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

August 1, 2013

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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

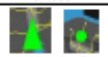
- ADS-B Industry Survey
- ADS-B Symbology Study
- Use of Color on Airport Moving Maps & CDTIs

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

Table 6. Functionality. A dash (--) indicates that the function is not available.

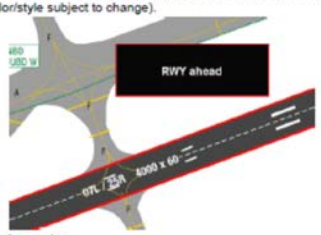
	Participants	Ownship Depiction	Traffic Display	Route Guidance	Decluttering	Panning	Zooming/ Autozoom
Manufacturer Displays	Airbus	 Magenta aircraft icon	In development	In development	x	x	x
	AirGator	 Red triangle	x	In development	x	x	x
	Astronautics	 Magenta triangle outlined with white border	x	x	x	x	x
	ACSS	 Magenta triangle	x	–	x	–	x
	FlightPrep	User customizable	–	–	x	x	x
	Garmin	 Airplane icon	x	–	x	x	x
	Honeywell	N/A	x	–	x	–	--
	Jeppesen Airport Moving Map	 Amber chevron (class 2) Isosceles triangle (class 3)	–	–	x	x	x
	JeppView	 FliteDeck: Green chevron MFD: Varies depending on manufacturer	–	–	–	x	x
	Lufthansa Systems	 Orange chevron	–	x	x	x	x
	MAPTECH Aeronautical Data	User customizable	--	x	–	x	x
	Rockwell-Collins	 White triangle at high map ranges; white aircraft icon when map range is 400 m or less	x	x	x	x	x
	TerraVision	 Green triangle. Green circle at low speeds or when heading is unreliable.	In development	In development	x	x	x
	Thales	Aircraft symbol (typically purple or yellow)	In development	x	x	x	x

Example of Manufacturer Page Information

Lufthansa Systems	Location: Frankfurt, Germany
Product(s)	Lido Airport Moving Map
Website(s)	www.lhsystems.com
Approvals / Compliance	*Avionics Box Type*: ☐ Installed/MFD ☒ EFB (Class ☐ 1 ☒ 2 ☒ 3) *Authority*: ☒ FAA ☒ EASA ☐ Other *Type of Approval/Compliance* – In progress TSO: ☐ C113 ☒ C165 ☐ C166A ☐ Other AC: ☒ AC 20-159 ☒ AC120-76A ☐ TC ☐ STC *Aircraft*: _____ ☒ Order 8900.1 ☒ RTCA DO-178B (Level D)
Product Overview	
Lido Airport Moving Map is intended to act as a runway incursion prevention system as well as airport information system. It replaces the (paper/static) ground chart and shows a dynamic ground chart using the Lido RouteManual charting standard. Own-ship position (north up or track up) is superimposed on the chart; the application is fully integrated into the Lido eRouteManual electronic charting solution.	

Photo provided courtesy of Lido. Research Display Only.

Hardware Platform	EFB Class 1-3 (Class 1 without own-ship position)
Display Size	Any
Data Format	☐ Raster ☐ Vector ☒ Database *Standards* ☒ ARINC Specification 816 ☒ RTCA DO-200A ☒ RTCA DO-272 *Other*: Lido proprietary format
Update Rate	Acc. RTCA DO-272

Lufthansa Systems	Location: Frankfurt, Germany
Airport Information Elements Depicted	
The method of depiction shown in the photo and described below reflects the night mode implementation, according to the Lido RouteManual charting standard.	
Runways	Light grey
Runway centerlines	Black dashed line
Runway labels	Deconflicted black text aligned to runway
Taxiways	Grey shape
Taxiway centerlines	Yellow line
Taxiway labels	Deconflicted white horizontal text
Hold lines	Yellow line
Non-movement areas	--
Ramp areas	Grey
Grassy areas	--
Buildings	Brown
Building labels	Deconflicted white horizontal text
Other	According Lido RouteManual charting standard
Functions Supported	
Ownship Depiction	Yes, orange chevron (look/color subject to change)
Indicators	Runway ahead warning; graphical NOTAM integration
Conditions	N/A
Visual Indicators	Runway ahead warning by overlay message with red outline and adding red outline to runway (color/style subject to change).  Screenshot in day mode.
Auditory Indicators	N/A
Decluttering	Yes, zooming in further shows more detail, like taxiway lines, labels, etc.
Panning	Yes (Plan Mode)
Traffic Display	No
Route Guidance	Colored line along taxi route. Route entered graphically or textually. Route could also be loaded from file (company routes) or any interface. NOTAMs to be interpreted and displayed, e.g. as restriction or closed taxiway.
Zooming/Autozoom	Yes

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:

Information Type	Symbols
Traffic aircraft	
Ground vehicles	

ADS-B Symbology Study - Method

- Paper-based questionnaire

- Symbol attributes examined:

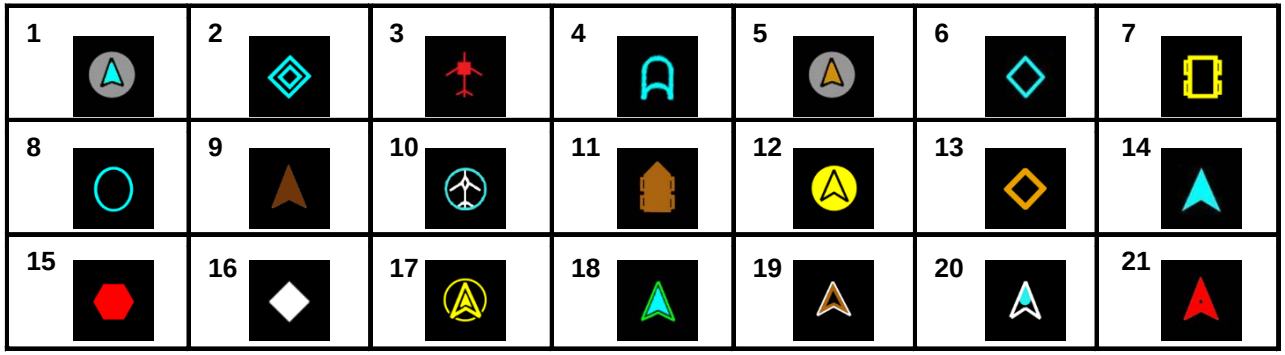
Directional/Non-directional	Selected
Proximate/Non-proximate	Low data quality
Airborne/Ground	Aircraft/Vehicle
Designated	Caution/Warning

- 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?



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.**

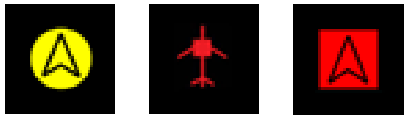
Main Findings

- 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)
  - Revised Draft Report – December, 2013

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

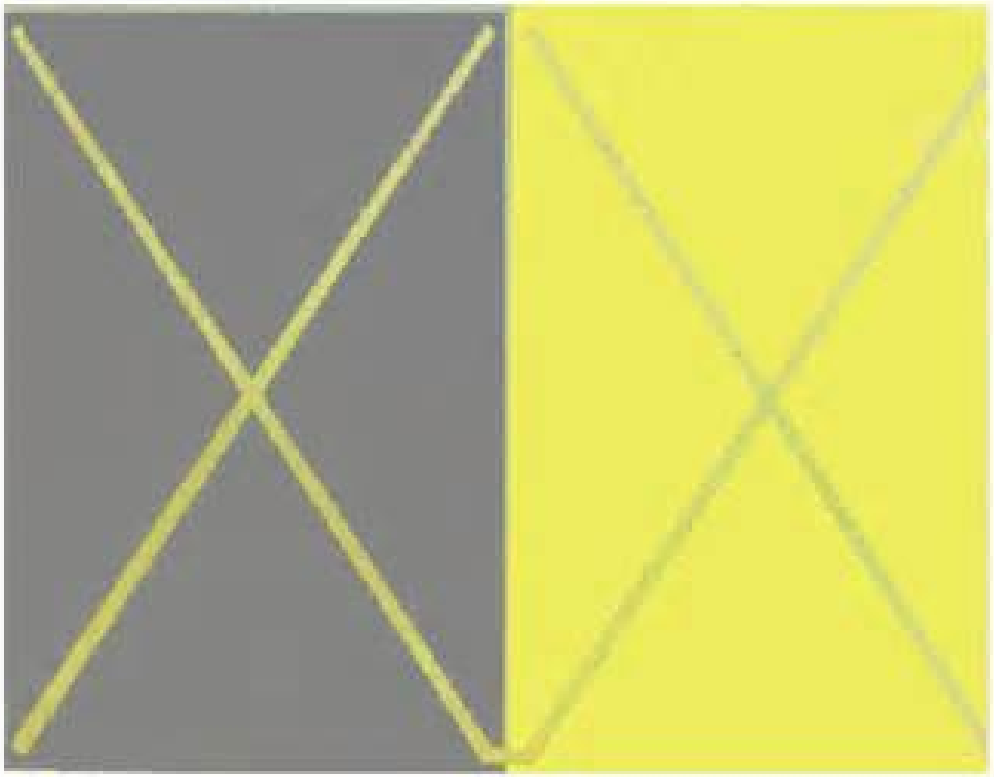
- Review of regulatory & guidance material, color literature
- Viewed relevant demonstrations (e.g., SURF-IA)

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

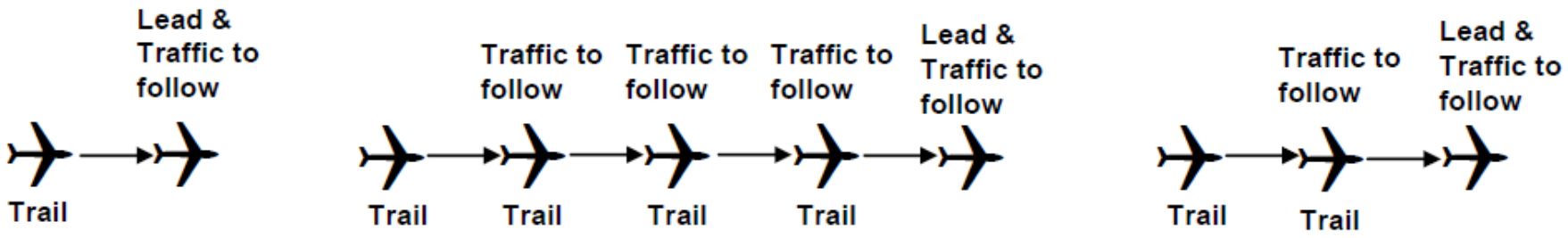


Figure from Bone et al., 2007

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

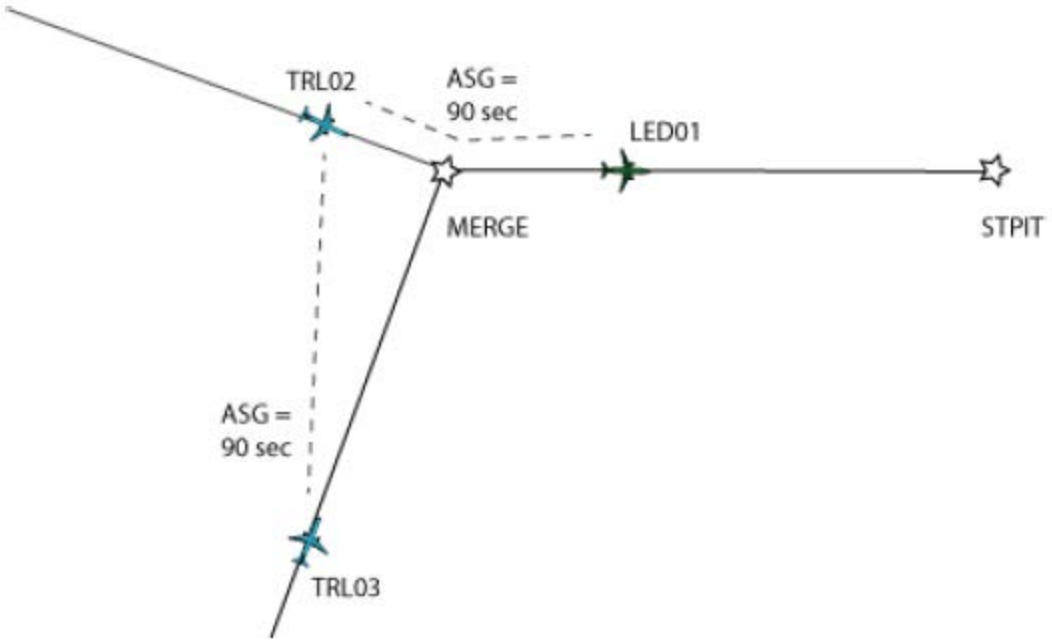
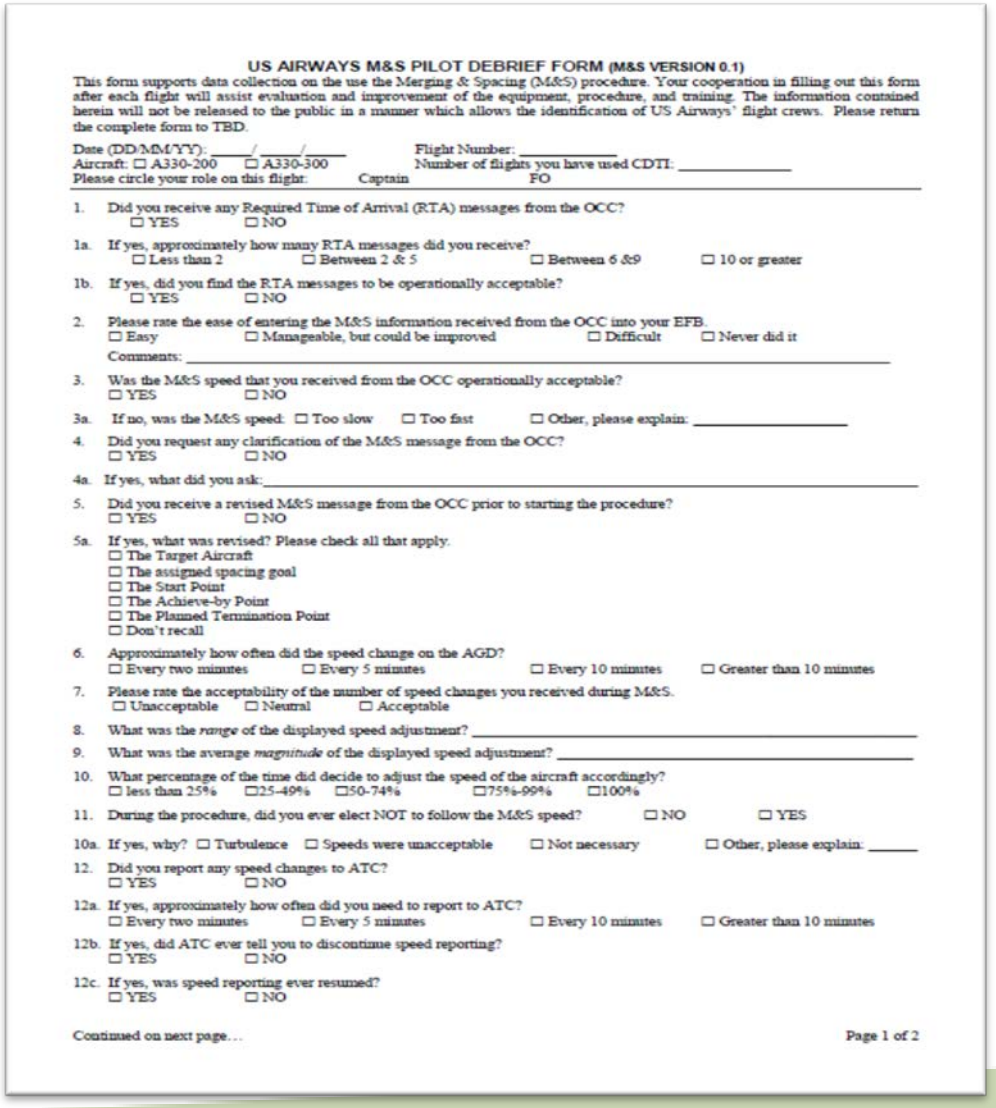


Figure from draft Operational Services and Environment Definition (2012)

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



US AIRWAYS M&S PILOT DEBRIEF FORM (M&S VERSION 0.1)

This form supports data collection on the use the Merging & 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.

Date (DD/MM/YY): ____/____/____ Flight Number: _____
Aircraft: ☐ A330-200 ☐ A330-300 Number of flights you have used CDTI: _____
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
1a. If yes, approximately how many RTA messages did you receive?
   ☐ Less than 2 ☐ Between 2 & 5 ☐ Between 6 &9 ☐ 10 or greater
1b. If yes, did you find the RTA messages to be operationally acceptable?
   ☐ YES ☐ NO
2. 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
   Comments: _____
3. Was the M&S speed that you received from the OCC operationally acceptable?
   ☐ YES ☐ NO
3a. If no, was the M&S speed: ☐ Too slow ☐ Too fast ☐ Other, please explain: _____
4. Did you request any clarification of the M&S message from the OCC?
   ☐ YES ☐ NO
4a. If yes, what did you ask: _____
5. Did you receive a revised M&S message from the OCC prior to starting the procedure?
   ☐ YES ☐ NO
5a. 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
6. Approximately how often did the speed change on the AGD?
   ☐ Every two minutes ☐ Every 5 minutes ☐ Every 10 minutes ☐ Greater than 10 minutes
7. Please rate the acceptability of the number of speed changes you received during M&S.
   ☐ Unacceptable ☐ Neutral ☐ Acceptable
8. What was the *range* of the displayed speed adjustment? _____
9. What was the average *magnitude* of the displayed speed adjustment? _____
10. What percentage of the time did decide to adjust the speed of the aircraft accordingly?
   ☐ less than 25% ☐25–49% ☐50-74% ☐75%-99% ☐100%
11. During the procedure, did you ever elect NOT to follow the M&S speed? ☐ NO ☐ YES
10a. If yes, why? ☐ Turbulence ☐ Speeds were unacceptable ☐ Not necessary ☐ Other, please explain: _____
12. Did you report any speed changes to ATC?
   ☐ YES ☐ NO
12a. 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
12b. If yes, did ATC ever tell you to discontinue speed reporting?
   ☐ YES ☐ NO
12c. 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

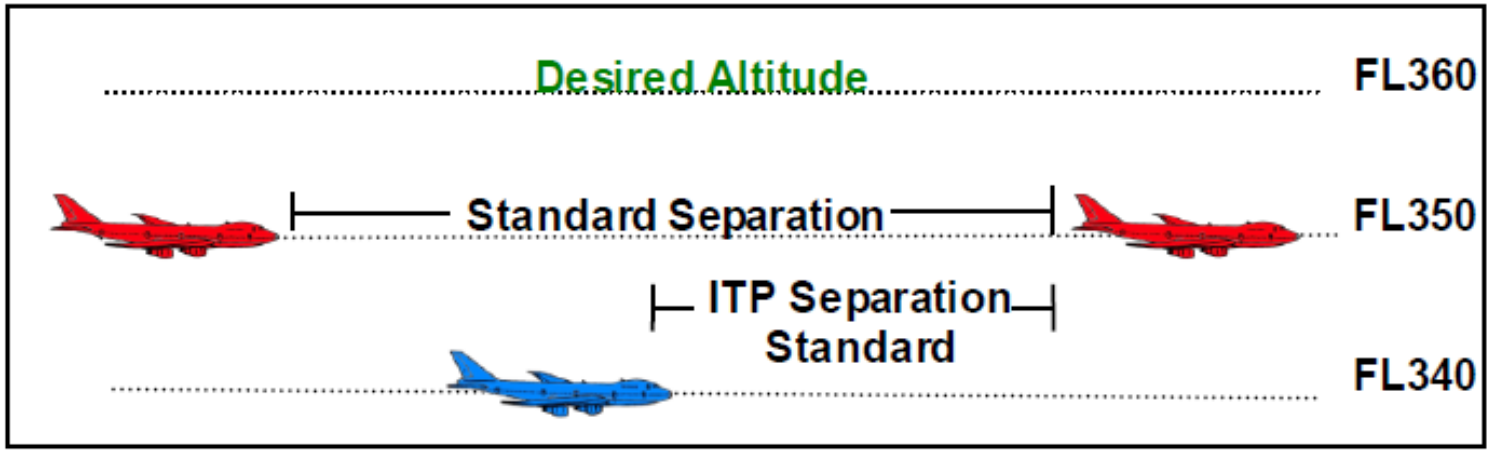


Figure from Jones, 2013

ITP - Overview

- 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)

Figures from Jones, 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: _____

Continued...

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-Trail Procedure below. _____

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