Human Factors Support For Automatic Dependent Surveillance-Broadcast (ADS-B)

August 1, 2013

This research is funded by the FAA Human Factors Division in support of the Office of Flight Standards and Aircraft Certification Service.
ADS-B Research Overview

Determine current state of CDTI design (Core)
- ADS-B Industry Survey*

CDTI Symbology: Examine CDTI symbology and display management (Core)
- ADS-B Symbology Study*
- ADS-B Color Coding on Surface Moving Maps*
- Traffic Symbol Information-Accessibility Analysis
- Proximate Status Indication Study

Analyze CDTI alerting (Core)
- Support to FAA for RTCA SC-186 – Traffic Situation Awareness with Alerts (TSAA)
- Alert Location

CDTI operational evaluation support (NextGen)
- Support for US Airways CDTI Operational Evaluation and related research*
- Support for the In-Trail Procedure (ITP)/FIM Literature Review*
- CDTI Operational Evaluation for Merging & Spacing (M&S)*

Sponsors:
- Kathy Abbott, Aviation Safety (AVS)
- Cathy Swider, Aircraft Certification Service (AIR-120)
- Paul VonHoene, Flight Standards Service (AFS-410)
- Don Walker, Aircraft Certification Service (AIR-130)
ADS-B Projects Funded by the “Core” Budget

Determine current state of Cockpit Displays of Traffic Information (CDTI) design, and examine CDTI symbology

- ADS-B Industry Survey
- ADS-B Symbology Study
- Use of Color on Airport Moving Maps & CDTIs
ADS-B Industry Survey

- **Purpose:** Develop a “consumer reports” type document that provides a listing of systems, features, and functions of currently available CDTI product
  - Catalog of approved displays/features will aid in approval of proposed systems

Excerpted from 2009 Surface Moving Map Industry Review
Example of Manufacturer Page Information

Excerpted from 2009 Surface Moving Map Industry Review
ADS-B Industry Survey

Schedule:

- Finalize templates for data collection – August, 2013
- Draft industry survey report – December, 2013
ADS-B Symbology Study

Purpose:

- To understand pilots’ perceptions of usefulness of the attributes & states (e.g., airborne, directional) on traffic symbols
- To understand which attributes or states are intuitive and which symbol features (e.g., fill, shape or color) are most often used to identify the traffic symbols
- Results will provide recommendations for symbols for ADS-B CDTI

Example subset of symbols used:

<table>
<thead>
<tr>
<th>Information Type</th>
<th>Symbols</th>
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<tbody>
<tr>
<td>Traffic aircraft</td>
<td>![Symbols]</td>
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<tr>
<td>Ground vehicles</td>
<td>![Symbols]</td>
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ADS-B Symbology Study - Method

- Paper-based questionnaire

- Symbol attributes examined:
  - Directional/Non-directional: Selected
  - Proximate/Non-proximate: Low data quality
  - Airborne/Ground: Aircraft/Vehicle
  - Designated: Caution/Warning

- Symbols came from eight manufacturers & six research institutions

- Participants were shown
  - Symbols in use on approved and proposed displays
  - Prototype symbols - not currently in use
  - Foils: shapes that do not exist
Symbol Intuitiveness Task (Categorization)

Which symbols best represent airborne traffic and directionality?

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**Airborne, directional traffic:** Traffic aircraft that is in the air with indication of track or heading.

Symbol(s) that represent this category is/are:

1, 3, 4, 10, 12, 14, 18

Reason(s) used for this grouping:

Showed heading. Didn’t look like a vehicle or truck.
Main Findings

- Two intuitive symbols for *airborne* - symbol shape was the prominent feature

- No intuitive symbols for *ground traffic*; four ground vehicle symbols were correctly identified 72% of the time

- Non-directional *ground vehicle* traffic was thought as showing both directional and non-directional information

- Color was the key feature in determining the alert status – caution & warning
ADS-B Symbology

Schedule:
- Draft Report Phase 1 – July, 2013 (completed)
Use of Color on Airport Moving Maps & CDTIs

**Background:** Aircraft Certification asked, “Why is ground traffic hard to see on some airport moving maps and CDTIs?”

**Purpose:** Identify issues and best practices for the use of color when integrating traffic on airport moving maps and CDTIs

- Will be used to support MOPS for ADS-B CDTI
Approach & Main Issues

Approach
- Review of regulatory & guidance material, color literature
- Viewed relevant demonstrations (e.g., SURF-IA)

Some identified issues
- When contrast is poor, symbol will be hard to see
- Red and amber/yellow are used inappropriately
- Potential issues with blue
- A lack of redundant coding
What Color Is It?

Simultaneous color contrast
Example: 
Traffic is Not Always Easy to See

- Evaluation Criteria:
  - Evaluate all possible combinations of traffic symbol sets and background
    - For example, a dark brown may be hard to see next to a black background, while a lighter tan may be too similar to other traffic (e.g., an amber caution alert)
Use of Color on Surface Moving Maps & CDTIs

- Schedule
  - Presentation at RTCA SC-186 Meeting – March, 2013 (completed)
  - Preliminary draft report – April, 2013 (completed)
  - Revised draft report – August, 2013
ADS-B Projects Funded by the “NextGen” Budget

Provide support to the FAA for operational evaluations and input on relevant ADS-B literature

- Flight Interval Management (FIM) Literature Review
- CDTI Operational Evaluation for Merging & Spacing (M&S)
- Support for the In-Trail Procedure
Flight Interval Management (FIM)

- Airline operations center (AOC) identifies IM candidate pairs
- AOC determines the time-based assigned spacing goal
- AOC sends a message via ACARS to the IM Aircraft
- The message contains the
  - Target Aircraft Identification
  - The Time-Based ASG
  - The Start Point
  - The Achieve-by Point
  - Planned Termination Point

- The IM Aircraft flight crew enters the M&S message elements into the M&S Application
Flight Interval Management (FIM) Literature Review

- **Purpose:** Provide summary and analysis for relevant literature and identify potential gaps in research.
  - Aircraft Certification and Flight Standards personnel requested this information for use in SC–186
  - Will identify what research has been done and what needs to be done

Figure from Bone et al., 2007
FIM Literature Review

- Schedule:
  - Draft annotated bibliography/literature review - August, 2013
CDTI Operational Evaluation for Merging & Spacing (M&S)

**Purpose:** Provide human factors support to the FAA for US Airways CDTI operational evaluation—focus on Merging & Spacing

Do the pilots have the necessary information and tools to successfully perform these operations?

- Information will be used by Aircraft Certification and Flight Standards in their assessment of the operational trials
Flight Interval Management

Figure from draft Operational Services and Environment Definition (2012)
# Comment Sheet for Pilot Feedback

- **Questions address:**
  - Acceptability of clearance
  - Ease of data entry
  - Communication with ATC
  - Frequency of speed changes
  - Effectiveness of cockpit displays
  - Experience with alerts
  - Perceived workload
  - General feedback

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**US AIRWAYS M&S PILOT DEBRIEF FORM (M&S VERSION 6.1)**

This form supports data collection on the use of the Merger & Spacing (M&S) procedure. Your cooperation in filling out this form after each flight will assist evaluation and improvement of the equipment, procedure, and training. The information contained herein will not be released to the public in a manner which allows the identification of US Airways flight crews. Please return the complete form to TBD.

<table>
<thead>
<tr>
<th>Date (DD/MM/YYYY)</th>
<th>Flight Number:</th>
</tr>
</thead>
</table>

- **Aircraft:**
  - [ ] A320-200
  - [ ] A330-300

- **Number of flights you have used CDI:**

- **Please circle your role on this flight:**
  - [ ] Captain
  - [ ] FO

1. Did you receive any Required Time of Arrival (RTA) messages from the OCC?
   - [ ] YES
   - [ ] NO

2. If yes, approximately how many RTA messages did you receive?
   - [ ] Less than 2
   - [ ] Between 2 & 5
   - [ ] Between 6 & 9
   - [ ] 10 or greater

3. If yes, did you find the RTA messages to be operationally acceptable?
   - [ ] YES
   - [ ] NO

4. Please rate the ease of entering the M&S information received from the OCC into your EFB.
   - [ ] Easy
   - [ ] Manageable, but could be improved
   - [ ] Difficult
   - [ ] Never did it

5. Was the M&S speed that you received from the OCC operationally acceptable?
   - [ ] YES
   - [ ] NO

6. If no, was the M&S speed:
   - [ ] Too slow
   - [ ] Too fast
   - [ ] Other, please explain: _____________

7. Did you request any clarification of the M&S message from the OCC?
   - [ ] YES
   - [ ] NO

8. If yes, what did you ask:

9. Did you receive a revised M&S message from the OCC prior to starting the procedure?
   - [ ] YES
   - [ ] NO

10. If yes, what was revised? Please check all that apply.
    - [ ] The Target Aircraft
    - [ ] The assigned spacing goal
    - [ ] The Start Point
    - [ ] The Achieve-by Point
    - [ ] The Planned Termination Point
    - [ ] Don't recall

11. Approximately how often did the speed change on the AGD?
    - [ ] Every two minutes
    - [ ] Every 5 minutes
    - [ ] Every 10 minutes
    - [ ] Greater than 10 minutes

12. Please rate the acceptability of the number of speed changes you received during M&S.
    - [ ] Unacceptable
    - [ ] Neutral
    - [ ] Acceptable

13. What was the range of the displayed speed adjustment?

14. What was the average magnitude of the displayed speed adjustment?

15. Percentage of the time did the speed need to be adjusted to compensate for wind or other factors?
    - [ ] less than 25%
    - [ ] 25-49%
    - [ ] 50-74%
    - [ ] 75-99%
    - [ ] 100%

16. During the procedure, did you ever elect NOT to follow the M&S speed?
    - [ ] NO
    - [ ] YES

17. Did you report any speed changes to ATC?
    - [ ] YES
    - [ ] NO

18. Did you report any speed changes to ATC?
    - [ ] YES
    - [ ] NO

19. If yes, approximately how often did you need to report to ATC?
    - [ ] Every two minutes
    - [ ] Every 5 minutes
    - [ ] Every 10 minutes
    - [ ] Greater than 10 minutes

20. If yes, did ATC ever tell you to discontinue speed reporting?
    - [ ] YES
    - [ ] NO

21. If yes, was speed reporting ever resumed?
    - [ ] YES
    - [ ] NO

Continued on next page...
CDTI Operational Evaluation for Merging & Spacing (M&S)

- Schedule (depends on schedule of operational trials)
  - Draft summary of support of operational evaluation - March, 2013 (completed)
  - Updated summary of support of operational evaluation - November, 2013
  - Update on human factors data collection - August, 2014
In-Trail Procedure (ITP)

- **Purpose:** Investigate human factors issues associated with the In-Trail Procedure (ITP) in oceanic airspace
  - Aircraft Certification and Flight Standards will use this information in their assessment of the operational trials
  - “Lessons learned” will be applicable to other NextGen applications

Figure from Jones, 2013
Working with FAA and United Airlines on operational evaluation of ITP

- Evaluation began in August 2011 (due to airline merger)
- Human factors data collection recommenced in June 2013
- Two means to collect feedback:
  1) comment forms
  2) focus groups (Sept 2013)
## Comment sheets

### Pilot Comment Sheet

Instructions: Please complete this comment sheet when time permits, each time an In-Trial Procedure (ITP) opportunity is available to the flight crew.

1. Why was the ITP was requested (check all that apply)?
   - ☐ Altitude change based on the Operational Flight Plan
   - ☐ More fuel-efficient flight level based on Flight Crew analysis
   - ☐ Weather Deviation due enroute weather (Turbulence or Thunderstorms)
   - ☐ Opportunity available due to airspace restrictions
   - ☐ Other ____________________________

2. Was the ITP request approved?
   - ☐ YES
   - ☐ NO
   **IF NO**, was it clear to you why the ITP request was not approved?
   - ☐ YES
   - ☐ NO

3. Please rate the difficulty/ease of identifying ITP opportunities:
   - ☐ Easy
   - ☐ Manageable, but could be improved
   - ☐ Difficult

4. Please rate the difficulty/ease of executing the ITP Procedure:
   - ☐ Easy
   - ☐ Manageable, but could be improved
   - ☐ Difficult
   - ☐ Didn’t try

5. Was the procedure outlined in the Flight Manual Bulletin sufficient to satisfy the safety of flight operation:
   - ☐ YES
   - ☐ NO
   **IF NO**, please describe: __________________________________________

6. Was there sufficient opportunity to discuss the proposed ITP between the Pilot Flying and the Monitoring Pilot before the request to ATC to satisfy the safe operating policy at United Airlines (Verify before execution)?
   - ☐ YES
   - ☐ NO
   **IF NO**, please describe: __________________________________________

7. Was there sufficient opportunity to discuss this ITP between the Pilot Flying and the Monitoring Pilot after receiving the ATC Clearance to satisfy the safe operating policy at United Airlines (Verify before execution)?
   - ☐ YES
   - ☐ NO
   **IF NO**, please describe: __________________________________________

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### Controller Comment Sheet

Instructions: Please complete this sheet each time an In-Trial Procedure is requested. Thank you for your time.

1. Date of request: ______________ Approximate time of request: ______________

2. Please rate the difficulty/ease of assessing the ITP request (that is, determining whether all conditions were met for approval):
   - ☐ Easy
   - ☐ Manageable, but could be improved
   - ☐ Difficult

   **Comments: __________________________________________

3. If the ITP WAS NOT approved, please specify why (check all that apply):
   - ☐ A standard flight level change was available
   - ☐ Controller workload could not accommodate request
   - ☐ Non-ITP traffic were blocking the desired flight level
   - ☐ Other; please specify: __________________________________________

4. Please share any comments you have regarding the In-Trial Procedure below.
   __________________________________________

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*Volpe*
In-Trail Procedures (ITP)

- Schedule:
  - Focus Groups - September, 2013
  - Draft summary of discussions with operators - December, 2013
  - Draft summary of HF issues from evaluation and ‘lessons learned’ - August, 2014
Questions?

Contact: Kim.Cardosi@dot.gov