Mixed Equipage Estimates in NAS Performance

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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
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 its 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
SWAC Functional Diagram

Operations Forecast

Future Schedule Generator

Unconstrained Schedules

Constrained Schedules

Trajectory Model

Aircraft Performance

ETMS Data

Fleet Forecast

Airport Capacities

Industry/Regulator Response

Queuing Model

Delay

Fuel

Sector Capacities

Weather
NAS Resources Represented by SWAC

Domestic Airspace

Airports (including Surface)

Oceanic Airspace

Arrival/Departure Fixes & Restrictions
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
SWAC Airports

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

100 Simulated Future Investment Paths Shown

Notional
Terminal Congestion Management

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

Notional PBN Forecast

Notional ADS-B Forecast
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
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

<table>
<thead>
<tr>
<th>Automation Support for Separation Management</th>
<th>Performance-Based Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Implement TMA at Additional Airports (104115-12)</td>
<td>A: RNAV SIDs/STARs (107103-13)</td>
</tr>
<tr>
<td>A: Extended Metering (104120-11)</td>
<td>A: OAPM (108209-12)</td>
</tr>
<tr>
<td>A: Use RNAV Data to Calculate Trajectories (104123-11)</td>
<td>A: Transition to PBN Routing for Cruise Operations (108209-14)</td>
</tr>
<tr>
<td>A: Ground-Based Interval Management (104123-12)</td>
<td>B: Speed Advisory Support for Merging Aircraft on RNAV Procedures (108209-15)</td>
</tr>
<tr>
<td>B: Interval Management – Cruise (102118-21)</td>
<td>B: Improved Arrival and Departure Management: Airspace Enhancements (104122-23)</td>
</tr>
<tr>
<td>B: Meet TBFM Constraints Using RTA Capability (104120-22)</td>
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<tr>
<td>B: Time-Based Metering in the Terminal Environment (104128-24)</td>
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### Improved Multiple Runway Operations

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<tr>
<td>A: Wake Turbulence Mitigation for Departures (102140)</td>
<td>B: Initial Conflict Resolution Advisories (102114)</td>
</tr>
<tr>
<td>A: 7110.308 Procedure (102141-11)</td>
<td>B: Automation Support for Separation Management (102137)</td>
</tr>
<tr>
<td>A: Wake Turbulence Mitigation for Arrivals - Procedure (102144-11)</td>
<td>B: Space-Based ADS-B (102137-33)</td>
</tr>
<tr>
<td>A: Dependent Runway Separation Standards (102141-14)</td>
<td>B: Wake Re-Categorization Phase II (102154-21)</td>
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<tr>
<td>B: Paired Approaches for Runways Spaced Less Than 2,500 ft. CAT I (102141-21)</td>
<td>B: Interval Management – Defined Interval (102148-01)</td>
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<td>B: Paired Approaches for Runways Spaced Less Than 2,500 ft. CAT II (102141-25)</td>
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<tr>
<td>B: Wake Turbulence Mitigation for Arrivals – System (102144-21)</td>
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### Improved Approaches and Low-Visibility Ops

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<tr>
<td>A: Initial Tailored Arrivals (104124-11)</td>
<td>B: Remote Operations at Non-Towered Airports (102153-02)</td>
</tr>
<tr>
<td>A: Optimized Profile Descents (104124-12)</td>
<td>CATM</td>
</tr>
<tr>
<td>A: GBAS Category I (107107-11)</td>
<td>B: Flexible Airspace Management (108206)</td>
</tr>
<tr>
<td>A: EFVS to 100 ft. (107117-11)</td>
<td>NAS Infrastructure</td>
</tr>
<tr>
<td>A: EFVS to Touchdown (107118-11)</td>
<td>B: Initial En Route DataComm Services</td>
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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.
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**

Total delay includes push-back, taxi out, airborne, and taxi-in delay

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

NextGEN

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