Fast-Time Modeling at the Federal Aviation Administration

Joseph Post, Office of NAS systems Engineering & Integration
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Essentially, all models are wrong, but some are useful.

George E. P. Box and Norman R. Draper, 
Uses of Fast-Time Models at FAA

• Air Traffic Management
  ✦ Cost/Benefit Analysis
    • Capital investments
    • Rulemaking
  ✦ Concept of Operations Evaluation
  ✦ Alternatives Analysis

• Airports
  ✦ Capacity Analysis
    • Runway and taxi-way closures, new construction
    • Revised procedures (e.g., LAX)
    • Slot Analysis

• Environmental Analysis
  ✦ Noise
  ✦ Emissions (CO$_2$, SO$_X$, NO$_X$, particulates)
  ✦ Fuel Burn
FAA’s Principal Fast-Time Models

System-Wide Analysis Capability (SWAC)

Global Oceanic Model (GOM)

Airfield Delay Simulation Model (ADSIM+)

Aviation Environmental Design Tool (AEDT)

AirTOp
System-Wide Analysis Capability

- FAA's fast-time NAS-wide model
- Discrete-event queuing model
- Integrated demand and trajectory generation
- Platform independent
- Multi-processing architecture
NAS Resources Represented by SWAC

- Domestic Airspace
- Oceanic Airspace
- Airports
- Arrival/Departure Fixes & Restrictions
Aircraft Trajectory Representation

- Waypoints / cruise alt.
  - Traffic Flow Management System (TFMS) flight plan
  - Historical final cruise altitude data (TFMS TZ)

- 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
  - LAMP En Route convection forecast
  - METAR surface weather observations
  - TAF surface weather forecasts

- Aircraft performance
  - Eurocontrol BADA 3.12+
  - 4D trajectory computed at 5 nmi intervals
**Airport Capacity Pareto Curves**

- Represent maximum sustainable arrival-departure combinations at 310 airports
- Adjusted for:
  - Anticipated NextGen improvements
  - Anticipated runway extensions and additions
  - Meteorological conditions (e.g., VMC, IMC)
- Curves created for all years out to 2025 and beyond
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
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. 6,400 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

The surface model is a sequence of queues and transits:

- **Taxi-In queues**
  - Airport-specific congestion-based taxi-in times
  - Ramp queues

- **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
  - Airport-specific congestion-based taxi-in times
  - Queue to check adherence to EDCT
  - Queue at runway for take-off
Traffic Flow Management (TFM)

- **Strategic TFM**
  - Ground Delay Program (GDP) generator
    - Imposes GDPs and assigns Expected Departure Clearance Times (EDCTs)
    - Weather-dependent airport capacities
    - Ration By Schedule (RBS)
      - Distance-based exemptions
      - International exemptions
  - Traffic Flow Management System (TFMS) generator
    - Imposes EDCTs based on excessive predicted airborne delay
  - Dynamic framework
    - TFM slot assignments revised based on simulation state
    - User-specified update interval
  - Excessive EDCT delay may result in flight cancellations

- **Tactical TFM**
  - Traffic metered to terminal airspace based on arrival queue length
  - User specifies queue length to start and stop metering
Virginia Tech **Global Oceanic Model (GOM)**

- FAA has partnered with Virginia Tech to develop a mathematical model of oceanic operations
- Broadly applicable to oceanic airspace
- Implemented using *Matlab*, compiled for Windows OS
- Implements Eurocontrol BADA aircraft performance model
  - Individual aircraft are flown from origin to destination along specified flight paths
  - Aircraft request climbs as fuel is burned off
- Pair-wise separation minima are enforced for specified oceanic airspace
  - “Strategic” conflict resolution prior to entering oceanic airspace
  - “Tactical” conflict resolution within oceanic airspace
- Current uses:
  - U.S. Advanced Surveillance Advanced Procedural Separation (ASEPS) Separation cost-benefit analysis
  - ICAO North Atlantic data link mandate and Space-Based ADS-B cost-benefit analyses
  - U.S. Caribbean initiative
Global Oceanic Model

Los Angeles - Auckland

User Preferred Route (UPR)

Great Circle Route

TFMS Flight Plan Data

Airline Data (Airlines for America)

Oceanic Route Data (TFMS)

NavCanada GAATS+ Data

ZNY and Gander Oceanic Control Rules/Heuristics

BADA Model (3.13.1 and 4.0)

Flight Planning Function

Fuel and Travel Time Cost Matrices

Track Assignment Module

Conflict Detection and Resolution Module

BADA Model Implementation (Aircraft Performance)

Historical Track Data

Load Factors Takeoff Mass Distribution

Historical Flight Routes

Model Outputs

Fuel used
Travel time
Track assignment
ATC/Pilot Exchanges
Level of service

Validation of Track Level of Service

Operational Track Data (NATS UK)

42 Commercial and Corporate Aircraft Modeled

NAT Track Data (NavCanada and FAA Notams)

NextGEN

NCAR Reanalysis Module (Derives Wind Information for Model)

NCAR Reanalysis Model Data

Time-step Numerical Simulation

User Preferred Route (UPR)
Strategic and Tactical Conflict Algorithms

Tactical conflict logic checks for conflicts ahead as the aircraft approach others.

Strategic conflict logic checks for conflicts 1-2 hours ahead as the aircraft enters oceanic airspace.

Conflict resolution rules for OTS flights:
- a) Mach number control
- b) Variable headway control
- c) Climbs inside OTS

Conflict resolution rules for non-OTS flights:
- a) Change flight level
- b) Change Mach number
- c) Change route

Strategic conflict logic checks for conflicts 1-2 hours ahead as aircraft enters oceanic airspace.
OTS Track Assignment Logic

- The track assignment module assigns flights to NAT OTS and random tracks based on their relative costs compared to an optimal track selected as preferred alternative.
- Flights are assigned to a track considering competing flights requesting the same track.

Flight Plan Changes
- Necessary when a flight approaches the OTS entry point.
- Use of variable Mach number headway rules in OTS assignment.

Fuel Cost Matrix (in kilograms of fuel)
Multiple Airspace Volumes

- GOM can now represent multiple airspace volumes with different separation standards.
- This capability was recently used to study Caribbean airspace.
  - 14 FIRs were represented.
Air Traffic Optimization (AirTOp)

- **AirTOp**
  - High-fidelity
  - Agent-based
  - Gate-to-Gate

- **Simulation Capabilities**
  - EnRoute & TRACON
  - Ground Operations
  - Traffic Flow Management
    - Arrival/Departure Management
  - Conflict Resolution
  - Controller Workload

- **Developed by AirTOpsoft**
- http://airtopsoft.com/
ADSIM+ Concept of Use

- ADSIM+ is discrete-event Monte Carlo simulation capable of modeling current and future concepts of terminal area operations (including Metroplex)

- ADSIM+ has two modes of operations:
  - Delay (output is a standard set of delay statistics)
  - Airport Runway Capacity (output is a capacity envelope)

- Includes an aircraft performance model (BADA-based) to represent terminal area operations

- The user will be able to identify terminal area trajectories, assign aircraft to the trajectories, and provide separation rules
ADSIM+ Data Requirements

- Airport Layout: Runways, Taxiways, Gates, Waypoints, Routes
- Historical Configuration Distributions
- Runway Usage
  - Exit choice by aircraft type
  - Occupancy time by aircraft type and exit choice
- Taxi Paths
  - From each gate to each runway entrance
  - From each runway exit to each gate
- Fleet Makeup
- Wake Vortex Separation Rules (Aggregation Required)
- Runway Separation Rules (Aggregation Required)
- Aircraft Data
  - Aircraft Length and Wingspan
  - BADA data (for departure runway occupancy times & terminal performance)
- ATC Rules
  - Buffers
  - Dependent Separations (Wake Vortex & Runway)
Convert FAA Data Files to Model Data

AIXM Data to Airport Layout

Airfield Taxi Paths, Runway Exit Choice, and Runway Occupancy Times
Aviation Environmental Design Tool (AEDT)

Features
• Computes noise, fuel burn, emissions, and air quality
• Able to conduct analyses at airport, regional, national, and global scales
• Replaces NIRS, EDMS, SAGE, INM and MAGENTA

Applications
• Air space and airport design and planning (e.g., National Environmental Policy Act reviews)
• International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) analyses
• Assessing benefits from introducing NextGen and new aircraft and engine technologies (e.g., from FAA CLEEN and NASA Programs)

For more information on AEDT or to download it, please visit: https://aedt.faa.gov/
AEDT Modeling Process Overview
Questions?
Challenges for Modelers

Our models are generally not used to inform decisions!

Why?

- Complexity
- Responsiveness
- Openness
- Validation