Quiet Skies: Mitigating the Impact of Aircraft Noise

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Impact of Aircraft Noise

- Source of disturbance

- Impediment to airport expansion
  - New runway at Logan: 25-year litigation battle
  - Five additional runways at US 30 busiest airport in past 10 years

- Factor in air traffic congestion and delay
  - Limiting the future growth of air transportation

"The first recorded noise complaint was recently discovered in a cave near St. Louis."
Technological Opportunity

- **Advanced flight guidance technologies**
  - Global Positioning System (GPS)
  - Flight Management System (FMS)

- **Enable procedures that significantly reduce noise**
  - Thrust management strategies redistribute noise during departure and reduce noise during approach
  - Area Navigation (RNAV) enables flexible trajectories with noise mitigation as a consideration
  - Lateral navigation consistently directs aircraft away from populated areas
Noise Abatement Approach Procedures

Existing approach

- Aircraft intercepting the 3° glide slope from below (technology constraint)
- Fly close to the ground and at high thrust
- Flaps/gear extension initiated early
- High noise impact

3° decelerating approach

- Intercept 3° glide slope at high altitude (GPS guided)
- Fly higher above ground and at idle thrust
- Flaps/gear extension delayed
- Minimal noise impact (Global Positioning System (GPS))
Noise benefit of 3° Decelerating Approach (JFK 13L)

Existing Approach

3° Decelerating Approach
Continuous Descent Approach at Louisville International Airport 10/2002
Noise Monitor Locations

<table>
<thead>
<tr>
<th>Loc</th>
<th>Lat(deg)</th>
<th>Long(deg)</th>
<th>Elv(ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>N38.38845</td>
<td>W085.89724</td>
<td>898</td>
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<tr>
<td>P2</td>
<td>N38.38428</td>
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<td>P3</td>
<td>N38.37959</td>
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<td>N1</td>
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<td>N2</td>
<td>N38.39439</td>
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<td>N3</td>
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<td>N4</td>
<td>N38.38247</td>
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</table>

SDF Elv ~ 500 ft
Noise Reduction

- 3.9 to 6.5 dBA noise reduction
- 400 to 500 lb fuel saving over “conventional” approach
- Up to ~100 sec reduction in flight time over “conventional” approach under no wind condition
Implementation Challenges

- **Air traffic control considerations**
  - Aircraft deceleration rate is sensitive to system uncertainty
  - Uncertainty (atmospheric, pilot response) in operational environment results in significant variability in aircraft performance
  - Controllers increase separation to account for variability
  - Increased separation results in lower throughput
  - End result: currently used only in low-traffic environment

- **FMS VNAV and auto-throttle logic design**
  - Delay in pilot response causes auto-throttle to provide disproportionately large thrust for speed envelope protection
  - VNAV logic creates level flight segment to arrest acceleration
Possible Solutions

Degree of A/C automation

Degree of Ground automation

- MIT Trajectory Planning
- MIT Weather-based Noise Abatement
- SDF Phase 2
- MIT, Boeing, NASA
- Full DAG
- Netherlands ACDA
- MIT/Delft Self-Spacing
- NASA Ames DAG
- NASA Langley Energy Indicator
- MIT On-line Optimization Algorithm

- Long-Term
- Mid-Term
- Near-Term

MIT, Boeing, NASA
Full DAG

Mid-Term
Near-Term

Long-Term

Trajectory Planning

Weather-based Noise Abatement

SDF Phase 2
MIT, Boeing, NASA
MIT Gates

Objective
- Provide pilots a means to manage a/c deceleration and meet targets without adding airborne automation

Approach
- Develop gates (altitude and speed checkpoints) using Monte-Carlo simulation (static solution) or ground based automation (to incorporate details of current weather, etc.)
- Provide gates to pilots as a feedback mechanism
- Pilots adapt given flap schedule based on deviations at gates

Key Feature
- Comparable performance to other forms of guidance that require change in aircraft equipage
Objective
- Improve trajectory using Satellite Landing System (SLS) technology

Approach
- Sensitivity analysis to determine key factors affecting performance
- Searching design space for best parametric procedure and control logic
- Airborne trajectory planning: lateral vectoring, weather, a/c configuration

Features
- Flexible flight track allowing lateral vectoring
- Variable glideslope to minimize noise impact and assure safety
MIT Online Optimization Algorithm

- **Objective**
  - Real-time optimal noise abatement trajectory generation and control

- **Approach**
  - Dynamic programming for paths generation
  - Linear and nonlinear optimization over noise
  - Receding horizon control for real-time adaptation

- **Key Features**
  - ATC controller retains control during approach
  - More friendly and flexible NAP trajectory for pilots
MIT Weather-based Noise Abatement

### Wind Speeds

<table>
<thead>
<tr>
<th>Scenarios / dB SEL</th>
<th>60 &lt; 70</th>
<th>70 &lt; 80</th>
<th>80 &lt; 90</th>
<th>90 &lt; 100</th>
<th>&gt; 100</th>
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<tr>
<td>Standard departure</td>
<td>405,887</td>
<td>235,083</td>
<td>43,825</td>
<td>5,764</td>
<td>192</td>
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<tr>
<td>Optimal departure</td>
<td>293,745</td>
<td>94,574</td>
<td>18,882</td>
<td>5,320</td>
<td>143</td>
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Summary

- Noise is an impediment to growth of air transportation
- Advanced flight guidance technologies (GPS, RNAV) enable flexible operational procedures for noise reductions
  - Simulation work
  - Flight demonstration test at Louisville
- Implementation challenges: inability of controllers to separate and sequence a/c for maximum throughput and safety
- Current work:
  - Develop candidate architectures and ground and airborne decision support tools
  - Evaluate controller/pilot performance through simulation and flight test
  - Develop appropriate solutions for near, medium, and long term
  - Develop procedures for Louisville and London Heathrow
Next Steps at Louisville (SDF)

- **Controller-in-the-loop Study**
  - Understand limitation of controller and pilot performing CDA
  - Quantify ability of controllers to predict future separation violations
  - Develop “model” of appropriate control actions – course and fine control

- **Controller Tools Study**
  - Quantify benefit to controllers of support tools
  - Develop improved model of controller actions given different tools

- **Crew Model Study**
  - Determine impact of advanced FMS and displays on pilot and aircraft performance (given controller models)
  - Develop improved model of pilot performance

- **Procedure Design and Full Distributed Simulation Study**
  - Develop procedures for Louisville
  - Evaluate performance and implementation issues of procedures