Reduced Separation in US Oceanic Airspace
Benefits Analysis through Fast-Time Modeling

Presented by:
Dan Howell, Rob Dean, and Joseph Post
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The Surveillance & Broadcast Services Advanced Surveillance Enhanced Procedural Separation (SBS ASEPS) Project has been investigating the use of reduced oceanic separation to enhance operations in US oceanic airspace.

- Space-based ADS-B (SBA)
- Automatic Dependent Surveillance – Contract (ADS-C, more frequent update)

**Goal:** Increase the efficiency and capacity of operations in Oceanic Flight Information Regions (FIRs) through surveillance enhancements for reduced oceanic separation standards.

FAA has been conducting a cost-benefit analysis of increased ADS-C reporting and SBA.
Iridium NEXT Satellites

- 66 cross-linked satellites in Low Earth Orbit (LEO)
  - 11 satellites in each of 6 polar orbits
- Aireon ADS-B receiver hosted payload

SpaceX Falcon 9

<table>
<thead>
<tr>
<th>Iridium NEXT Satellite Specifications</th>
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<tbody>
<tr>
<td>Deployed Wingspan</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Stowed Dimensions</td>
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</table>
Reduced Separation in US Oceanic Airspace

*Note: ATOP in Anchorage covers Anchorage Oceanic FIR and part of Anchorage Continental FIR over the Aleutian Islands

**Map from http://gis.icao.int/flexviewer/
Benefits of Improved Oceanic Surveillance

- Improved Accommodation of altitude requests
- Improved arrival/departure services at non-radar airports
- Reduced Vertical Collision risk
- Reduced convective weather impact
- Improved accommodation of descents, routing, and speed requests
- Improved controller situational awareness
- Accurate and timely information for search and rescue
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Improved Accommodation of Altitude Requests

- Oceanic flights often long
- Strong desire to minimize fuel
- Higher altitudes generally result in higher fuel efficiency
- Aircraft frequently take off very heavy and cannot reach optimal altitude until some fuel is burned off

- Once aircraft are light enough, they often want to climb to reach a more fuel-efficient altitude
- Competition for optimal altitudes frequently occurs
My Flight (PHL-LHR June 15)

My Flight to Europe

Step Climbs and Surveillance Gap

*www.flightaware.com*
Simulation Model & Methodology

• Global Oceanic Model (GOM)
  ➢ Fast-time simulation tool developed in MATLAB for examining fuel burn and flight time in oceanic airspace
  ➢ Time-based model that simulates individual aircraft from origin to destination along specified paths
  ➢ Randomness built into model through aircraft takeoff mass and equipage levels
  ➢ Produced under partnership between FAA and Virginia Tech

Flight Schedules
• Representative Days
• Growth Assumptions for future demand

Aircraft Avionics
• ADS-B Out
• FANS (ADS-C + CPDLC)

Routes
• Historical Flight Plans
• Existing Route Structure

Altitude Request Information
• Historical Altitude Request Information
• Magnitude of altitude changes

Aircraft Performance
• BADA Performance Model
• Takeoff weight estimates

Fleet Evolution
• Carrier Fleet Forecasts
• Future aircraft types

Separation And Conflict Management Data
• Current and Future Separation Standards
• Types of resolutions used in ocean

Global Oceanic Model

Modeled Trajectories

Summary Metrics

Reduced Separation in US Oceanic Airspace
Current Oceanic Environment

• Advanced Technologies and Oceanic Procedures (ATOP) System
  ➢ Designed to reduce manual processes controllers have historically used to ensure separation
  ➢ Processes oceanic aircraft and weather data and calculates separation criteria near instantaneously
  ➢ Provides efficient track and altitude alternatives through Conflict Prediction and Reporting (CPAR)

• Mixed equipage leads to varying separation minima
  ➢ Current standards lead to high likelihood of preferred routings and altitudes, but expected increases in traffic in future will impact this

• Procedural Separation and Control
  ➢ “Control By Exception”: Procedural separation whereby controller notified of possible separation situation when there is an actual or predicted violation. Controller does not continuously monitor aircraft positions and altitudes as with tactical separation in a radar environment
  ➢ ATOP uses 2 hour lookahead for conflicts and controllers are expected to resolve conflicts that will occur 30 minutes or less in the future
FANS Equipage

- Future Air Navigation System (FANS) interfaces with ATOP and includes avionics to support Performance-Based Navigation, Data Link, and ADS-C position reporting

- FANS equipage is primary constraint of SBA-usage since ADS-B Out (required) will soon be mandated in US airspace

- Current FANS equipage levels (by aircraft type) were obtained from an analysis of flight plans provided by MITRE

- Logistics curve fitted to the percentage of Datalink equipped aircraft time trend in each ocean to specify overall equipage levels for future years

- FANS equipage randomly assigned to unequipped flights until overall target level was achieved

- Remaining unequipped flights passing through Gander, Shanwick, and Santa Maria were equipped to reflect upcoming mandate

Reduced Separation in US Oceanic Airspace
Separation Standards and Schedules

- Separation Standards for US Oceanic Airspace

<table>
<thead>
<tr>
<th>Aircraft Equipage</th>
<th>Legacy Case</th>
<th>More Frequent ADS-C</th>
<th>SBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>FANS via SATCOM with RNP</td>
<td>30/30 NM</td>
<td>23/23 NM</td>
<td>15/15 NM</td>
</tr>
<tr>
<td>No FANS</td>
<td>50/80 NM</td>
<td>50/80 NM</td>
<td>50/80 NM</td>
</tr>
</tbody>
</table>

- Schedules And Traffic Growth
  - 20 representative days from FY16 used in model
  - 2016, 2020, 2025, 2030 and 2035 were modeled
  - Results linearly interpolated for intervening years
  - Using current FAA policy on traffic growth for investment decisions, growth was capped in 2028 based on a 10 year sliding window.
Aircraft Altitude Requests

- In controlled airspace, aircraft must request an ATC clearance to deviate from their assigned altitude.

- Historical altitude requests and requests cleared were analyzed in ZAN/ZOA and ZNY.

- A regression was used to determine whether pilot requests increased as a result of separation changes in ZNY and ZAN.
  - Two independent variables: monthly trend variable and separation change variable.
  - ZNY: Change was significant, indicated a 15% increase in requests handled over the previous average.
  - ZOA/ZAN: 11% over the previous average.
  - Monthly trend variable was not significant in Atlantic, negative in Pacific.

- A similar increase in altitude requests was applied in GOM to approximate possible effect of reduced separation on pilot behavior.
Other Model Considerations

- **Aircraft Performance**
  - Base of Aircraft Data (BADA) model used
  - Assumes nominal take-off weight related to aircraft type and distance to be flown
  - No consideration of actual flight planning process

- **Fleet Evolution**
  - SWAC model incorporates a fleet evolution algorithm that replaces old aircraft types with newer ones as specified by FAA’s Carrier Fleet Forecast for 2016-2037
  - Some types are not supported in GOM. In these cases, we assumed an increase in fuel efficiency of 40% compared to previous type of the same size/range
Other Model Considerations

• Interaction with neighboring FIRs
  ➢ Agreements with surrounding international Air Navigation Service Providers (ANSPs) are a major factor in how the US controls flights in oceanic airspace
  ➢ Example: if neighboring ANSP requires higher longitudinal separation than U.S., U.S. controllers must plan and respond appropriately
  ➢ FAA must consider this when deciding if and when to approve reduced separation standards

• Model Validation
  ➢ Number of Altitude Change Requests
  ➢ Percentage of altitude change requests granted
  ➢ Distribution of flight times and distances traveled across oceanic regions
  ➢ Distribution of cruise altitudes upon entry to U.S. oceanic airspace

• Limitations
  ➢ Only conflicts in oceanic airspace considered
  ➢ No adjustments of wheels-off times for foreign departures
  ➢ GOM does not model convective weather or turbulence
Modeled Airspace and Trajectory Data
Results

- 480 simulations conducted to get a full set of results across years, representative days, oceans, and alternatives
  - 4 years
  - 20 unique days
  - 2 oceans
  - 3 alternatives

- Annual Direct Fuel Savings (kg)

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<tr>
<th></th>
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<th>Enhanced ADS-C</th>
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<tbody>
<tr>
<td>FY</td>
<td>Atlantic</td>
<td>Pacific</td>
</tr>
<tr>
<td>2020</td>
<td>16,265,582</td>
<td>18,547,428</td>
</tr>
<tr>
<td>2025</td>
<td>21,524,161</td>
<td>24,156,380</td>
</tr>
<tr>
<td>2030</td>
<td>25,429,404</td>
<td>25,586,382</td>
</tr>
<tr>
<td>2035</td>
<td>25,926,102</td>
<td>24,885,958</td>
</tr>
</tbody>
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**Additional Cost-To-Carry Benefit**

- Oceanic Flights long in duration, ranging up to 14 hours in the Pacific and 10 hours in the Atlantic

- To account for reduced fuel loading and a consequent additional reduction in fuel burn, we adjusted the results using a method to quantify the incremental fuel impact of reducing takeoff mass[1]
  
  \[ \text{Incremental fuel Savings} = \text{Weight Savings} \times \text{flight hrs} \times 0.005 \]

- Annual Indirect (Cost-to-Carry) Fuel Savings (kg)

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<tr>
<td>FY</td>
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<td></td>
</tr>
<tr>
<td>2020</td>
<td>4,259,587</td>
<td>6,013,700</td>
</tr>
<tr>
<td>2025</td>
<td>5,575,130</td>
<td>7,865,542</td>
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<tr>
<td>2030</td>
<td>6,587,617</td>
<td>8,312,610</td>
</tr>
<tr>
<td>2035</td>
<td>6,695,970</td>
<td>8,070,657</td>
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Results (Graphical)

Cost to Carry

Annual Fuel Savings (M kg)

Year:
- 2020
- 2025
- 2030
- 2035

Regions:
- SBA Atlantic
- SBA Pacific
- ADS-C Atlantic
- ADS-C Pacific

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Model Variability

• Additional runs performed to examine the variability of the results
  - Random seed affecting take-off weights built into the model
  - Manually randomized which flights for a particular aircraft type were equipped when equipage was not 100%

• Developed distribution of ratios between variability and default simulations
  - Considerable variability (up to 25% in inner-quartile range)
  - Default results near middle of range
Conclusions

• Results from this analysis suggest that reduced separation in oceanic airspace produces significant benefits through improved accommodation of altitude requests.

• Results vary greatly by airspace volume. Factors include:
  - Route length
  - Traffic density
  - Equipage

• Results sensitive to modeling assumptions
  - Aircraft gross weight
  - Avionics capability
  - Climb Request Behavior

• Continuing to explore the potential for SBA to save fuel and provide other benefits to airspace users and the FAA.
ASEPS Going Forward

FUTURE STATE

LONG-TERM (5+ years)

Near-Term (1-3 years)

Mid-Term (3-5 years)

Reduced Separation in US Oceanic Airspace
THANK YOU
References

- ICAO FIR viewer available at website http://gis.icao.int/flexviewer
- Skybrary, Use of Selected Altitude by ATC, 2011.