Mixed Equipage Estimates in NAS Performance

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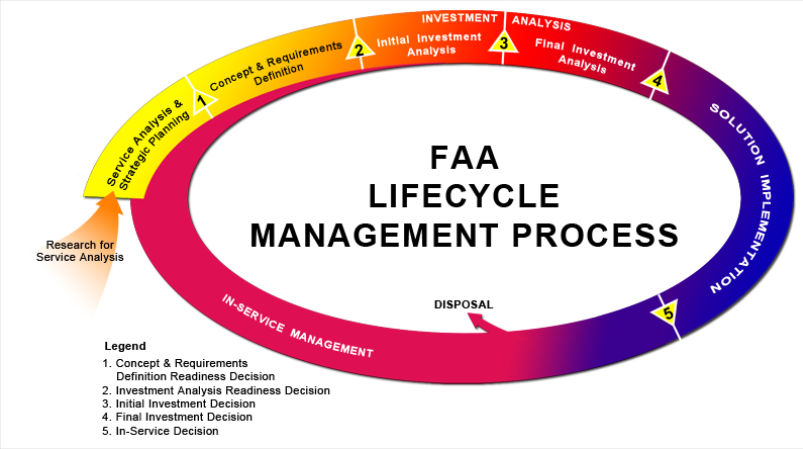
August 13, 2015

Outline

- Background
- MITRE Avionics Equipage Initiative
- FAA System-Wide Modeling
- NextGen Business Case

Background – FAA Planning

- NextGen Organization Responsibilities
  - Early lifecycle cost-benefit analysis
  - Portfolio trade studies
  - Enterprise modeling and analysis
  - Enterprise risk analysis
- Program Management Office (PMO) Responsibilities
  - Detailed program cost-benefit analysis
  - Program trade studies
  - Program modeling and Analysis
  - Program risk analysis



MITRE Avionics Equipage Initiative

- Primary source of fleet equipage data for NextGen analyses
- Data on current levels of Part 121 fleet equipage by capability
- Ad hoc assessments of current and forecast equipage by specific capability, location, or sub-fleet
- Cost estimating capability
  - Estimates of the cost to bring the existing Part 121 fleet up to X% equipped for any combination of capabilities

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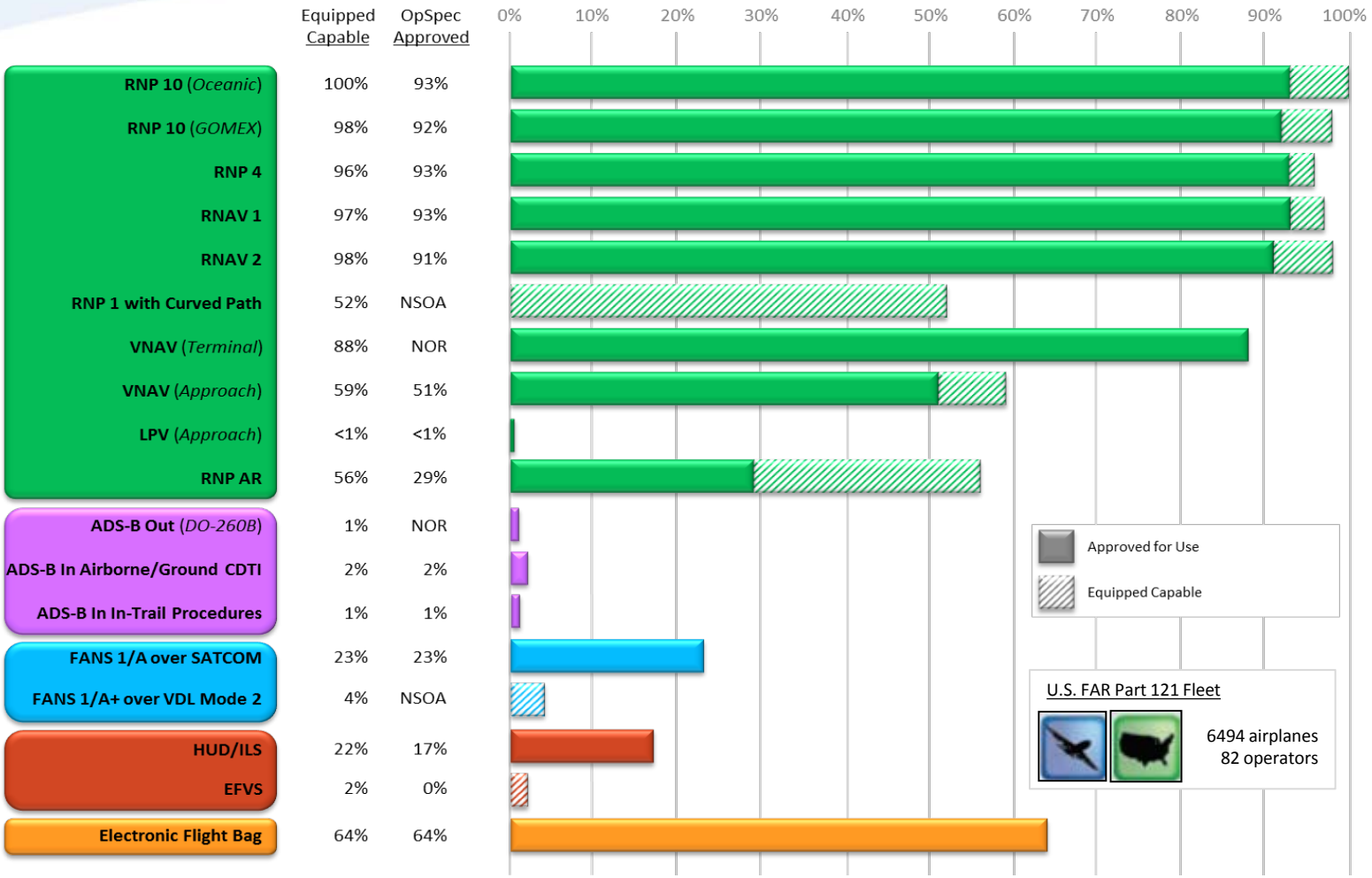
MITRE's Equipage Database

- MITRE CAASD has developed a detailed database of equipage by airframe
- By working with individual air carriers, MITRE estimates exactly what avionics are on each aircraft
  - This level of detail is important. The specific equipment that an aircraft has on board determines the cost and feasibility of upgrading
- FAA's Systems Analysis & Modeling Division uses this information for modeling the benefits of those operational improvements which depend on equipage, e.g.,
  - RNAV and RNP procedures
  - Lower RVR minima
  - Clearance delivery via Data Comm
  - GBAS approaches

FAR Part 121 Avionics Enablers: Current Status of Equipage and Approvals



Note: "OpSpec Approved" based on issuance of Operations Specification
"NSOA" (No Specific Ops Approval Available) indicates capability not covered by a specific Operations Specification
"NOR" (No Ops Approval Required) indicates capability does not require ops approval for utilization

MITRE's *avionicsCoster*

- MITRE CAASD has leveraged it's in house database to create a tool for NextGen Systems Analysis that can be used to generate the estimated forward-fit and retro-fit costs to reach a specified level of equipage
- This capability is particularly useful to ANG, as it does not double-count the cost of duplicate equipment
- For example, if a particular aircraft would require the same FMS upgrade for both RNP and Advanced Interval Management, the cost of this upgrade would only be counted once for such a bundle
- This will be the first year that we will utilize the avionicsCoster for our NextGen Business Case, and it is going to make our cost estimates more realistic, and lower than in the past

System-Wide Analysis Capability

- FAA's fast-time NAS-wide model
  - Builds upon and replaces National Airspace System Performance Analysis Capability (NASPAC)
  - Discrete-event queuing model
  - Can be stopped and restarted, allowing dynamic responses
    - Re-routing
    - Traffic Flow Management (TFM)
- Improved demand and trajectory generation approach
- Aircraft equipage aware
- Completely new software
  - Fortran, C, Pascal, SIMSCRIPT II.5 → Java
  - Sun Solaris → Linux
    - Platform independence
  - Multi-processing architecture

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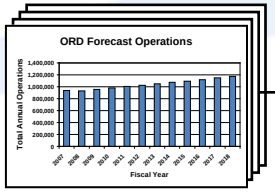
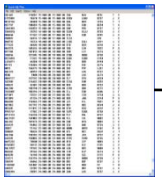
SWAC Functional Diagram

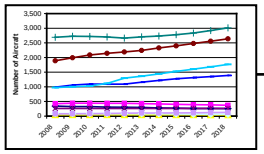
Operations Forecast



ETMS Data

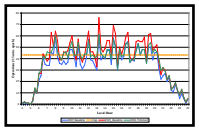


Fleet Forecast



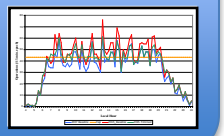
Future Schedule Generator

Unconstrained Schedules

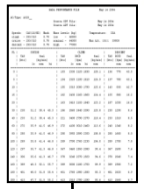


Industry/ Regulator Response

Constrained Schedules

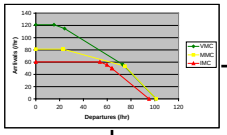


Aircraft Performance



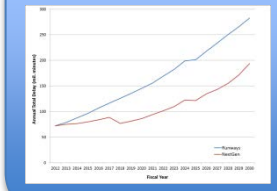
Trajectory Model

Airport Capacities

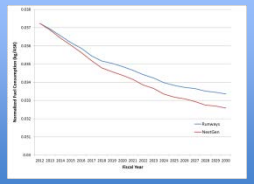


Queuing Model

Delay

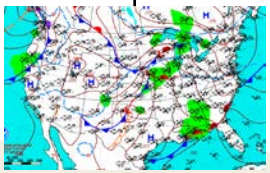


Fuel



Sector Capacities

Weather



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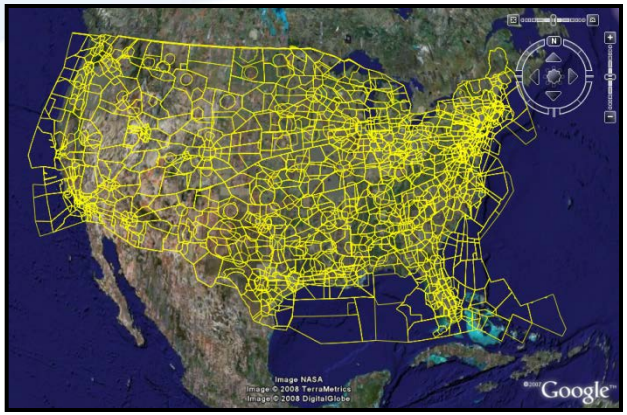
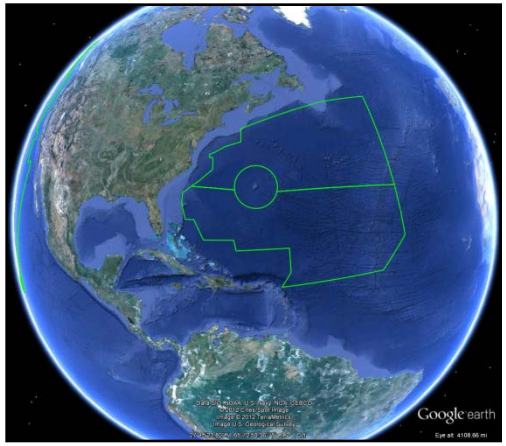
NAS Resources Represented by SWAC

Domestic Airspace



Airports (including Surface)

Oceanic Airspace



Arrival/Departure Fixes & Restrictions

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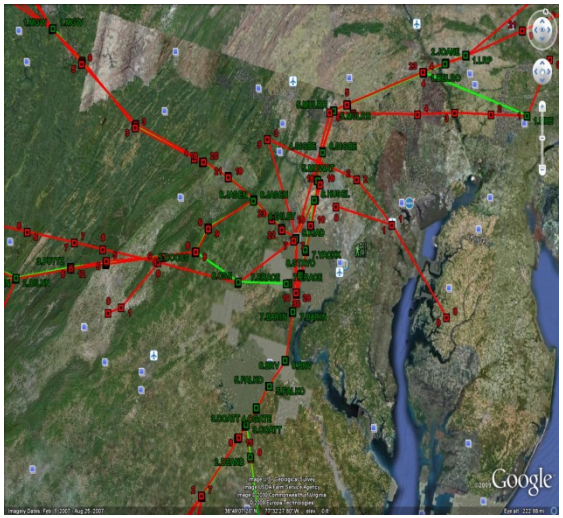
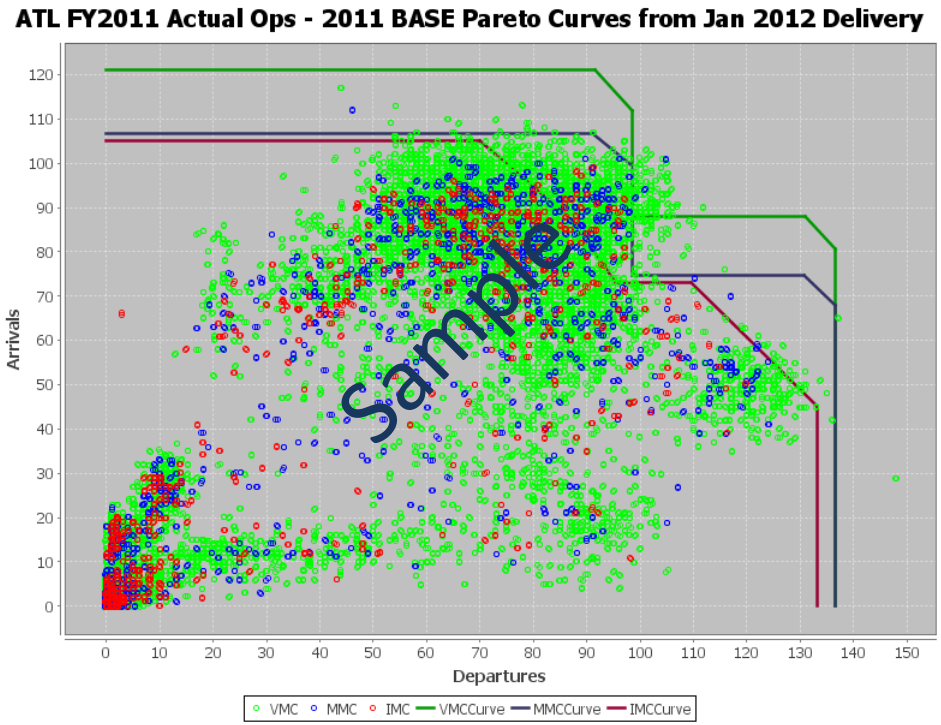
Aircraft Trajectory Representation

- Waypoints / cruise alt.
  - Traffic Flow Management System (TFMS) flight plan
- Arrival/departure procedures
  - SIDs/STARs appended to trajectories for specified airports
  - Approach Procedures also appended
  - Includes altitude restrictions
  - Aircraft type/equipage can be used
- Weather data
  - NCEP/NCAR Global Reanalysis Model
  - METAR surface weather observations
- Aircraft performance
  - Eurocontrol BADA 3.11+
  - 4D trajectory computed at 1 min. intervals



Airport Capacity Pareto Curves

- Produced using MITRE's *runwaySimulator* model for 58 airports
- Represent maximum sustainable arrival-departure combinations
- Adjusted for:
  - Anticipated NextGen improvements
  - Anticipated runway extensions and additions
  - Meteorological conditions
- Curves created for all years out to FY25 and beyond
- An additional 252 airport capacities included without NextGen improvements



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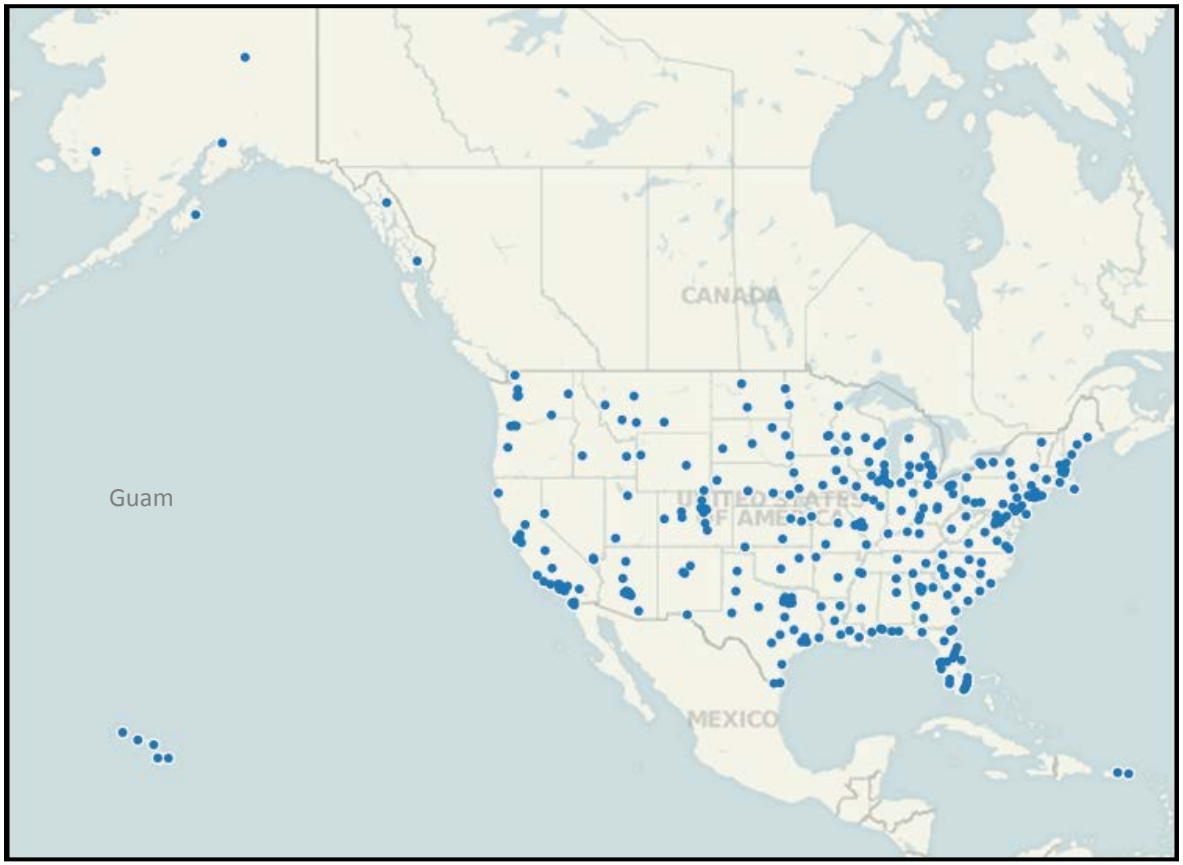
SWAC Airports

- All IFR operations are modeled
- Currently 310 airports are represented with capacity curves



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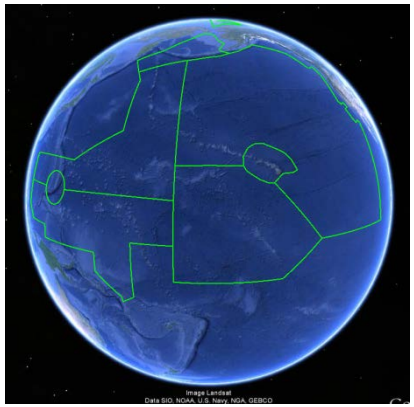
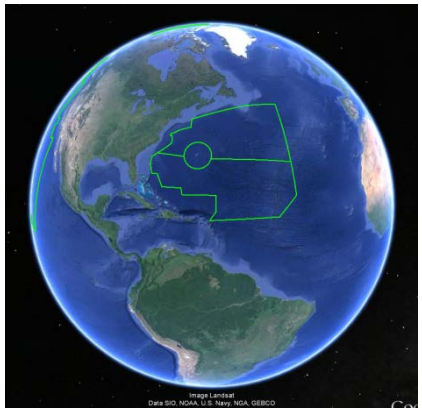
Oceanic Modeling

SWAC represents two oceanic effects: *in trail spacing* and *step climb blocking*

- In trail (i.e., longitudinal) spacing is imposed at entry to oceanic airspace
  - Restrictions are 60 nmi in length, 1,000 ft. in height
  - Restrictions are sensitive to aircraft equipage (spacing can vary)
  - Approx. 31,000 restrictions are currently being used
- Step climbs requested in oceanic airspace as demanded by flight performance model
  - A probabilistic model is used to determine if climb is conflict free
    - Probability determined by traffic density and separation standard
  - A blocked flight is forced to fly at suboptimal altitude until that flight can “try again” to request a climb





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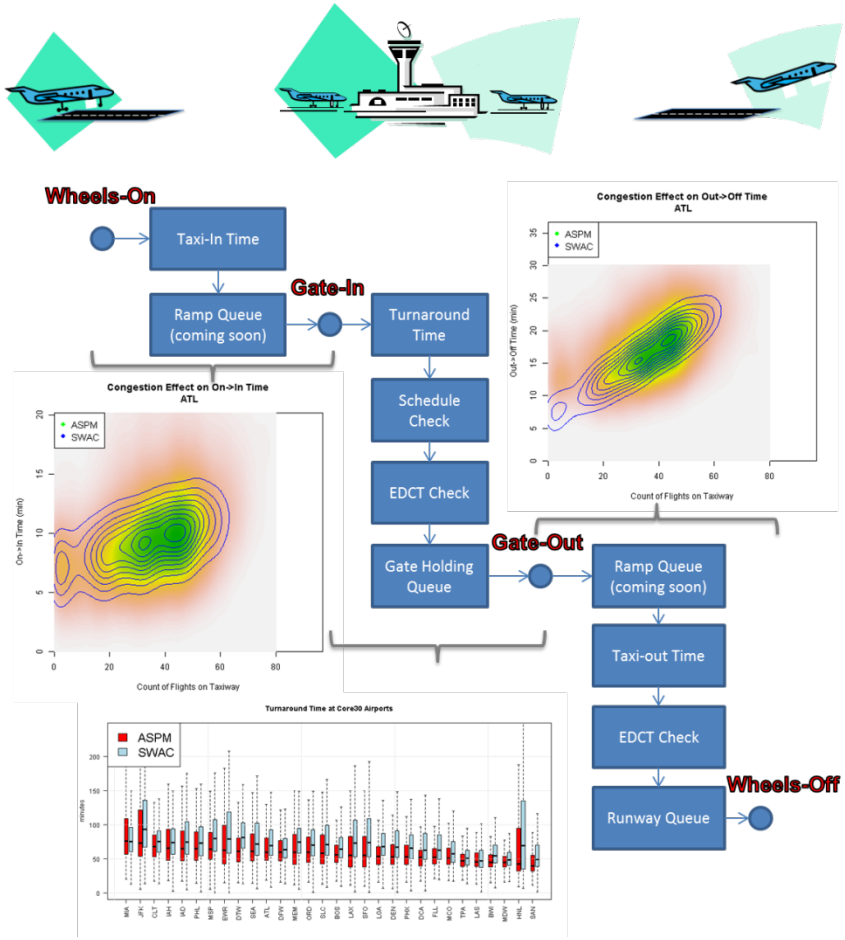
Surface Modeling

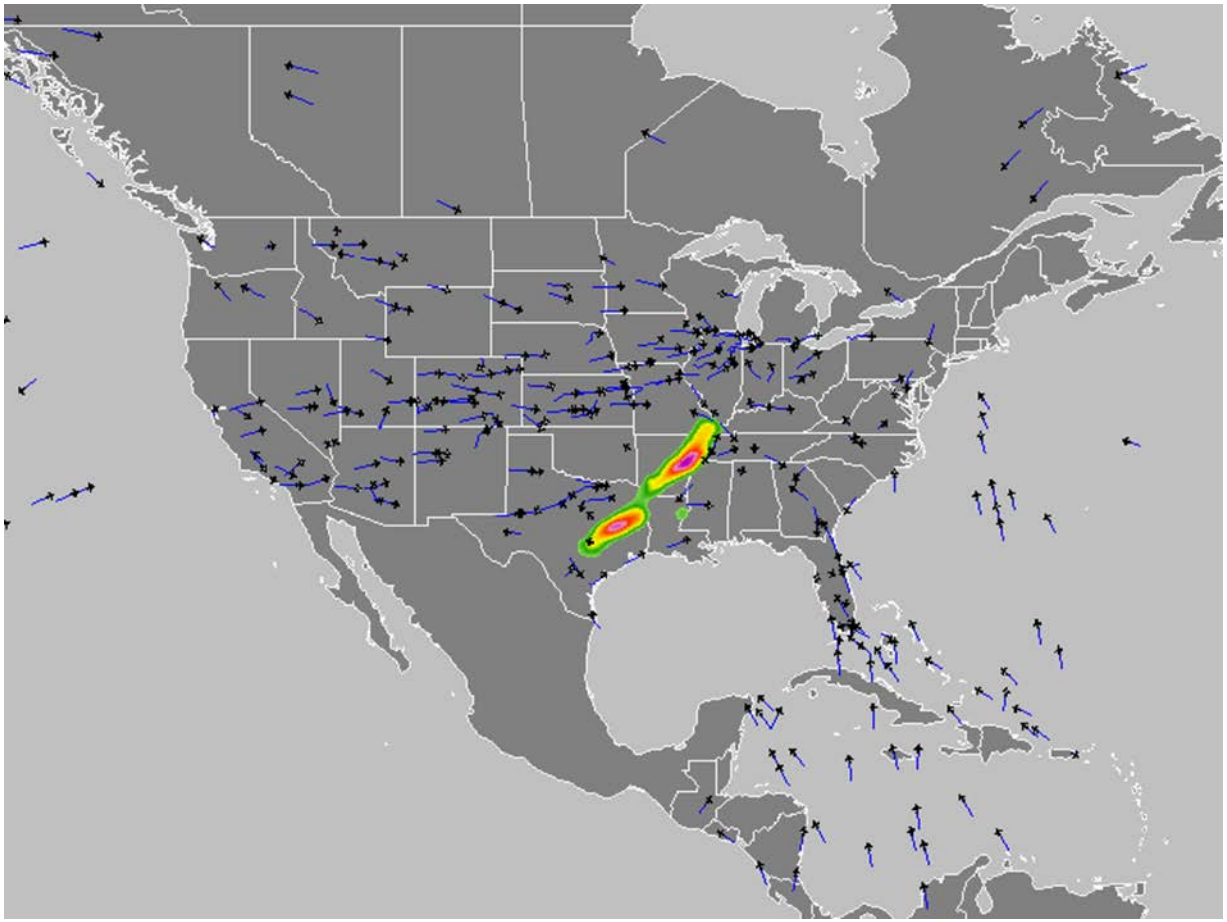
Surface operations are represented by a sequence of queues and transits:

- Taxi-In queues
  - Airport-specific congestion-based taxi-in times
  - Ramp queues (coming soon)
- At Gate queues
  - Airport, aircraft type, and airline-specific turnaround times
  - Queues to check adherence to scheduled times and EDCT
  - Gate holding queue for Departure Flow Management
- Taxi-Out queues
  - Ramp queues (coming soon)
  - Airport-specific congestion-based taxi-in times
  - Queue to check adherence to EDCT
  - Queue at runway for take-off



Rerouting

- Two-dimensional re-routing to avoid weather polygons, Special Activity Airspace (SAA), or regions of system outages
- User specifies
  - Polygons
  - Active times
  - Look-ahead times



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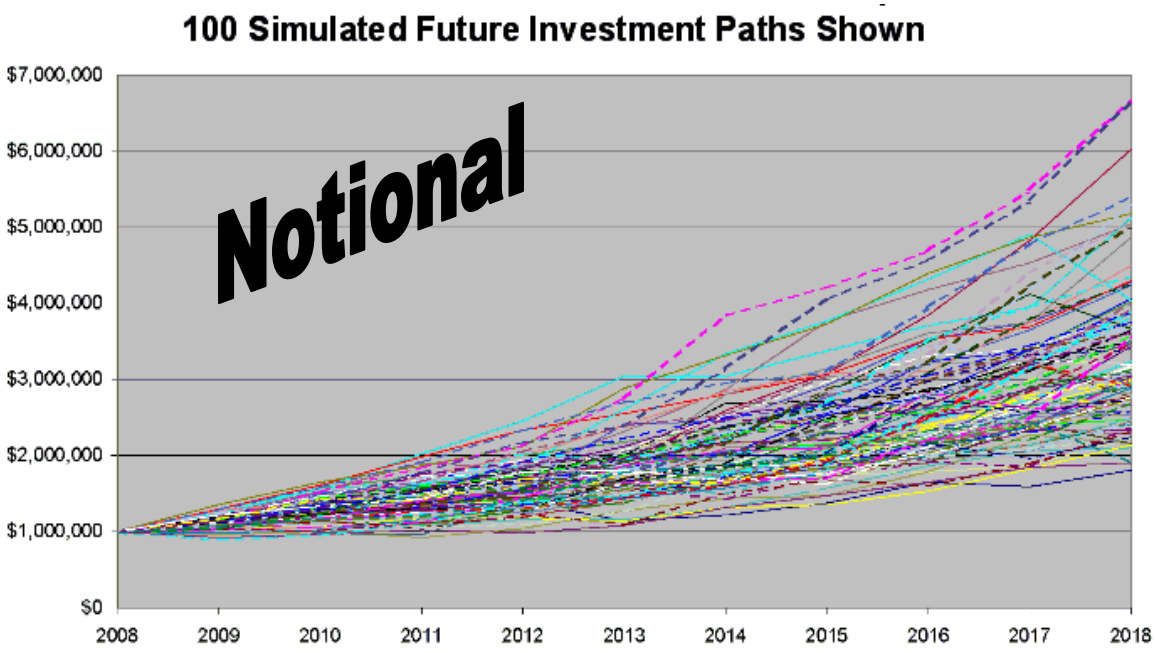
Monte Carlo Capability

- System-wide models traditionally have produced point estimates
- SWAC now allows randomization of select input parameters
- Select output variables can be aggregated across an arbitrary number of model replications, yielding interval estimates



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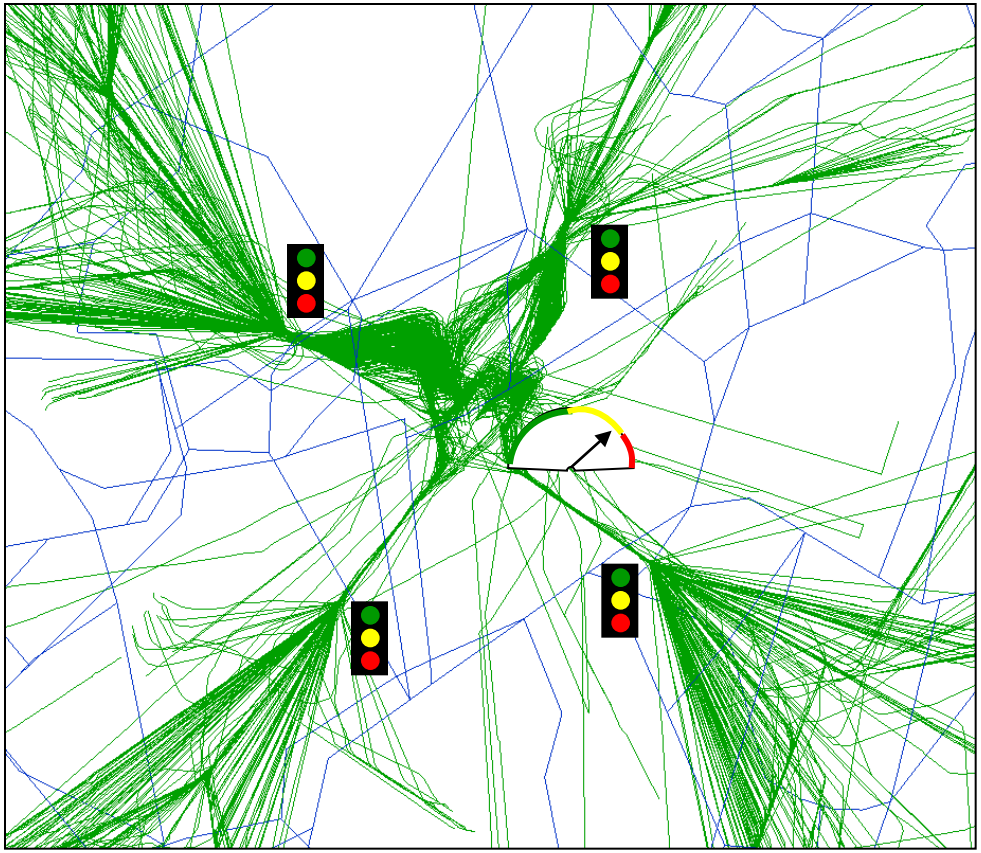
Terminal Congestion Management

- Traffic now metered to TRACON based on arrival queue length
- User specifies queue length to start and stop metering



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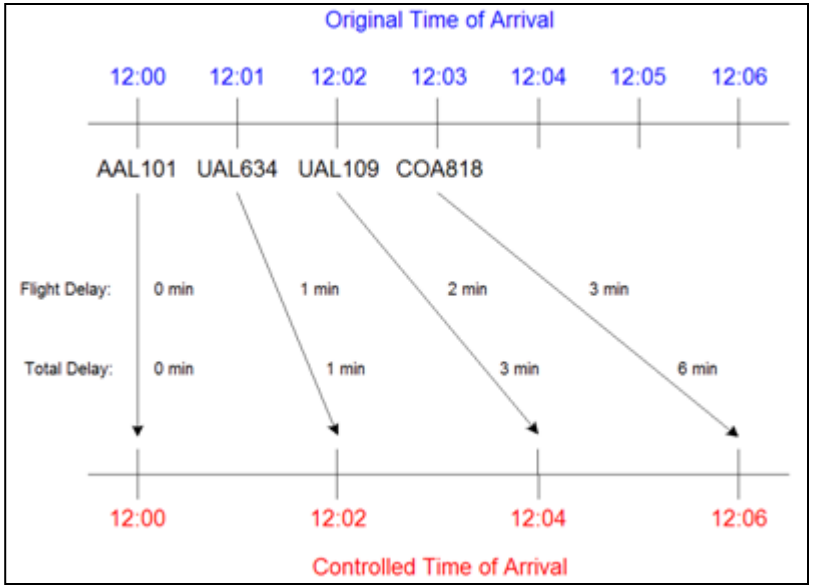
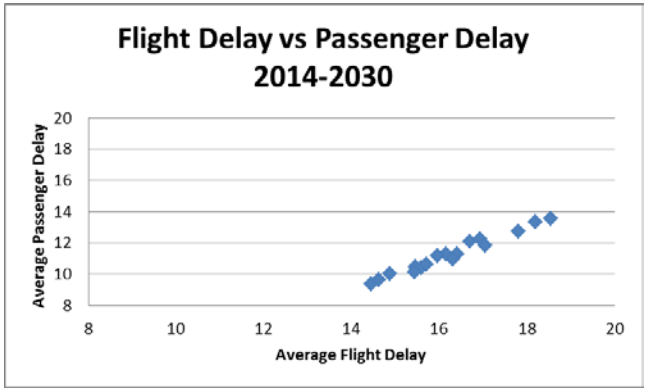
Ground Delay Program (GDP) Generator

- Module imposes GDPs and assigns expected departure clearance times
  - Weather dependent airport capacities
  - Ration By Schedule (RBS)
    - Distance-based exemptions
    - International exemptions
- Airport specific GDP triggers
  - Max flight delay
  - Max queue length
- Dynamic framework
  - GDP slot assignments revised based on simulation state
  - User-specified update interval



Passenger Flow Model

- Passenger Origin/Destination demand taken from DoT DB1B data
- Passengers fit onto SWAC flights to satisfy O/D demand
  - Direct flights preferred
  - Itineraries with one transfer possible
- Based on flight leg delay, passengers may miss connections
  - Re-booked to final destination if possible; if not, counted as “stranded”
- Passenger delay calculated relative to arrival time of original passenger itinerary
  - Not just delay of individual flight legs



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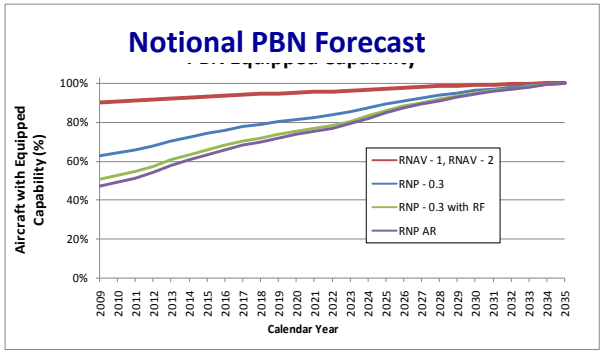
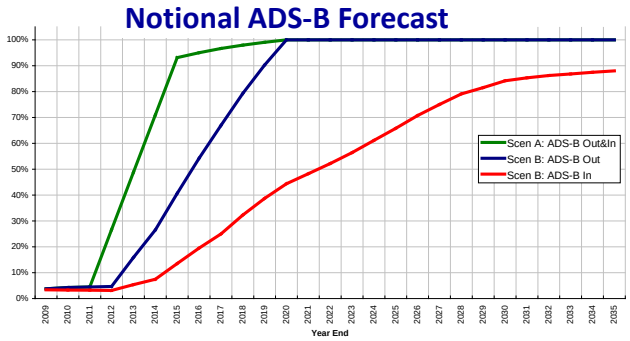
Avionics Equipage Sensitivity

- Comm/NAV/Surveillance capabilities can be assigned to specific aircraft, e.g.,
  - DataComm
  - ADS-B In and Out
  - PBN: RNAV and RNP
  - Category II/III ILS
  - EVS/SVS
- Future fleet equipage may be scheduled
  - User-specified forecast
- Various simulation elements may be varied based on equipage
  - Airport capacities
  - Sector capacities
  - Flight paths
  - Cruise altitudes
  - Airspace restriction intervals





NextGen Business Case
SWAC Experiment Design

Two scenarios examined:

1. "Runways" Scenario
   - New runways, runway extensions, and airport configurations included as they are projected to occur

2. “NextGen” ≡ Runways + ATM Improvements
   - New runways, runway extensions, and airport configurations included as they are projected to occur
   - NextGen technologies and procedures also included

The difference between these two scenarios represents the "benefit" of NextGen

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Sample Day Selection

- 16 sample days selected by the Office of Performance Analysis to represent the year for fast-time modeling purposes
- Optimization technique (mixed integer program) used to select days in order to minimize the weighted difference for defined metrics between the true population and the sample
  - Metrics include total delay, IMC delay, and operations counts at Core 30 airports; operations counts and flight durations at 20 ARTCCs.
- Updated annually

Traffic Growth

- Future traffic assumptions based on FAA Terminal Area Forecast (TAF) and international traffic forecast
- Fratar algorithm used to convert airport-level operations forecasts (from TAF) to origin-destination forecasts
- Flight plans from 16 sample days randomly chosen to create specific flight itineraries
  - Departure times varied randomly (within specified limits)
- Attributes of flight objects representing avionics then assigned according to forecast details

Operational Improvements Modeled in SWAC

Automation Support for Separation Management
A: Implement TMA at Additional Airports (104115-12)
A: Extended Metering (104120-11)
A: Use RNAV Data to Calculate Trajectories (104123-11)
A: Ground-Based Interval Management (104123-12)
B: Interval Management – Cruise (102118-21)
B: Meet TBFM Constraints Using RTA Capability (104120-22)
B: Time-Based Metering in the Terminal Environment (104128-24)
Improved Multiple Runway Operations
A: Wake Turbulence Mitigation for Departures (102140)
A: 7110.308 Procedure (102141-11)
A: Wake Turbulence Mitigation for Arrivals - Procedure (102144-11)
A: Independent Runway Separation Standards (102141-13)
A: Dependent Runway Separation Standards (102141-14)
B: Paired Approaches for Runways Spaced Less Than 2,500 ft. CAT I (102141-21)
B: Paired Approaches for Runways Spaced Less Than 2,500 ft. CAT II (102141-25)
B: Wake Turbulence Mitigation for Arrivals – System (102144-21)
Improved Approaches and Low-Visibility Ops
A: Initial Tailored Arrivals (104124-11)
A: Optimized Profile Descents (104124-12)
A: GBAS Category I (107107-11)
A: EFVS to 100 ft. (107117-11)
A: EFVS to Touchdown (107118-11)

Performance-Based Navigation
A: RNAV SIDs/STARs (107103-13)
A: OAPM (108209-12)
A: Transition to PBN Routing for Cruise Operations (108209-14)
B: Speed Advisory Support for Merging Aircraft on RNAV Procedures (108209-15)
B: Improved Arrival and Departure Management: Airspace Enhancements (104122-23)
Separation Management
A: Wake Re-Categorization Phase I (102154-11)
A: ADS-B Separation (102123)
B: Initial Conflict Resolution Advisories (102114)
B: Automation Support for Separation Management (102137)
B: Space-Based ADS-B (102137-33)
B: Expanded Use of 3 nmi Separation in Transition Airspace (104122-21)
B: Wake Re-Categorization Phase II (102154-21)
B: Interval Management – Defined Interval (102148-01)
Surface
A: Initial Surface Management System (104209-17)
B: Remote Operations at Non-Towered Airports (102153-02)
CATM
B: Flexible Airspace Management (108206)
NAS Infrastructure
B: Initial En Route DataComm Services

Note that not all increments of the indicated operational improvements have been modeled, and in some cases like operational improvements have been combined for modeling purposes.

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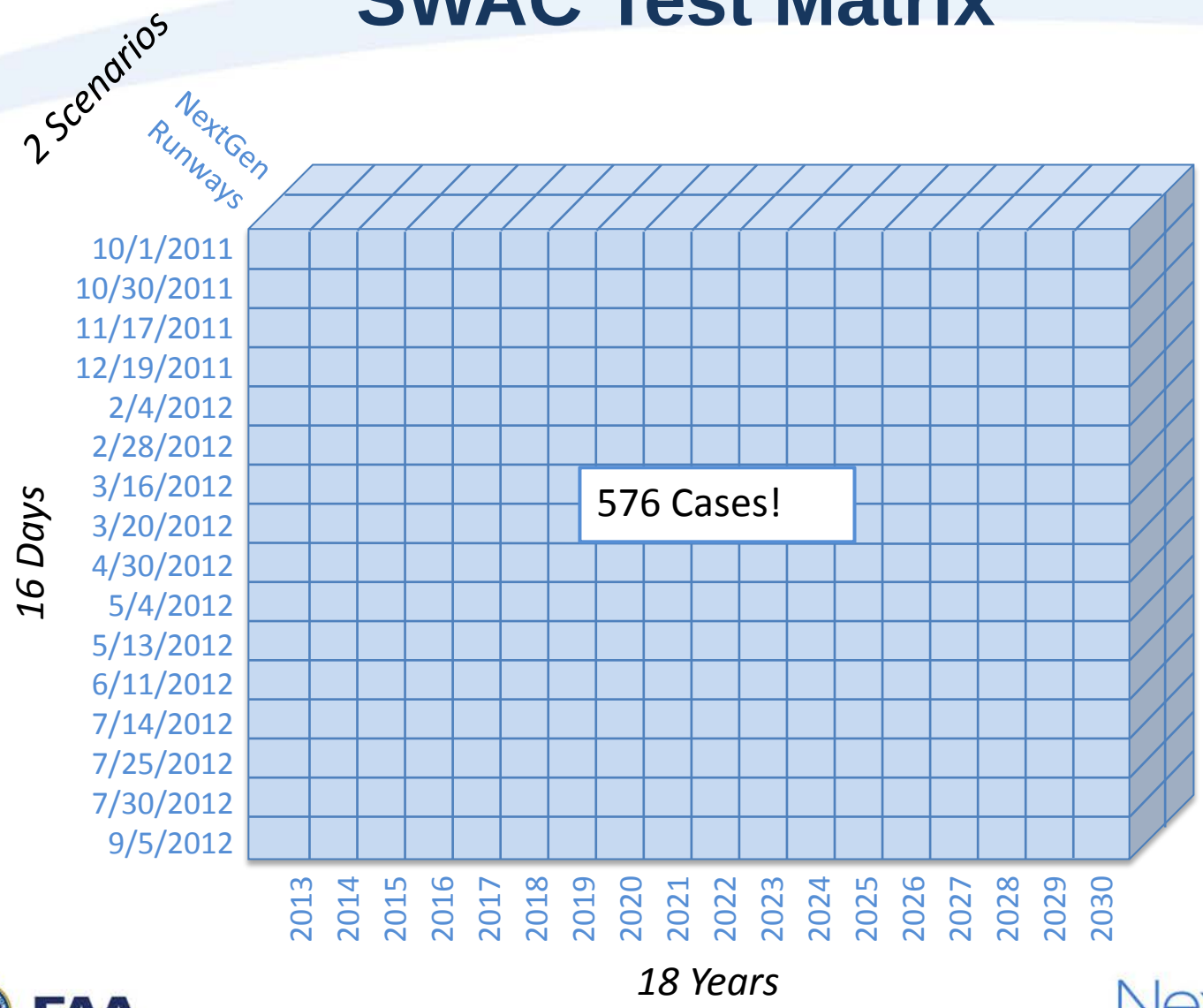
SWAC Test Matrix



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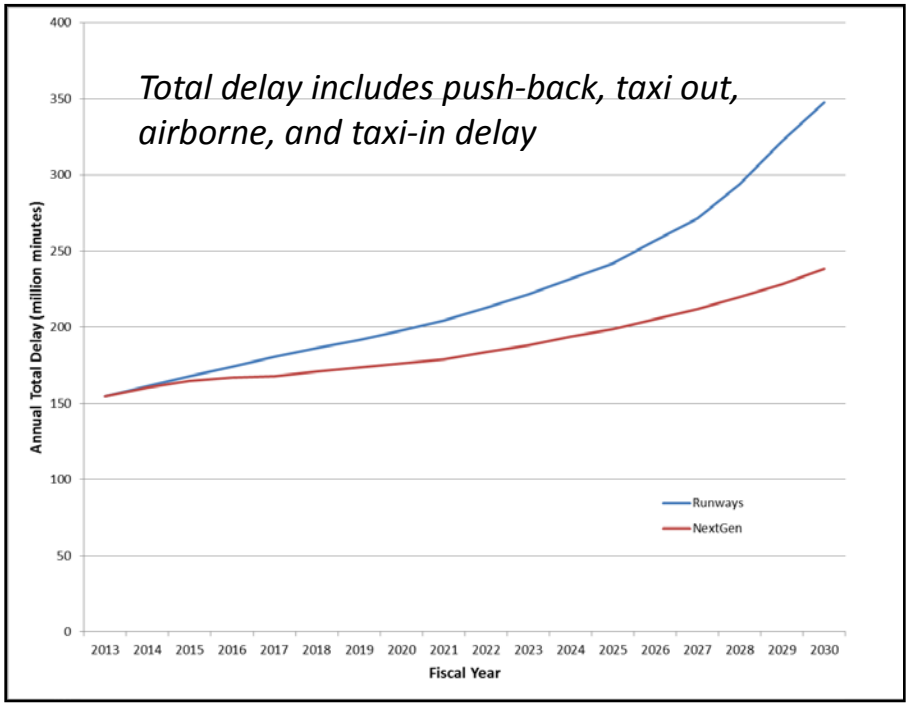
Output Metrics

SWAC output metrics include total IFR flights, flight segment delay (gate, surface, airborne), cancellations, fuel burn (entire flight, U.S. airspace), passenger delay

Annual Total Flight Segment Delay



All IFR operations in U.S. Flight Information Regions (FIR)

Questions?

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