Flight Test Assessments of Pilot Workload, System Usability, and Situation Awareness of TASAR

Kelly A. Burke, PhD
Human Factors Principal Investigator
NASA Langley Research Center
kelly.a.burke@nasa.gov
Cockpit automation and connectivity to real-time operational data are leveraged to enhance route-change procedures for flight optimization.
Traffic Aware Planner (TAP) and the Emerging “Connected Aircraft”

*Designed as an Electronic Flight Bag (EFB) application*

- **Ownship data via standard avionics interfaces (read only)**
  - Aircraft current state, active route, traffic data

- **Environment data via air/ground connectivity**
  - Latest winds, weather, airspace status, etc.

**Two Modes of Operation**

**Auto Mode**
- Computes real-time route optimizations

**Manual Mode**
- Analyzes pilot-entered route changes
Flying an aircraft involves a complex, multidimensional series of behaviors, only some of which can be observed directly.

- Cockpit procedures, technology, and instrumentation continue to change and become more complex.
- New technologies require evaluation of the potential impact on pilot workload and situation awareness.
- One method is the use of subjective assessments of workload and situation awareness.
Flight Test Objectives

- Conduct a human factors evaluation of the TAP software application and interface

- Investigate interaction with TAP Human Machine Interface (HMI) during normal flight operations

- Assess effects on perceived workload and situation awareness

- Assess system usability, comprehensibility, and usefulness
TASAR Flight Tests
in the National Airspace System

Nov 2013, June 2015

Flown in Aircraft Certified for Normal Operations
AdvAero Piaggio Avanti

Evaluated in Flight by Senior Airline Pilots

Operated in Congested Airspace

Also Assessed from ATC Perspective

Tested on Airline Hardware

Flown in Aircraft Certified for Normal Operations
AdvAero Piaggio Avanti
Methodology

Data Collection
- Two evaluation pilots per flight (cockpit and cabin)
  - 12 flights
  - 2 to 2.5 hours per flight
- Subjective measures administered
  - In flight
  - Post flight

Subjective Measures
- **Bedford Workload Scale.** The Bedford Workload Scale is a uni-dimensional rating scale designed to identify operator’s spare mental capacity while completing a task.
- **System Usability Scale (SUS).** The SUS provides a quickly administered and reliable tool for measuring subjective assessments of usability.
- **Situation Awareness Rating Technique (SART).** The SART is a subjective measure of situation awareness that can provide an index of how well operators are able to acquire and integrate information in a complex environment.
- **Post-Flight TAP HMI Evaluation.** This questionnaire consisted of five-point Likert-type rating scales regarding the overall comprehensibility, usability, and usefulness of the TAP HMI as well as questions about specific display features.
**Results**

**Bedford Workload Scale**

- Evaluation Pilots reported their cognitive workload as low ($M = 2.64$, $SD = 0.84$)
  - Rating of 1 indicating insignificant workload and a rating of 10 indicating a very high level of workload and task abandonment

---

**Bedford Workload Scale**

<table>
<thead>
<tr>
<th>OPERATOR DEMAND LEVEL</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload insignificant</td>
<td>1</td>
</tr>
<tr>
<td>Workload high</td>
<td>2</td>
</tr>
<tr>
<td>Enough spare capacity for all desirable additional tasks</td>
<td>3</td>
</tr>
<tr>
<td>Inadequate spare capacity for all desirable additional tasks</td>
<td>4</td>
</tr>
<tr>
<td>Reduced spare capacity. Additional tasks cannot be given the desired amount of attention</td>
<td>5</td>
</tr>
<tr>
<td>Little spare capacity. Level of effort allows little attention to additional tasks</td>
<td>6</td>
</tr>
<tr>
<td>Very little spare capacity, but the maintenance of effort in the primary task is in question</td>
<td>7</td>
</tr>
<tr>
<td>Very high workload with almost no spare capacity. Difficulty in maintaining level of effort.</td>
<td>8</td>
</tr>
<tr>
<td>Extremely high workload, no spare capacity. Serious doubts as to the ability to maintain level of support</td>
<td>9</td>
</tr>
<tr>
<td>Tasks abandoned. Pilot unable to apply sufficient effort</td>
<td>10</td>
</tr>
</tbody>
</table>

**Distribution of Bedford Workload Scale Scores**

Collapsed Across Pilot Position

(Figures: Median = 3.0)
System Usability Scale

- No significant differences based on pilot position (cockpit vs. cabin)
- SUS calculated scores were collapsed across pilot position
- Pilots reported ratings of high perceived usability ($M = 80.0$, $SD = 14.33$)
Results

Situation Awareness Rating Technique

- No significant differences based on pilot position (cockpit vs. cabin)

- SART calculated scores were collapsed across pilot position

- Pilots reported mid-range situation awareness scores ($M = 7.93$, $SD = 2.95$)
  - Indicates that situation awareness in the cockpit was not affected, either positively or negatively, by interacting with the TAP HMI
TAP HMI Evaluation

• Startup Checklist and Auto Mode Screens comprehension was either “Easy” (2) or “Very Easy” (1)
  – $M = 4.43, 4.79; SD = 0.76, 0.43$

• Manual Mode Screen slightly less comprehensible, with 43% of pilots reporting that comprehension was “Somewhat Easy” (3)
  – $M = 3.86, SD = 0.86$

• All three display screens were found to be either
  – “Useful” or “Very Useful” and
  – “Usable” or “Very Usable”
Conclusions

- Interaction with the TAP HMI did not create a significant level of additional workload and generally did not inhibit successful completion of tasks

- TAP HMI has a high degree of comprehensibility, usefulness, and usability

- Pilot situation awareness, as rated in flight, was not affected either positively or negatively by interacting with the TAP HMI
  - However, when asked post-flight, the pilots indicated that TAP enhanced their situation awareness

- Results are being used to further refine and improve the capabilities and features of the TAP HMI in preparation for operational trials with partner airlines planned for 2017-2018
Questions?