Improving Flight Efficiency Through Terminal RNAV

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What is ‘RNAV’?

Pre-RNAV: Aircraft Navigate Via Ground Based Navigation Aids (VOR, DME) or ATC Heading Vectors

RNAV Procedure: Aircraft Self-Navigate Via Waypoints, Resulting in More Predictable Flight Path and Improved Situational Awareness

Extension of STAR
Current RNAV arrival procedures were turned on Nov 12, 2003 at LAS
Operational Analysis

- Compared flights from 2000 and 2004 along the west flow and gathered key metrics
  - West flow tracks used due to overlay nature of ground track
- Other flows had modified ground tracks, making direct comparison across years impossible
- Measured Time and Distance from Terminal area entry point to final controller handoff point, collected other metrics at intermediate points
# Results of Case Study: Operational Findings

<table>
<thead>
<tr>
<th>Metric</th>
<th>Measuring Point</th>
<th>2000</th>
<th>2004</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flight Distance</strong></td>
<td>TRACON -&gt; Final W</td>
<td>35.01</td>
<td>34.99</td>
<td>0.713</td>
</tr>
<tr>
<td><strong>Flight Time</strong></td>
<td>TRACON -&gt; Final W</td>
<td>379 sec</td>
<td>410 sec</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Groundspeed</strong></td>
<td>TRACON West</td>
<td>302 kts</td>
<td>283 kts</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>Final W</td>
<td>248 kts</td>
<td>238 kts</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Lateral Track Dispersion</strong></td>
<td>West Intermediate 1</td>
<td>0.36 nmi</td>
<td>0.27 nmi</td>
<td>0.037</td>
</tr>
<tr>
<td></td>
<td>West Intermediate 2</td>
<td>0.24 nmi</td>
<td>0.12 nmi</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Altitude</strong></td>
<td>West Intermediate 1</td>
<td>10,846 ft</td>
<td>11,622 ft</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>West Intermediate 2</td>
<td>10,273 ft</td>
<td>10,949 ft</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Inter-Arrival Time Variance</strong></td>
<td>Final E</td>
<td>51 sec</td>
<td>46 sec</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

* - measured using east flow data
Simulation Modeling

• Motivation
  – Routes redesigned for RNAV implementation
    • Environmental reasons, interaction with departures
  – Impact of 9/11
  – Continuing growth of Las Vegas air traffic

• Steps undertaken
  – Collect metrics from vectored traffic
  – Create overlay RNAV routes
  – Produce a new track set with traffic on RNAV route
  – De-conflict RNAV traffic with speed or lateral adjustments when necessary
  – Collect metrics from de-conflicted RNAV traffic
  – Analyze data
Baseline + Simulated Tracks
Analysis Results; Overall Time and Distance Savings

- Overall time and distance savings from TRACON to threshold approximately 38 seconds and 0.8 nautical miles per flight
- Both the time and distance savings are statistically significant

<table>
<thead>
<tr>
<th></th>
<th>RNAV</th>
<th>Vectored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time* (sec)</td>
<td>615</td>
<td>653</td>
</tr>
<tr>
<td>Distance* (nm)</td>
<td>43.6</td>
<td>44.4</td>
</tr>
</tbody>
</table>

Average flight statistics for actual versus simulated flights; Least Squares Means

*P < .0001
2004 Operational Analysis

- Compare RNAV-equipped flights in October 2004 with non-equipped flights from the same data set
- Use flight plan data to determine who filed for RNAV procedures
  - This will lead to some flights being listed as RNAV although they received radar vectors to the runway
- Analyze tracks for time and distance
  - This does not accomplish the original goal of comparing the pre-RNAV environment to the post-RNAV environment, but should still provide some insight into the benefit of RNAV
Results of 2004 Operational Analysis

- RNAV flight times by flow:
  - West: RNAV flights 15 seconds shorter
  - Southwest: RNAV flights 10 seconds shorter
  - East: No significant change statistically
Other RNAV Sites

- Dulles – 4 RNAV STAR procedures implemented in January 2005
- Atlanta - 13 SID procedures implemented in April 2005, 4 STARS implemented May 2005
- PHL – 2 RNAV STAR procedures implemented in March 2005
- DFW – 16 RNAV SID procedures to be implemented in September 2005
- 200 more RNAV procedures planned at OEP 35 Airports within the next several years
Questions? Comments?
Operational Data Analysis: Time and Distance

- Environmental issues required path modification
- Flights from northeast (GRNPA) not analyzed, procedure largely unused
- Results vary depending on overlay vs. non-overlay RNAV procedures
  - Distance/time does not improve (much, if at all) for overlays
  - Non-overlays increase distance/time if longer route than vectored path

<table>
<thead>
<tr>
<th>Flow (RNAV route)</th>
<th>2000</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (avg)</td>
<td>Distance (avg)</td>
</tr>
<tr>
<td>Southwest (KEPEC)</td>
<td>336 sec</td>
<td>28 nmi</td>
</tr>
<tr>
<td>West (SUNST)</td>
<td>379 sec</td>
<td>35 nmi</td>
</tr>
<tr>
<td>East (TYSSN)</td>
<td>230 sec</td>
<td>18 nmi</td>
</tr>
</tbody>
</table>
Simulation Benefit: Shorter Downwind

Here the left, middle, and right lines of the boxes represent the 25th, 50th (median) and 75th percentiles, respectively. The whisker marks represent the min/max elements, excluding outliers (defined as being further than 1.5 \* [Inter Quartile Range] from the box).
# RNAV vs. Conventional Flights During Peak Time

<table>
<thead>
<tr>
<th>RNAV Procedure</th>
<th>Average Flight Time (sec)</th>
<th>Conventional Procedure</th>
<th>Average Flight Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYSSN</td>
<td>294</td>
<td>KADDY</td>
<td>330</td>
</tr>
<tr>
<td>KEPEC</td>
<td>312</td>
<td>CLARR</td>
<td>323</td>
</tr>
<tr>
<td>SUNST</td>
<td>267</td>
<td>FUZZY</td>
<td>308</td>
</tr>
</tbody>
</table>

**Time Savings**
- TYSSN: 36 seconds/flight
- KEPEC: 11 seconds/flight
- SUNST: 41 seconds/flight
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