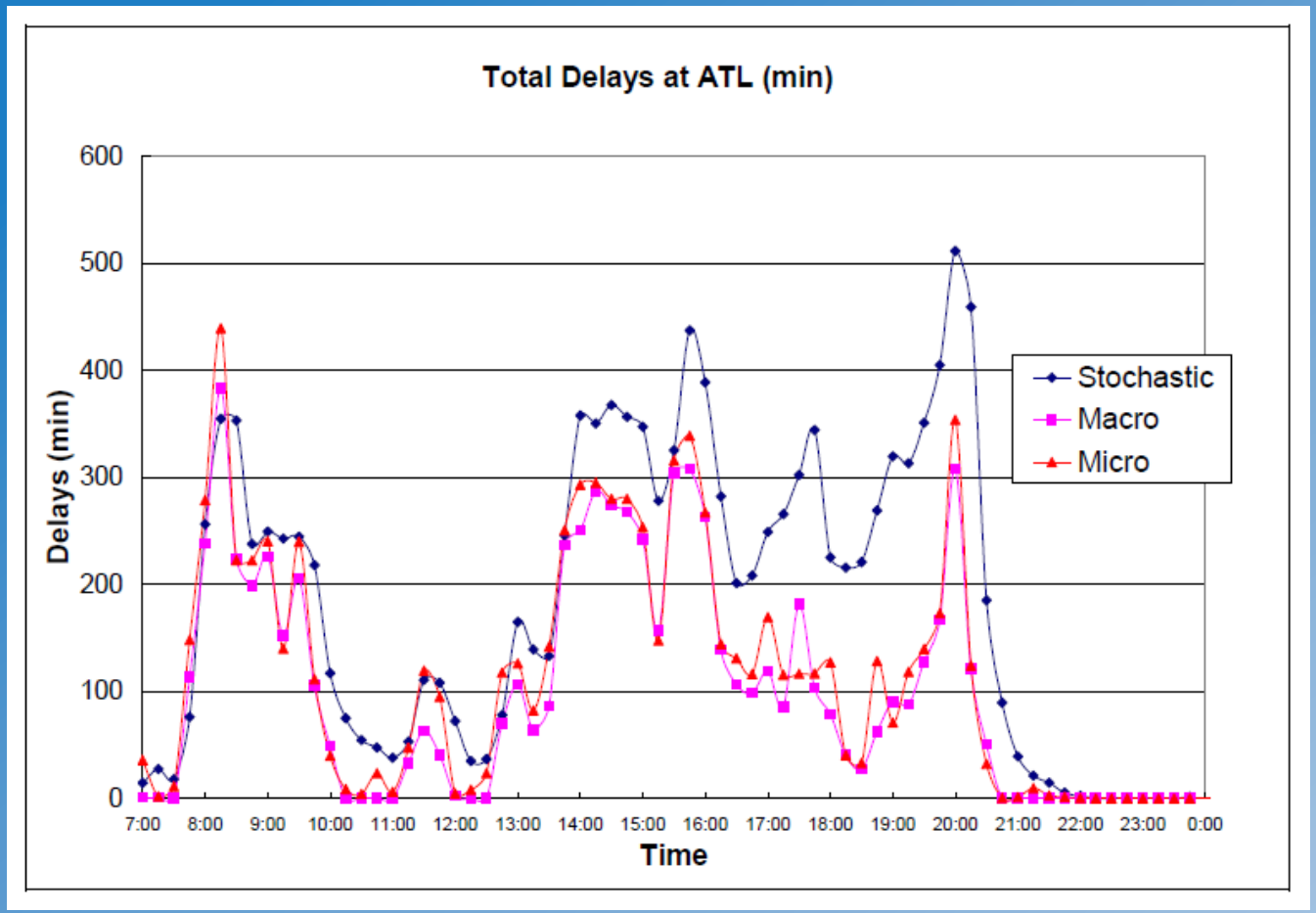
Glover:
Unpublished paper on distance-based rationing mechanisms, 2011.

Rationing algorithm performance



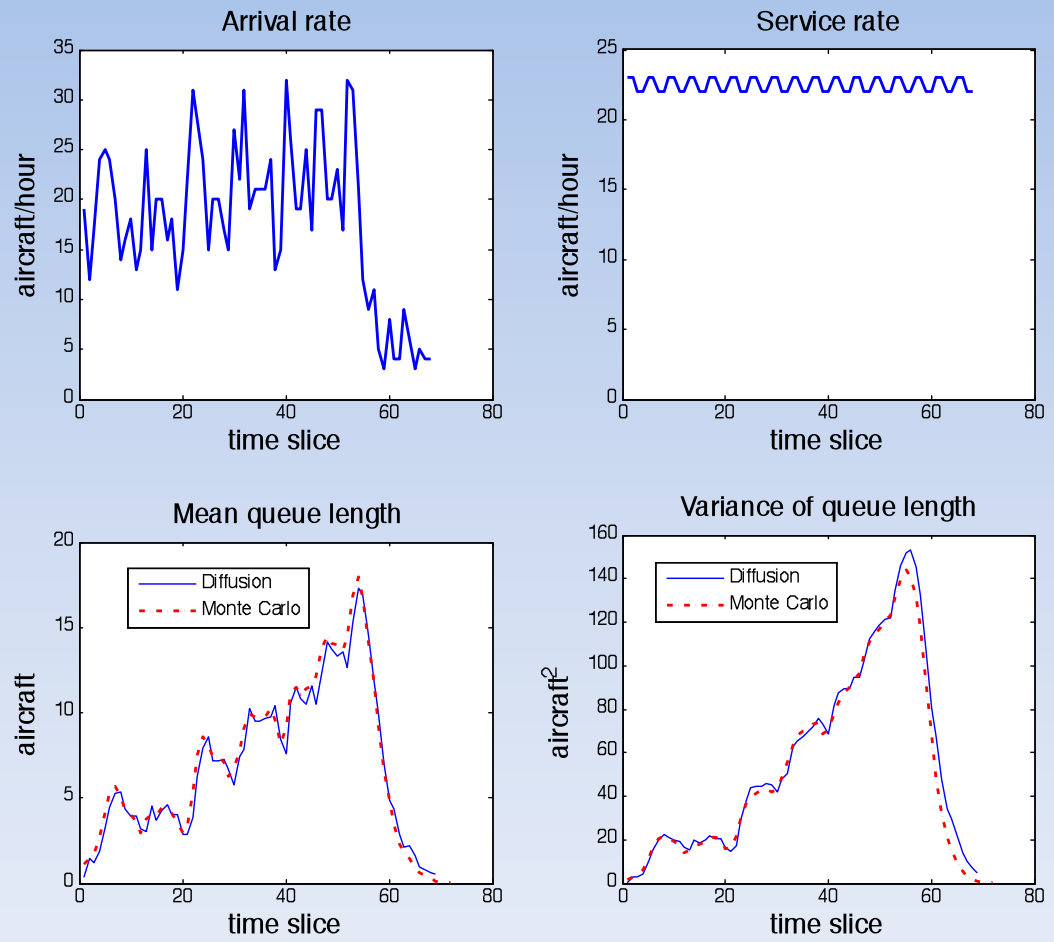
Glover:
Unpublished paper on distance-based rationing mechanisms, 2011.

Queuing analysis at Atlanta Hartsfield



Hansen, Nikoleris, Lovell, Vlachou, Odoni: *Use of Queuing Models to Estimate Delay Savings from 4DT Trajectory Precision.* Eighth USA/Europe Air Traffic Management Research and Development Seminar, Napa Valley, CA, 2009.

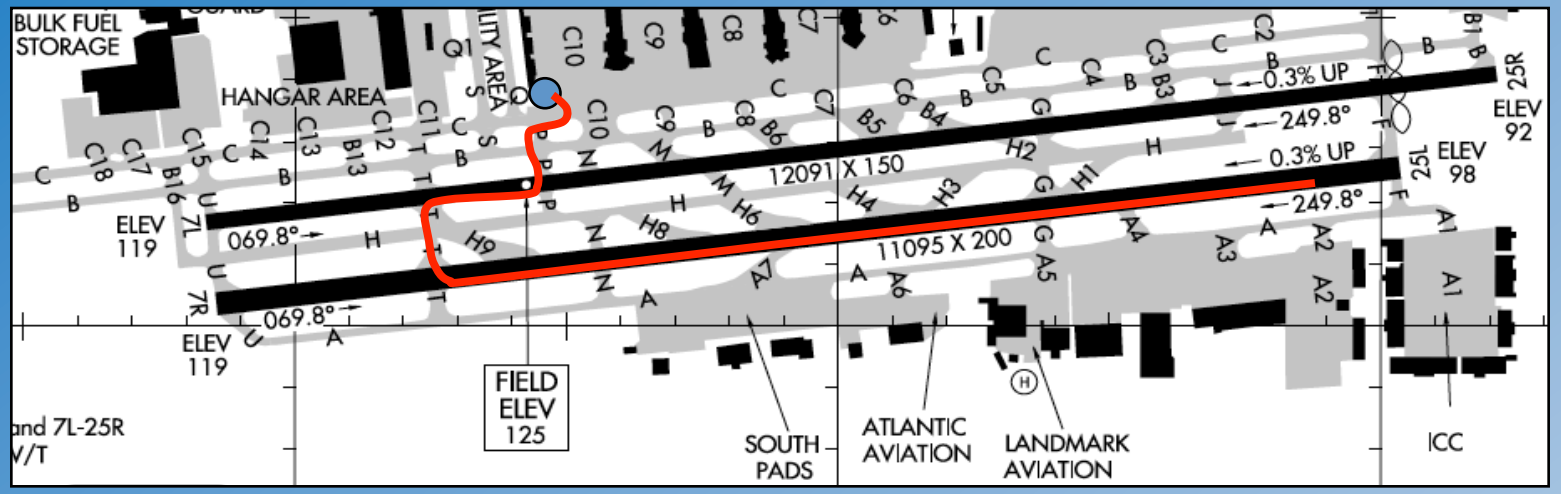
Diffusion models of queues at O'Hare



Lovell, Vlachou: *A Diffusion Approximation to a Single Airport Queue. Transportation Research Part C,* forthcoming.

A380s on the South Runway Complex at LAX

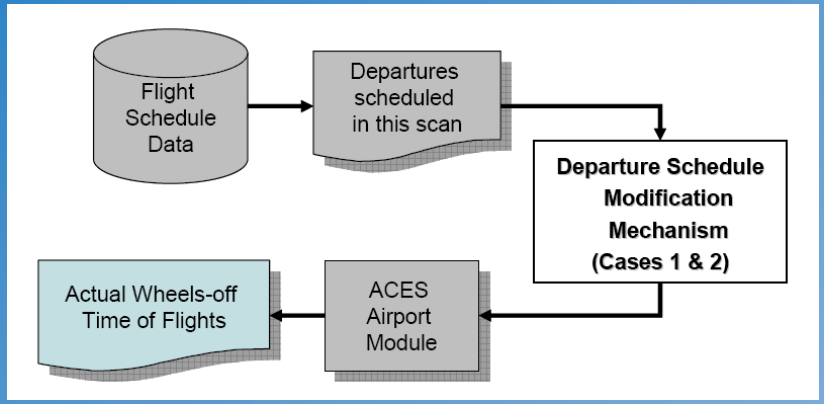
No aircraft can land or depart on the South Runway complex for 4 min after touchdown of an A380

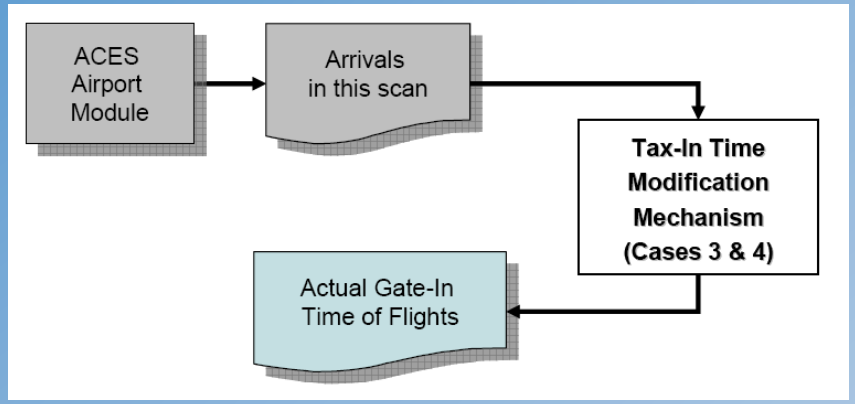


Tien, Lovell: *Modeling Surface Delay due to Super Heavy Transports in a Large-Scale Simulation Environment*. 28th Digital Avionics Systems Conference, Orland, FL, 2009.

Integrating A380 Surface Impacts into ACES Simulation

- Used to predict the impact on airport operations of super heavy airframes
- Expected increase in operations, particularly in busier times of day





Tien, Lovell: *Modeling Surface Delay due to Super Heavy Transports in a Large-Scale Simulation Environment*. 28th Digital Avionics Systems Conference, Orland, FL, 2009.

Present system vs. NextGen

Present system	NextGen system
Ground-based navigation and surveillance	Satellite-based navigation and surveillance
Voice communications	Digital communications
Disconnected information systems	Networked information systems
Disparate, fragmented weather forecast delivery system	Single, authoritative system in which forecasts are embedded into decisions
Airport operations limited by visibility	Operations continue in lower visibility
Air traffic "control"	Air traffic "management"

NEXTGEN Concepts

- Net-Centric Operations (Network-Enabled Information Access)
- Performance Based Operations and Services
- Weather assimilated into Decision Making
- Layered, adaptive security
- Positioning, Navigation, and Timing (PNT) Services (Broad Area Precision Navigation)
- Trajectory-Based Operations (TBO)
- Equivalent Visual Operations (EVO)
- High-density Arrival/Departure Operations

Areas where UMD is participating

Resource allocation w/ PBOS

Weather affects capacity → FAA allocates capacity to flights

Weather affects capacity → FAA allocates capacity to flights → Carriers cancel and substitute flights → FAA compresses schedule

Weather affects capacity → FAA allocates some capacity to regular flights → Carriers cancel and substitute flights → FAA compresses schedule

Weather affects capacity → FAA allocates some capacity to equipped flights → Carriers cancel and substitute flights → FAA compresses schedule

NEXTGEN Technologies

- Automatic Dependent Surveillance-Broadcast (ADS-B)
  - Out: 1090 MHz or 978 MHz (USA only)
  - In
- System Wide Information Management (SWIM)
- Next generation data communications
- Next generation network-enabled weather (NNEW)
- NAS Voice Switch

Performance-based navigation

- Area Navigation (RNAV)
  - Navigate within a network of beacons, rather than beacon-to-beacon
  - Allows more direct or otherwise optimal routes
  - Developed in the 60's, routes published in 70's, routes revoked in 1983, re-instituted after GPS
- Required navigation performance (RNP)
  - Similar to RNAV, except that the equipment has to have on-board performance monitoring and alerting
  - RNP *X*: *X* = radius of 95% performance circle, nm

RNAV/RNP

NEXT GEN Components: RNAV/RNP

Moving to Performance-Based Navigation

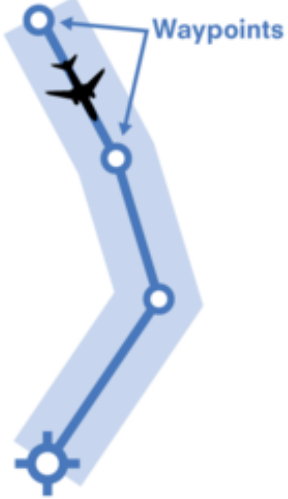
Conventional Routes

Today's airways connect ground-based navigation aids

Limited Design Flexibility

RNAV

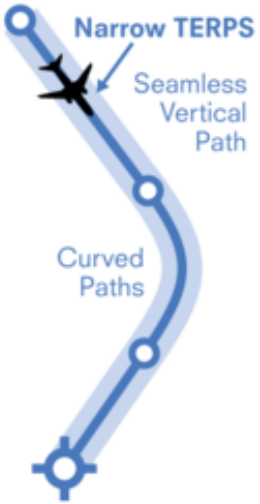
Area Navigation (RNAV) routes follow defined "waypoints"



Increased Airspace Efficiency

RNP

Required Navigation Performance (RNP) routes within specified "containment area"

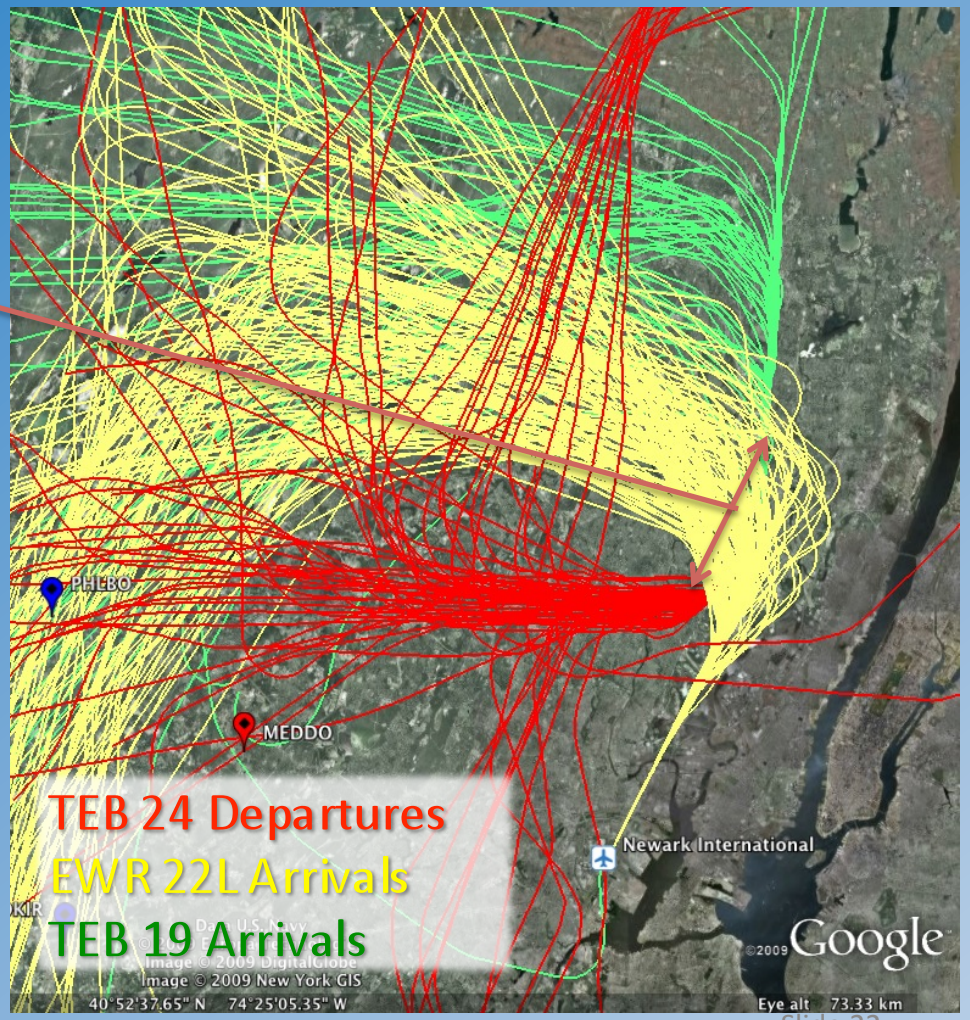


Optimize Use of Airspace

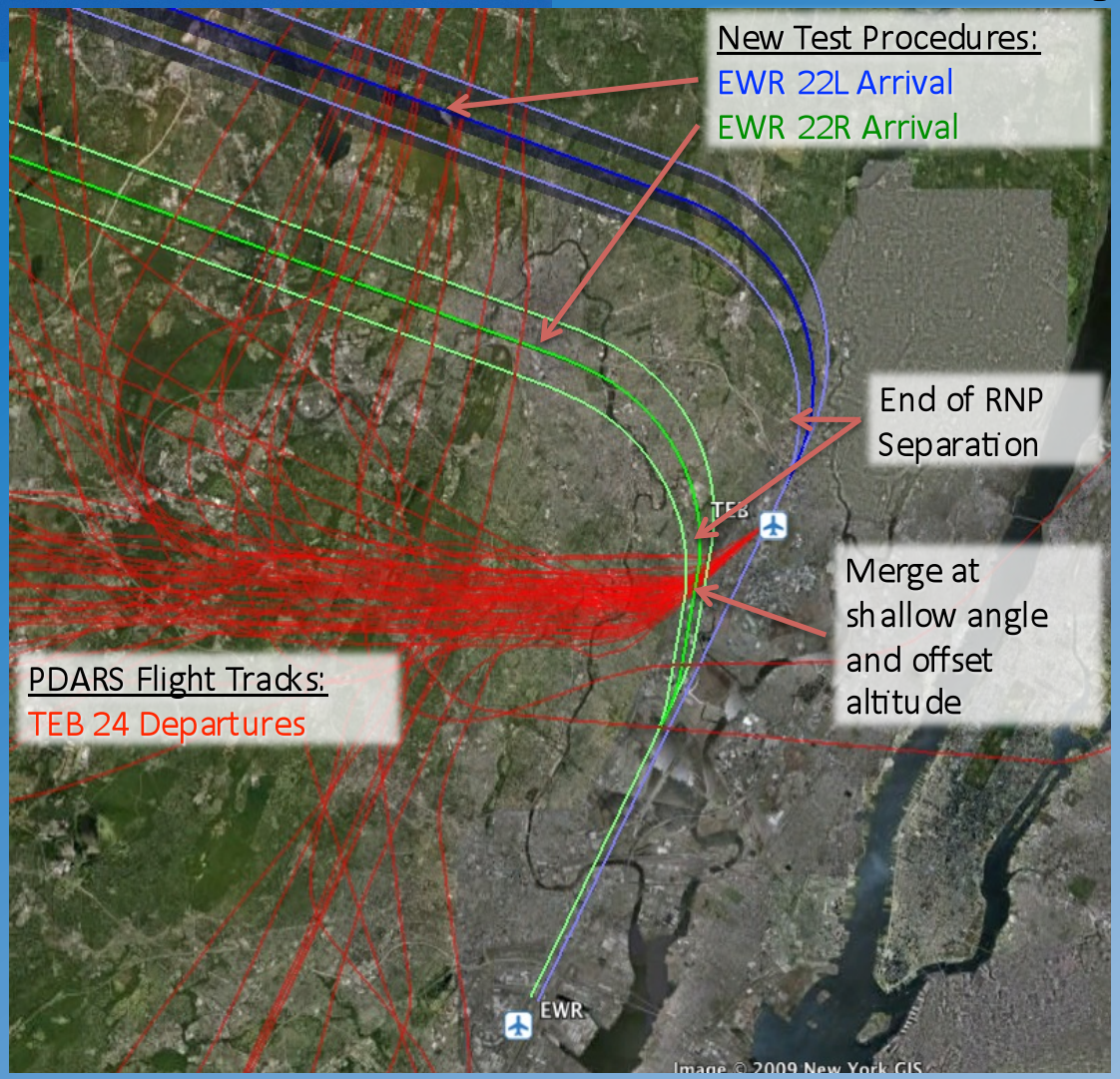
Source: Federal Aviation Administration

EWR 22 Approach Constraint

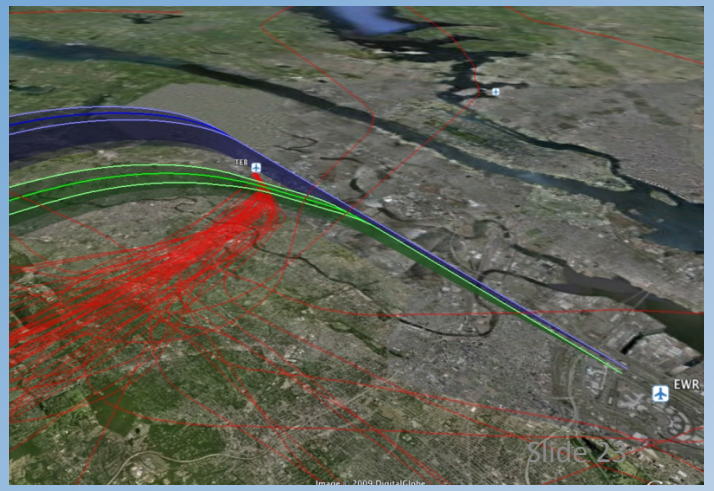
- TEB 24 departures currently prevent use of EWR 22R for arrivals
- Arrivals to EWR 22L must cross TEB and maintain safe separation from TEB 19 & 24 arrivals and departures.



Potential NextGen EWR 22 Approach

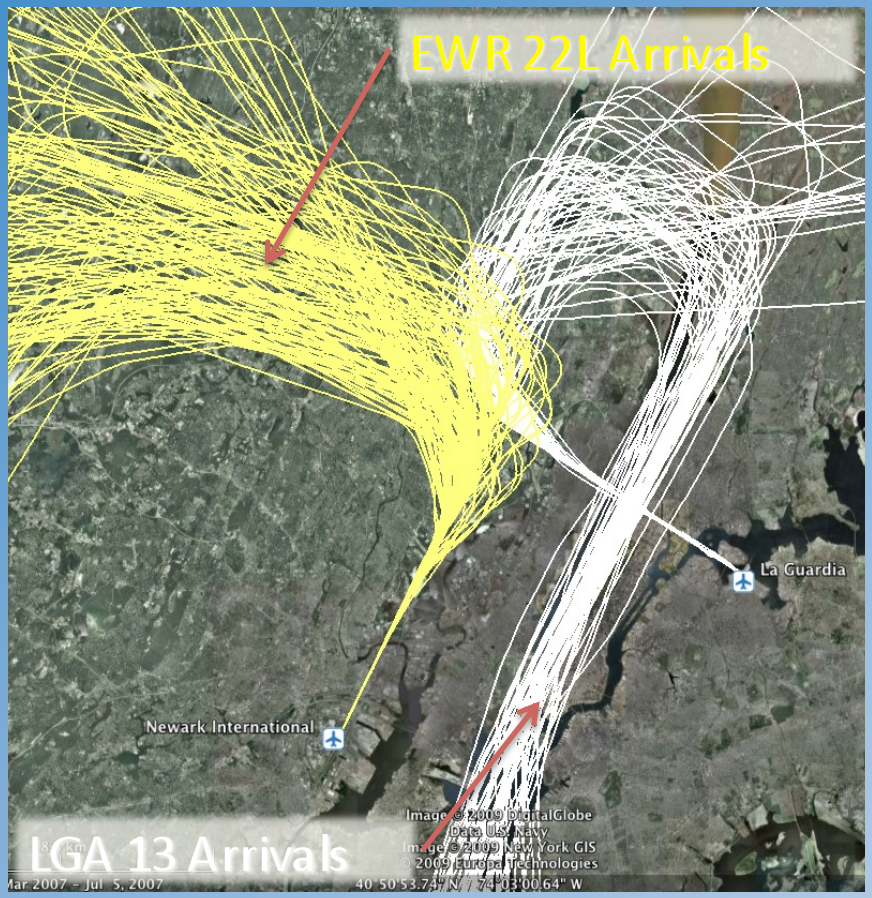


- Assume tight RNP (0.3 shown) is available
- Use current 22L maneuvering space for new 22R turn & merge



LGA-EWR Approach Interaction

- An OPD to EWR 22s would conflict with an OPD to LGA
- More direct RNP approaches to LGA could remove the OPD conflict and simplify the traffic flows



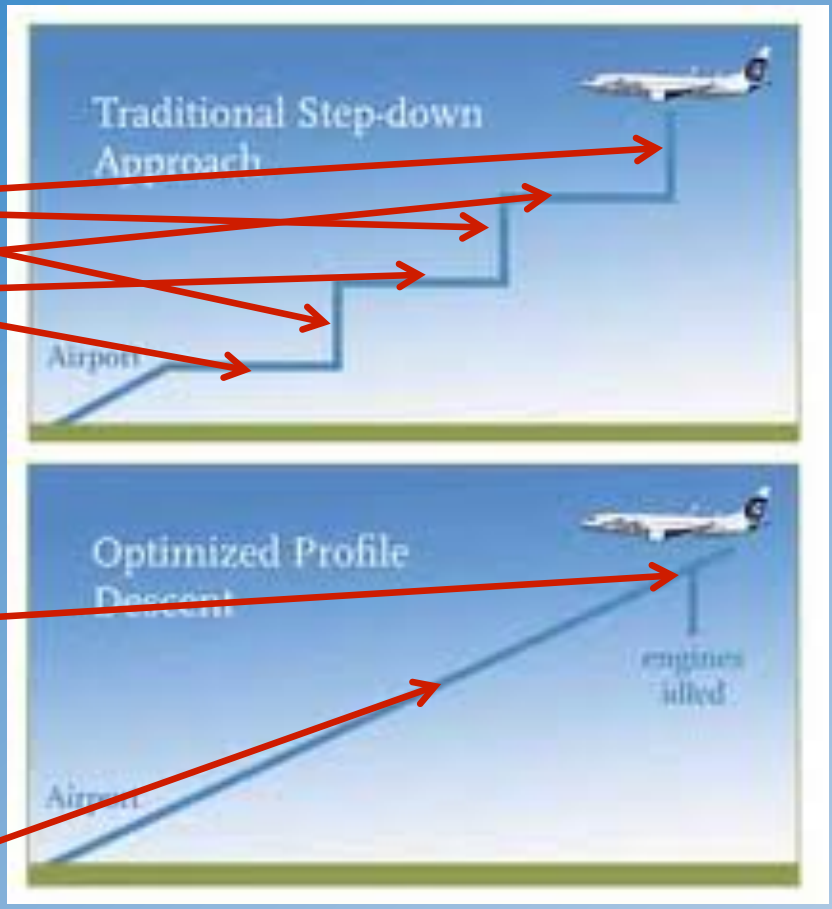
LGA-EWR Arrival-Arrival Interaction

Precision navigation may permit unusual interaction geometries in NextGen, such as:

- Simultaneously maneuvering arrivals
- Parallel opposite direction arrival flows

Optimized Profile Descents (OPD)

- Benefits:
  - Reduced fuel consumption
  - Reduced emissions
  - Reduced noise
  - Reduced controller workload
- Requirements:
  - Navigation precision
  - Predictability
  - Pilot responsibility



Radio activity: controller tells pilot new altitude and heading to adopt

Fuel burn: Aircraft must increase throttle to maintain level trajectory

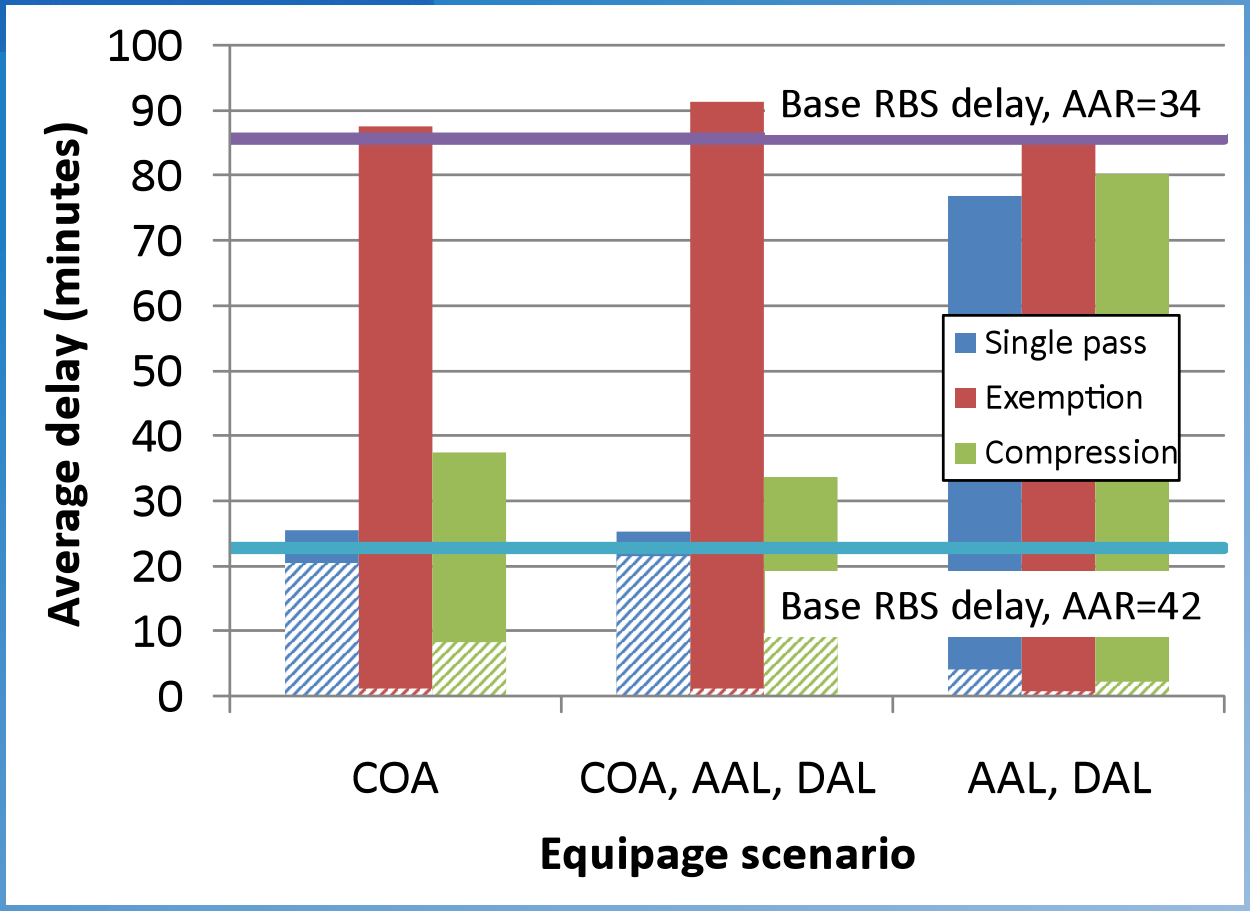
Radio activity: controller tells pilot to follow an OPD from Top-of-Descent

Aircraft descends with engines idled, pilot has no need to communicate with controller

Automatic Dependent Surveillance-Broadcast (ADS-B)

- Intended to replace radar as the primary surveillance mechanism for controlling aircraft worldwide
- On-board location (certified high-integrity GPS)
- Transmission from the aircraft (ADS-B out)
- ADS-B ground stations
- Reception at the aircraft (ADS-B in)
  - Traffic (altitude, heading, speed)
  - Weather reports and weather radar
  - Terrain
  - Flight information: Temporary Flight Restrictions (TFRs) and Notices to Airmen (NOTAMs)

BEBS Results at Newark



Churchill, Ball, Donaldson, Hansman. *Integrating best-equipped best-served principles in ground delay programs*. 9th USA/Europe Air Traffic Management Research & Development Seminar, Berlin, Germany, 2011.

Comparison of aggregate mean delays across methods and equipage scenarios for equipped and unequipped ***flights***

Questions

?