Human Factors of Conflict Detection Tool for Terminal Area


10th USA/Europe Air Traffic Management Research & Development Seminar (ATM2013)
Outline

- Motivation
- Conflict Detection Tools
- Objective
- Experiment Details
- Results
- Conclusion
Motivation

• Conflict Alert (CA) is inadequate (Friedman-Berg, 2008)
  • Controllers respond to CA only 56% of time
  • 81% of CA alerts are nuisance alerts
  • CA does not help with operational errors
  • CA uses dead reckoning only

• Several tools exist in U.S. terminal airspace
  • No exchange of inputs or outputs between such tools
  • An integrated tool in the terminal airspace is missing

• NextGen and SESAR have requirements for a conflict detection & resolution tool
Conflict Detection Tool
Terminal-Tactical Separation Assured Flight Environment (T-TSAFE)

- Short-term conflict detection tool for terminal airspace alerts for potential loss of separation
- Based on similar principles as en route TSAFE (Erzberger & Paielli)
- Combines dead reckoning and flight intent information seamlessly
Eurocontrol Guidelines for Short Term Conflict Alert (STCA)

- Consider type of flight, wake category, Reduced Vertical Separation Minima (RVSM) status
- Use flight intent information
  - Airspace definitions including speed & altitude restrictions
  - RNAV departure routes
  - Controller entered flight levels
- Provide an alert with ample time for de-confliction
- User Interface that provide specific information about conflict
Previous Research

- Previous fast time simulation has shown (Tang et al.):
  - T-TSAFE had few false alerts when compared to CA
  - T-TSAFE provide a lead alert time of 38 sec
- Previous human-in-the-loop studies investigated:
  - Terminal area under current day operations
  - Altitude entries
  - T-TSAFE in final approach
  - Altitude & speed resolutions
Final Approach Tools in the Experiment
Final Approach Tools-
ATPA Cones vs. T-TSAFE cones

Automated Terminal Proximity Alert - ATPA

Terminal TSAFE cones

Appearance of cones
Final Approach Tools - ATPA Cones vs. T-TSAFE cones

Automated Terminal Proximity Alert - ATPA

Terminal TSAFE cones
Final Approach Tools

ATPA Cones

T-TSAFE Cones

Warnings are hard coded vs. 45 sec boundary
Final Approach Tools

ATPA Cones

T-TSAFE Cones

Altitude Entries by controller
Final Approach Tools-
ATPA Cones vs. T-TSAFE cones

Automated Terminal Proximity Alert - ATPA

Alerts on aircraft physical vs. schedule sequence

Terminal TSAFE cones
Objective

- Test one integrated tool in the terminal airspace and final approach (T-TSAFE alerts and T-TSAFE cones)
- Study the interaction of T-TSAFE alerts with ATPA cones
- Investigate robustness of T-TSAFE alerts under different operating conditions - Instrument and Mixed (mostly visual)
Interaction of ATPA with T-TSAFE vs. Integrated tool

Interaction between ATPA Cones & T-TSAFE Alerts

Integrated tool: T-TSAFE Cones & T-TSAFE Alerts
Experiment Details
Independent Variables

Cones(2) x Operating Conditions(2) within-subjects design

<table>
<thead>
<tr>
<th>Cones</th>
<th>Operating Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-TSAFE</td>
<td>ILS</td>
</tr>
<tr>
<td>ATPA</td>
<td>Mixed</td>
</tr>
</tbody>
</table>
Method

- Number of weeks = 2
- Number of participants = 8 recently retired SoCal Terminal controllers
- Number of Pseudo Pilots = 12
- Confederates = 4
- Total Number of Scenarios = 4
- Total Number of runs = 16 per week
  \[ 2 \text{ (cones)} \times 2 \text{ (operating conditions)} \times 4 \text{ (scenarios)} \]
- Days of pseudo pilot training = 2
- Days of controller training = 2
- Days of data collection = 3
<table>
<thead>
<tr>
<th>AAL154</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>230</td>
</tr>
<tr>
<td>SWA987</td>
<td>250</td>
</tr>
</tbody>
</table>

Red Alert with time to LoS below 45 sec and altitude entry
T-TSAFE Interface
(Visual approach entries)

Aircraft on Visual Approach to 24R
Results
Dependent Variables

- Total alerts calculated vs. displayed
- Controller look-ahead time
- Duration of alerts
- Keyboard entries
- Controller preference for cone features
- Workload and Situational Awareness
Frequency of alerts displayed in Mixed condition are nearly the same as those shown in ILS condition
Fewer T-TSAFE alerts shown under ATPA condition since they are suppressed to prevent clutter.

Marginal significance (*p<0.07) for T-TSAFE alerts displayed.
How long did controller select a look-ahead time? (ATPA vs. T-TSAFE)

Irrespective of position, type of cone, and type of operations controllers preferred to see T-TSAFE alerts within 60 sec.
Duration of Alerts (ILS vs. Mixed)

Aircraft under ILS have alerts with longer duration than Mixed conditions, significant at p<0.05
T-TSAFE alerts under T-TSAFE cones have longer durations than T-TSAFE alerts when available with ATPA cones.
Altitude entries are less likely to impact workload.

Statistical significance (*p<0.001) for visual entries.
Controller Preference for Cones

T-TSAFE Features are preferred over ATPA cone features by almost 100% participants except for the preference for compression error in ATPA vs. LoS in T-TSAFE cones.

T-TSAFE Features are preferred over ATPA cone features by almost 100% participants except for the preference for compression error in ATPA vs. LoS in T-TSAFE cones.
<table>
<thead>
<tr>
<th>Integrated Tool T-TSAFE cones &amp; T-TSAFE alerts</th>
<th>Interaction between ATPA Cones &amp; T-TSAFE alerts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly higher number of alerts with time to LoS shown in data block</td>
<td>Slightly fewer number of alerts with time to LoS <em>not</em> shown in data block</td>
</tr>
<tr>
<td>Longer Duration</td>
<td>Shorter Duration</td>
</tr>
<tr>
<td>Altitude entries impact both cones and alerts</td>
<td>Altitude entries did not impact cones but did impact alerts</td>
</tr>
<tr>
<td>Controller selected Look-ahead time impacts (filters) cones and alerts</td>
<td>Controller selected Look-ahead time does not filter ATPA cones but does impact T-TSAFE alerts</td>
</tr>
<tr>
<td>60% preferred the depiction of loss of separation on cones</td>
<td>40% preferred the depiction of compression error</td>
</tr>
<tr>
<td>Similar level of Workload &amp; Situational Awareness</td>
<td>Similar level of Workload &amp; Situational Awareness</td>
</tr>
</tbody>
</table>
Conclusions & Future Work

- The integrated system would be the ideal system to implement
- Interaction between ATPA cones and T-TSAFE alerts can be improved by incorporating features of T-TSAFE cones
- Visual conditions provided similar levels of alerts as instrument conditions

Future Work
- Continue test T-TSAFE for robustness under different operating conditions (e.g. 4 runways and Visual Separation)
- Investigate high severity alerts on aircraft on visual approach
Thank you
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Back up slides
Previous Research
(Fast-time analysis, Tang, et al.)

False Alert Rate
(per hour)

Without inferred altitude clearances
With inferred altitude clearances

False Alerts further reduced when altitude (flight intent) information is present
Irrespective of position, type of cone, and type of operations controllers preferred to see T-TSAFE alerts within 60 sec
Complacency Potential

- ILS conditions have higher potential for complacency than Visual conditions (Significant).
- T-TSAFE cones have higher potential for complacency than ATPA (Marginally Significant).
<table>
<thead>
<tr>
<th>Construct</th>
<th>F statistic (df values)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence</td>
<td>$F(1,7) = 15.91$</td>
<td>Significant for operation type at $p&lt;0.005$</td>
</tr>
<tr>
<td>Confidence</td>
<td>$F(1,7) = 4.82$</td>
<td>Marginally Significant for cone type at $p&lt;0.06$</td>
</tr>
<tr>
<td>Reliance</td>
<td>$F(1,7) = 5.90$</td>
<td>Significant for operation type at $p&lt;0.05$</td>
</tr>
<tr>
<td>Trust</td>
<td>$F(1,7) = 14.97$</td>
<td>Significant for operation type at $p&lt;0.05$</td>
</tr>
<tr>
<td>Trust</td>
<td>$F(1,7) = 3.94$</td>
<td>Marginally Significant for cone type at $p&lt;0.08$</td>
</tr>
<tr>
<td>Safety</td>
<td>$F(1,7) = 6.67$</td>
<td>Significant for operation type at $p&lt;0.05$</td>
</tr>
</tbody>
</table>
ATPA vs. T-TSAFE Cones

**ATPA cones**
- Compression error
- Cones appear after established on localizer
- Altitude intent has no impact
- Warnings are hard coded at 45 sec and 24 sec to predicted time to LoS
- T-TSAFE compression alerts are suppressed
- Alerts shown for aircraft physically ahead

**T-TSAFE Cones**
- Loss of Separation
- Cones appear 30 sec before established on localizer
- Altitude entry reduces false alerts
- Warnings are coded as yellow above 45 sec and red below 45 sec as predicted time to LoS
- Only time to LoS is shown in data block
- Alerts are shown for aircraft ahead in the schedule
How long did controller select a look-ahead time? (ILS vs. Mixed)

- **ILS (all positions)**
- **Mixed (Stadium only)**

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>ILS (all positions)</th>
<th>Mixed (Stadium only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 sec</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>60 sec</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>90 sec</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>120 sec</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>
Initial values for look-ahead time

These are usually 60 but sometimes changed by controllers to different values.