Near-Term Operational Changes (Project 32)

Delri Muller, Karen B. Marais, Payuna Uday (Purdue)
R. John Hansman, Tom G. Reynolds, Jonathan Lovegren (MIT)

AAE Systems Day
August 28, 2010
Motivation

• Demand
  – Latest FAA forecasts:
    ▪ Domestic enplanements are projected to grow at an average of 2.5% each year from 2011-2030
    ▪ International enplanements are projected to grow at an average of 4.1% each year from 2011-2030

• Environment
  – Increasing concern about the environmental impacts of aviation

• Interdependencies: Throughput, Safety, Environment

Example: Boston-Logan International Airport – RWY 14/32
Initial proposal for construction: early 1970s
Final completion of runway construction: 2006
Motivation

- Environmental Impacts of Aviation
  - Emissions
    (NO\textsubscript{x}, SO\textsubscript{x}, Hydrocarbons, VOCs, CO)
  - Noise
  - Surface runoff
    (de-icing fluids, fuel spills, oil leaks)

[Images of airplanes and aeroplane trails]
Motivation

• Ways to address environmental impacts
  – Fly less
  – Improved Technology
    • Advanced Airframe/Engine Technologies
    • Alternative Fuels
  – Fly better
    • Improved Operational Procedures

• Need to identify and evaluate ways to reduce the environmental impacts of aviation in the near-term with minimal implementation barriers
Objectives & Approach

- Objectives:
  - **Stage 1**
    - Provide promising fuel, noise & emissions reduction measures list
    - Show environmental impact reduction potential
    - Indicate implementation barriers
  - **Stage 2**
    - Conduct quantitative analysis of most promising mitigation options

- Approach:

  ![Diagram](image_url)
Flight Phases
Approach

• Concepts and technologies compiled into a master mitigation list

• Mitigation options & barriers collected and reviewed by a variety of sources
  – Journals, conferences, key industry docs (e.g. ICAO, RTCA, IPCC, etc.)
  – Expert interviews with wide spectrum of stakeholders
  – Professional knowledge
  – Professional, Stakeholder and FAA reviews

• Categorized and prioritized using expert judgment
  – Environmental benefit (Fuel/CO2, climate, air quality, noise)
  – Implementation barriers
Environmental Impact and Implementability Classification

- Mitigations rated **Primary** (P), **Secondary** (S), **Neutral** (0), or **Adverse** (A) in each environmental impact category.

- Ease of implementation rated **Easy**, **Medium**, or **Hard**
  - "Easy" if it had already been successfully implemented somewhere, or did not require significant stakeholder change or technical development.
  - "Hard" if there were significant technical barriers or stakeholder opposition.
  - E.g., a mitigation requiring major ATC changes or controversial policy shifts would be “Hard,” while building a new taxiway or modifying an instrument approach procedure might be “Easy” or “Medium”.

- Potential impact rated **Strong**, **Moderate**, or **Weak** depending on impacts at a system-wide level.
## Master mitigation snapshot

<table>
<thead>
<tr>
<th>Mitigation</th>
<th>Description</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-4.3: Hold or pass areas near runway ends</td>
<td>Hold or passing areas near runway ends allow re-sequencing of aircraft. This can maximize capacity of a runway by allowing optimized sequencing of flights as well as preventing an aircraft blocking a depart queue. When it is unable to depart due to ATC constraints, equipment issues, weight delays, or other constraints.</td>
<td><strong>Secondary Fuel, Climate, Air Quality</strong>: Primary motivation is increased capacity/reduced delay, but this leads to secondary savings in fuel, climate and air quality impacts. <strong>Neutral Noise</strong>: No obvious effect on noise. <strong>Medium</strong>: Relies on infrastructure addition. <strong>Moderate</strong>: Can be implemented at a wide range of airports, and effectiveness at reducing delay at any given airport is likely to be greater than the other mitigations outlined above.</td>
</tr>
</tbody>
</table>

### DEPARTURE (D)

<table>
<thead>
<tr>
<th>D-1: Departure Procedures</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D-1.1: Intersection departures</strong></td>
<td>Depart further down the runway than standard. Used to expedite traffic by saving time in taxi and departure queue. More engine power might have to be used than if the entire runway length was used in the takeoff.</td>
</tr>
<tr>
<td><strong>Neutral Fuel, Climate, Air Quality, Noise</strong>: Offers limited fuel, emissions and noise savings because higher thrust might be required for a shorter runway takeoff. <strong>Easy</strong>: Does not require any extra equipment, technical development or stakeholder changes. <strong>Weak</strong>: Can be implemented at a wide range of airports, but potential benefits are small.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D-2: Increased flexibility in departure routes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D-2.1: RNP/RNAV Enabled SIDs</strong></td>
<td>RNP/ RNAV Standard Instrument Departures enable aircraft to fly more precise and flexible departure trajectories potentially including fuel optimized climbs.</td>
</tr>
<tr>
<td><strong>Primary Fuel, Climate</strong>: Reduces fuel use by enabling more precise and flexible departure trajectories nearer to optimum profiles. <strong>Secondary Air Quality, Noise</strong>: Most benefits at intermediate altitudes, but some low altitude reduced fuel burn and routing around noise sensitive regions have secondary air quality and noise impacts. <strong>Medium</strong>: Requires extra equipment and changes to existing departure procedures. <strong>Moderate</strong>: Potentially significant reductions which can be implemented at a wide range of airports.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D-2.2: Increased number of departure routes, multilaning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multi-laning</strong>, or adding multiple parallel routes to existing routes, is one opportunity to create additional capacity in the system. If done in ways consistent with controller structure-based abstractions, the cognitive complexity benefits should delay the onset of congestion. The increased precision of aircraft trajectories in RNAV and RNP operations provides opportunities to “multi-lane” existing flows through the addition of minimally spaced, laterally separated, routes. Adding multiple parallel routes to existing routes create additional capacity in the system.</td>
<td><strong>Secondary Fuel, Climate, Air Quality</strong>: Primarily designed to increase airspace capacity and reduce delay which in turn offers secondary fuel, climate and air quality benefits. <strong>Neutral Noise</strong>: impacts primarily at higher altitudes so noise impacts not significantly different. <strong>Medium</strong>: Requires extra equipment and changes to existing departure procedures. <strong>Weak</strong>: Cannot be implemented at all airports due to airspace.</td>
</tr>
</tbody>
</table>
RNAV/RNP Background

Conventional Routes
Airways connect ground-based navigation aids

RNAV
Area Navigation (RNAV) routes follow defined “waypoints”

RNP
Required Navigation Performance (RNP) routes within specified “containment area”

- Limited Design Flexibility
- Increased Airspace Efficiency
- Optimize use of Airspace

• Enable aircraft to fly more precise and flexible arrival and departure trajectories closer to the optimal procedures
**RNP/RNAV**

- **Primary Fuel and Climate**: Reduces fuel use by enabling more precise and flexible departure trajectories
- **Secondary Air Quality & Noise**: Possible reduced fuel burn at low altitude routing around noise sensitive areas;
- **Medium Implementability**: Requires extra equipment and changes to existing departure procedures;
- **Moderate System-wide Impact**: Can be implemented at a wide range of airports

**Purpose/ Goal of the Study:**
- Show trends in RNAV/RNP adoption in domestic airlines.
- Present a number of case studies
  - Indicate current barriers and Issues encountered (e.g. Aircraft equipage and crew/controller training or new procedure development)
- Show quantitative potential environmental benefits of RNAV/RNP procedures
- Recommend a set of best system wide practices in RNAV/RNP implementation
Airport-centric Operations

- End-around taxiways
- Improved locations of high speed turn-offs
End-Around-Taxiways Background

Jackson-Hartsfield International Airport (Atlanta)

Landing aircraft need to wait to cross the active departure runway

GAO Report Aviation Runway and Ramp Safety (Nov 2007)
End-Around-Taxiways Background

Landing aircraft can directly move towards the terminal

GAO Report Aviation Runway and Ramp Safety (Nov 2007)
End-Around-Taxiways

- **Secondary Fuel, Climate and Air Quality Impacts**: Offers limited fuel savings
- **Neutral Noise Impacts**: Does not provide noise mitigation benefits
- **Medium Implementability**: Does not require any major policy or stakeholder changes and minimal technological improvements, but some infrastructure addition
- **Weak System-wide Impact**: Can be implemented at a wide range of airports, but potential system wide environmental benefit is small

**Purpose/Goal of the Study:**
- Quantify environmental benefits of these taxiways in terms of fuel savings.
  - Provide quantification and sensitivity analyses of potential fuel savings based on specific airport configurations and fleet constraints.
- Conduct trade-off studies of the actual environmental advantages provided vs. cost of implementation
- Determine types of airports at which EAT implementation can provide maximum benefit.
Improved Locations of High Speed Turn-offs Background

• Aircraft extend their landing roll when:
  ▪ Runway exit is too close to the landing point, or,
  ▪ Speed of the aircraft is too high

• Increases taxi-time, runway occupancy and delay

• Potential to save fuel
Improved Locations of High Speed Turn-offs

- **Secondary Fuel, Climate and Air Quality Impacts**: Offers limited fuel savings
- **Neutral Noise Impact**: Does not provide noise mitigation benefits
- **Medium Implementability**: Does not require any major policy or stakeholder changes and minimal technological improvements, but some infrastructure addition
- **Weak System-wide Impact**: Can be implemented at a wide range of airports, but potential system wide environmental benefit is small

**Purpose/ Goal of the Study:**

- Quantify environmental benefits of high speed turn-off locations to determine when an implementation is warranted from an environmental viewpoint.
- Identify barriers and constraints to implementation.
- Conduct trade-off studies of the actual environmental advantages provided vs. cost of implementation.
- Propose new turn-offs at selected airports based on calculated estimate of potential environmental benefit.
Summary

- Aviation and the environment
- Operational methods that reduce the environmental impact of aviation
  - Provided most promising fuel, noise & emissions reduction measures list
  - Showed environmental impact reduction potential
  - Indicated implementation barriers
- Background and research approach of thesis topics
  - RNAV/RNP
  - End around taxiways
  - Improved high speed turn-off locations