Transition Flow Analysis and Visualization

The MITRE Corporation's Center for Advanced Aviation System Development (MITRE/CAASD), a federally funded research and development center sponsored by the United States Federal Aviation Administration (FAA), supports safe, clean, and efficient air traffic by providing a variety of cutting edge tools and analyses.

New analyses and visualizations for procedures in airport transition airspace will aid air traffic control facilities, aviators, and researchers in monitoring and improving the routes that aircraft use to arrive to and depart from the airport. Following are three types of analyses MITRE/CAASD has conducted at 48 airports, representing more than 600,000 operations during a 30-day period. Ongoing work is looking at additional locations and dates.

**Flowtubes**

Large airports have hundreds or thousands of flights per day, each of which fly a slightly different path. These differences can be due to a variety of factors including wind, aircraft performance, airspace, and air traffic controller vectoring of aircraft. Flow behavior can be monitored over time. For these analyses, a flow is a grouping of aircraft arriving to/departing from a particular runway from/to a particular direction. A flow tube is a visualization of the airspace that encapsulates 90 percent of the aircraft along a flow.

![Figure 1. Single Arrival Flow Tube](image)

Flowtubes are best viewed in a Three Dimensional (3D) environment, such as a Graphical Information System (GIS). The images on this page are flow tubes displayed in Google Earth. In addition to monitoring flow behavior, flow tubes are a promising new tool for use in designing new Performance Based Navigation (PBN) procedures and assessing the impact and benefits of creating more predictable traffic flows.

**Level Segments**

Level segments are portions of an arrival or departure route where aircraft stop descending or climbing and level off temporarily. From a fuel and emissions efficiency perspective, level segments are undesirable when they occur at a lower altitude than an aircraft's preferred cruise altitude. Level segments along flows are of particular interest in procedure design because altering the vertical profile improves flight efficiencies and can result in significant fuel and emissions savings.

<table>
<thead>
<tr>
<th>Level Segment Altitude (Feet)</th>
<th>Percent of Flow Leveling Off</th>
<th>Average Time (s)</th>
<th>Average Distance (Nautical Mile)</th>
<th>Estimated Fuel Burn (Gallon/Year)</th>
<th>Estimated Emissions (Tons CO2/Year)</th>
<th>Estimated Cost ($/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24000</td>
<td>56%</td>
<td>230</td>
<td>26</td>
<td>9000</td>
<td>100</td>
<td>$ 26,000</td>
</tr>
<tr>
<td>17000</td>
<td>92%</td>
<td>158</td>
<td>16</td>
<td>20000</td>
<td>220</td>
<td>$ 60,000</td>
</tr>
<tr>
<td>11000</td>
<td>30%</td>
<td>115</td>
<td>10</td>
<td>7000</td>
<td>80</td>
<td>$ 21,000</td>
</tr>
</tbody>
</table>

Fuel savings are greatest when long, low altitude level segments can be reduced or eliminated. By analyzing the level segments along all flows at an airport, PBN design opportunities can be easily identified. Additionally, constraints such as nearby flows can be easily identified and visualized. Important characteristics of level segments are provided, including length, duration, and the frequency with which they are flown.
Flow Interactions

In constrained terminal airspace, interacting flows—those which use the same or nearby airspace—increase operational complexity, and in some cases create dependencies between operations at different airports. De-coupling of adjacent airport interactions enables improved operational efficiencies and throughput.

Automatically identifying these locations is important for procedure designers, since visually inspecting raw traffic data does not readily provide the insights needed to determine whether the flows are interacting with each other.

Figure 2. Complex Flow Interactions