Surface Operations Usability Study Utilizing Capstone Phase I Avionics

Quick Look Report

Oct 7, 2003

Eric Nadler, Alan Yost, Andrew Kendra

USDOT Volpe Center

Jack Giurleo, Bedford Systems

Acknowledgements

The authors gratefully acknowledge the assistance of the FAA Air Traffic New England Region, NATCA, KBED and KPWM ATCT management and staff and the KBED and KPWM Airport Authorities.

We appreciate the time and valuable suggestions offered by the 16 volunteer pilots who participated.

This study was sponsored by and performed for the FAA's Safe Flight 21 Program.

Purpose

1. Evaluate usability, suitability and acceptability of of the surface moving map implemented within Capstone Phase 1 Avionics for surface operations
    - Task 1: Airport Surface Situational Awareness (ASSA)
    - Task 2: Surface-Final Approach Runway Occupancy Awareness (Surface FAROA)
2. Identify best design practices, design tradeoffs and any areas needing improvement.

Airport Surface Situational Awareness (ASSA)

- Using a cockpit display, increase the pilot's situational awareness of ownship and traffic position on the airport surface
  - relative to taxiways, ramps and the position of other equipped vehicles, e.g., snow plows, emergency vehicles, tugs, follow-me vehicles, baggage vehicles, fuel trucks, catering trucks.
- The intended use is to supplement the pilot's out-the-window visual assessment.
  - it can be used to assist the pilot in making maneuvering decisions on the surface in accordance with ATC instructions or self-generated taxi plans at non-towered airports.
  - it is not meant for use as the primary source of guidance information.

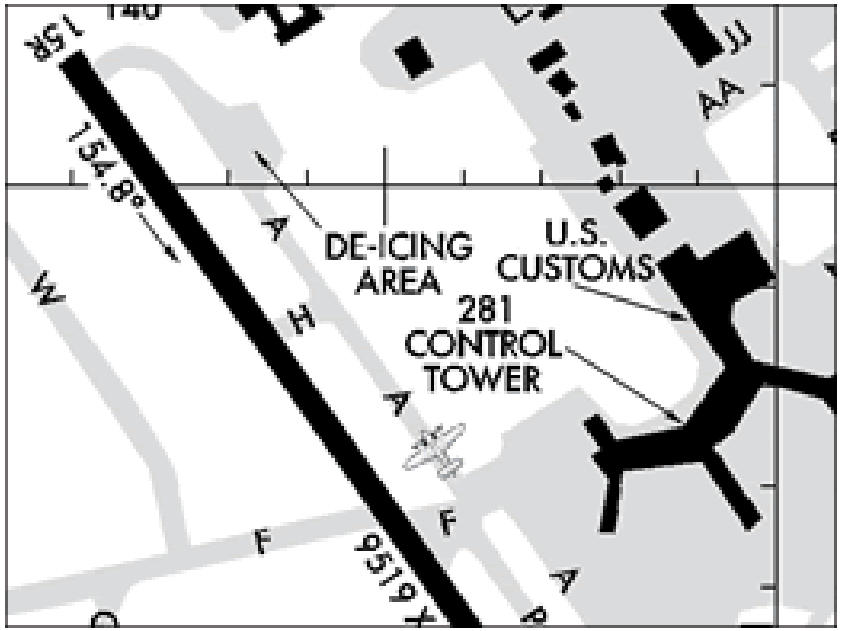
Final Approach and Runway Occupancy Awareness (FAROA)

- Using a cockpit display that shows the runway environment and other traffic, increase the flight crew's awareness of aircraft and surface vehicles that are on or near the runway surface or up to approximately 1000 feet above ground level (AGL) on final approach.
  - The display could be used by the flight crew to help determine runway occupancy and go-around decision-making.
  - On landing, the application begins on final approach and ends when ownship is clear of the landing runway.
  - On takeoff, the application begins prior to ownship entering the runway for takeoff and ends once ownship is airborne.
  - The application is also conducted at any time during taxi when a runway has to be crossed. (RTCA, 2003)

Capstone Phase I Avionics – MX20 Multifunction Display / GX60 IFR GPS

MX20

GX60



Surface Moving Map

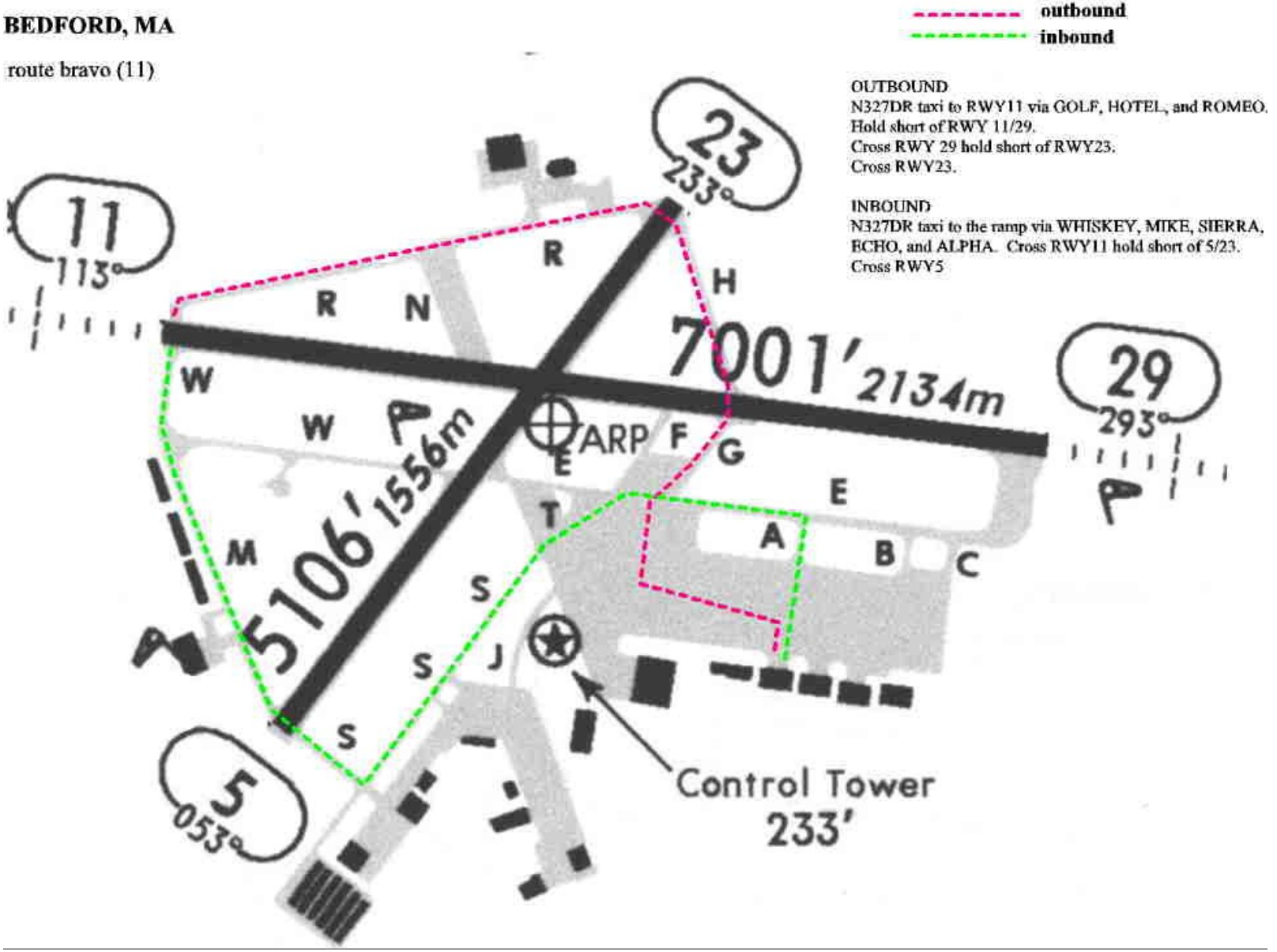
Assumptions and Experimental Conditions

- Emphasis on single pilot operations
  - Safety pilot was always present.
  - Pilots received complex but realistic taxi routes like what they could receive given a closed taxiway or airport reconfiguration.
  - Examples of the 8 routes follow.
- Pilots performed the evaluations in three conditions:
  - Familiar airport (night)
  - Unfamiliar airport (day and night)

Test Aircraft and Evaluation Pilot

BEDFORD, MA

route bravo (11)



PORTLAND, ME

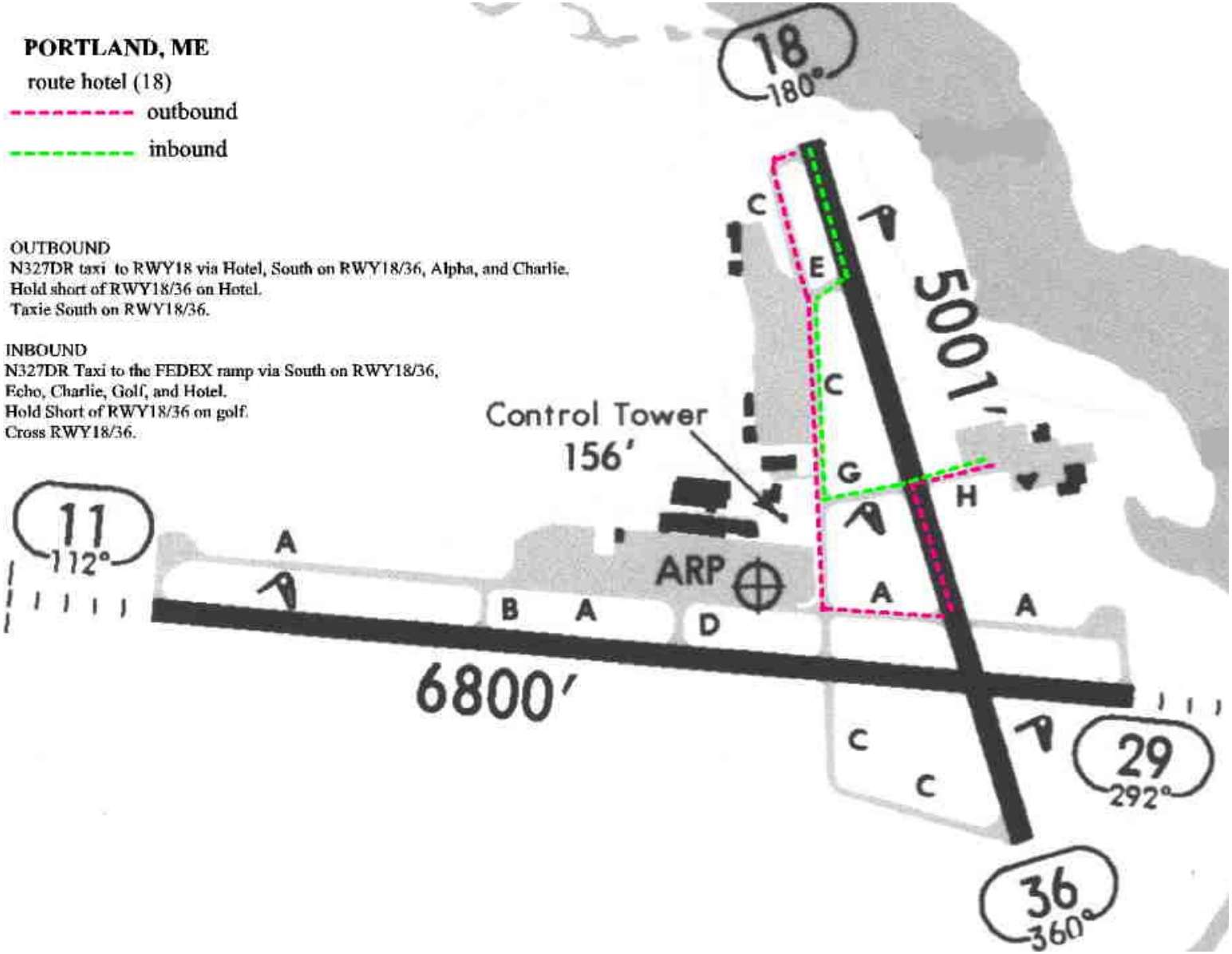
route hotel (18)

---------- outbound

---------- inbound

OUTBOUND
N327DR taxi to RWY18 via Hotel, South on RWY18/36, Alpha, and Charlie.
Hold short of RWY18/36 on Hotel.
Taxie South on RWY18/36.

INBOUND
N327DR Taxi to the FEDEX ramp via South on RWY18/36,
Echo, Charlie, Golf, and Hotel.
Hold Short of RWY18/36 on golf.
Cross RWY18/36.



Subjects and Airports

- Subjects: 16 pilots
- Airports where the study was conducted:
  - KBED (Bedford, MA)
  - KPWM (Portland, ME).

Study Metrics

- Primary Metrics
  - Post-flight usability questionnaire - covered in Quick Look Report
  - Post-test subjective workload scale
  - Eye tracker measurements
  - Taxi time
  - Taxi errors

Procedure

- In each of the three conditions, pilots taxied on one route in Piper Aztec with the cockpit map display and a second route without the map display (baseline) in an order that was counterbalanced across pilots.
- Order of conditions for all pilots:
  - Unfamiliar airport/day
  - Unfamiliar airport/night
  - Familiar airport/night

Procedure (2)

- Half of the subjects were familiar with PWM and half with BED.
  - Night and day conditions were defined as before or after civil twilight. A dinner break was taken during civil twilight.
- Surface FAROA
  - During final taxi (familiar airport/night), ADS-B airport van drove along runway toward intersection at which the aircraft was holding short.

Questionnaire

- Questionnaire included 51 items worded so that agreement meant that the feature was effective/usable/acceptable.
  - Likert-type 5-point scale
  - Strongly Disagree (1), Disagree (2), Somewhat Agree (3), Agree (4), Strongly Agree (5)

High Level Findings

- No features were considered to be unusable, unacceptable or unsuitable
  - All mean ratings >3.0 - BED and PWM
  - Some features were considered marginal (3.0 - 3.5)

Limitations

- Quick Look Report
  - Taxi error, head down time, taxi time, and subjective workload scale results will be included in the final usability and suitability evaluations.
- Evaluation Study Limitations
  - Displayed traffic was limited to one ADS-B target
    - Evaluations related to traffic display and display clutter were limited for this reason.

Summary and Conclusions

- Acceptability
  - Acceptability is a subjective criterion and most readily evaluated from questionnaire data.
  - The map display was very acceptable as an enhancement to pilot awareness of own ship position on the airport surface.

Summary and Conclusions (2)

- Usability
  - While usable, some deficiencies were also found.
  - Use of the surface moving map within the Capstone Phase I avionics led to pilot usage errors. Some errors in using the display can be attributed to incorrect map database and airport signage.
  - Display size and brightness, map display element presentation, symbology, and position accuracy were regarded as very usable.
  - Own ship movement appeared to lag when actual aircraft movements occurred or when the range was changed, and symbol directionality could be incorrect when the aircraft was stationary

Summary and Conclusions (3)

- Suitability for single-pilot use
  - The map display was very suitable for all environmental conditions evaluated (day and night)
  - Suitability for the Airport Surface Situation Awareness (ASSA) application was good, except that the map display was not always effective in indicating where to hold short of runways.
    - This result may be attributed to the lack of hold short lines on the evaluated may display implementation in combination with airport pavement markings and/or signage.

BACK UP SLIDES

Questionnaire Results (1)

Map Orientation Preferences

- North-up and track up options were available:
  - North-up preferred for taxi operations
  - BED
    - 5 pilots reported using track up
    - 3 pilots reported using North up
  - PWM
    - 6 pilots reported using North up
    - 2 pilots reported using both
  - Note that text remained upright on the North-up, but not on the heading-up implementation.

Questionnaire Results (2)

Display Clutter

- Tradeoff between providing sufficient information and display clutter is suitable for surface operations
  - Do you believe that additional or different features should be included on the map display?
    - Yes: 6 (see last page)
    - No: 10
  - Do you believe that fewer airport map features or airport information should be included on the map display?
    - Yes: 0
    - No: 15

Questionnaire Results (3)

Self-Reported Errors

- Did you make any errors in using the map display (any misinterpretations of displayed information, or anything you did incorrectly or omitted?
  - Yes: 8
  - No: 8

Questionnaire Results (4)

- Situation Awareness
  - Taking into account any added demands on my attention, overall, the map display increased my awareness of own ship position in relation to the assigned runway.
    - **4.8 (BED), 4.9 (PWM)**
  - The head down time required to view the map display during taxi was acceptable.
    - **4.4 (BED), 4.5 (PWM)**
  - The head down time required for map range adjustment was acceptable.
    - **4.3 (BED), 4.5 (PWM)**
  - My visual scan for objects on the taxiways and runways was not reduced when I used the map display.
    - **4.4 (BED), 3.9 (PWM)**

Questionnaire Results (5)

- Situation Awareness
  - I remained geographically oriented both in relation to the map display and in relation to the actual airport when I made a turn while taxiing.
    - **4.4 (BED), 4.8 (PWM)**
- Correlation of features from map to OTW scene
  - The position of own ship in relation to the map display was accurate enough to permit me to make timely turn decisions.
    - **4.0 (BED), 4.5 (PWM)**
  - I could tell from the map display where I should stop the aircraft to hold short of a runway.
    - **3.1 (BED, 3.1 (PWM) -** 5 pilots marked “disagree” (Selected either 1 or 2).
    - Note that hold short lines were not shown on the map display.

Questionnaire Results (6)

- OTW Correlation: Comparison with paper chart
  - Airport features as seen out the window were in the same position relative to own ship position as on the map display.
  - Airport features as seen out the window were in the same position relative to own ship position as on the paper airport map.
    - **Display: 4.3 (BED), 4.4 (PWM); Paper: 4.3 (BED), 4.5 (PWM)**

Questionnaire Results (7)

- Own Ship Symbol Direction on Airport Surface
  - The direction that the displayed own ship symbol was pointed was accurate while the aircraft was moving.
  - The direction that the displayed own ship symbol was pointed was accurate while the aircraft was stationary.
    - **Moving: 4.5 (BED), 4.4 (PWM)**
    - **Stationary: 3.5 (BED), 3.3 (PWM) -** 6 pilots marked “disagree” (Selected either 1or 2).
    - Note that aircraft direction is based on ground track so direction cannot be correctly shown without movement.

Questionnaire Results (8)

- Own Ship and Traffic Display
  - The position of own ship in relation to the position of the displayed traffic was accurate enough to permit me to determine its relevant (to predict a potential conflict).
    - **3.6 (BED), 4.0 (PWM)**
  - The head down time required for viewing traffic was acceptable.
    - **4.4 (BED), 4.3 (PWM)**
  - The range and bearing of the traffic as displayed on the map corresponded to what I saw out the window.
    - **3.7 (BED), 4.3 (PWM)**
  - Own ship and traffic position accuracy was sufficient to place these targets within the runway and taxiway widths for all map ranges that I used.
    - **4.3 (BED), 3.8 (PWM)**

Questionnaire Results (9)

- Own Ship and Traffic Display
  - When own ship moved or changed direction, its displayed traffic symbol moved without delay.
    - **3.4 (BED), 3.3 (PWM) -** 3 of 11 pilots marked “disagree” (Selected either 1or 2)
- Own Ship and Traffic Symbols
  - I did not confuse the own ship symbol with any other map feature.
    - **4.5 (BED), 4.6 (PWM)**
  - I did not confuse the traffic symbol with any other map feature.
    - **4.6 (BED), 4.6 (PWM)**

Questionnaire Results (10)

- Map Display Element Distinguishability
  - Runways were easily distinguishable from taxiways and other movement areas.
    - **4.6 (BED), 4.8 (PWM)**
  - Airport buildings were distinguishable from airport surface areas.
    - **4.5 (BED), 4.6 (PWM)**
- Use of color
  - Map display colors were meaningful and consistent with my expectations.
    - **4.1 (BED), 4.3 (PWM)**

Questionnaire Results (11)

- Display Element Prioritization and Clutter
  - The call sign of the displayed traffic did not interfere with my ability to read taxiway or runway labels.
    - **3.7 (BED), 4.0 (PWM)**
  - The own ship and traffic symbols did not interfere with the legibility of taxiway or runway labels.
    - **4.1 (BED), 4.0 (PWM)**
  - The taxiway and runway (or other) labels did not interfere with my view of own ship or traffic position.
    - **4.5 (BED), 4.6 (PWM)**

Questionnaire Results (12)

- Range Adjustment
  - I could select a map display range that was adequate for use during taxi.
    - **4.4 (BED), 4.4 (PWM)**
  - The speed with which range adjustments took effect on the map display was adequate.
    - **3.5 (BED), 3.6 (PWM) -** 4 pilots marked “disagree” (Selected either 1or 2)
  - I could easily determine the current map range.
    - **4.4 (BED), 3.9 (PWM)**
  - The workload required for range adjustment was acceptable.
    - **4.1 (BED), 4.5 (PWM)**

Questionnaire Results (13)

- Map Display Range Adjustment
  - The range I used to view any displayed traffic prior to crossing a runway was adequate.
    - **3.6 (BED), 4.0 (PWM)**
  - The available map display ranges were optimal for the airport surface operations I performed.
    - **4.1 (BED), 4.3 (PWM)**

Questionnaire Results (14)

- Display Size and Brightness
  - The size of the map display was adequate for the information presented.
    - **4.3 (BED), 4.4 (PWM)**
  - Map display brightness did not cause reflections to appear on the windscreen
    - **4.8 (BED), 4.6 (PWM)**
  - The manual map display brightness adjustment was effective in producing acceptable range of brightness levels.
    - **4.8 (BED), 4.6 (PWM)**
  - The automatic map display brightness adjustment was effective in producing an acceptable brightness level.
    - **4.0 (BED), 4.4 (PWM)**

Questionnaire Results (15)

- Suitability for Ambient Environmental Conditions
  - I could read the control labels during all daylight conditions that occurred during the evaluation.
    - **4.8 (BED), 4.4 (PWM)**
  - I could read all text on the map display during all daylight conditions occurred during the evaluation.
    - **4.4 (BED), 4.8 (PWM)**
  - I could read all text on the map display during the evaluations that occurred at night.
    - **4.9 (BED), 5.0 (PWM)**

Questionnaire Results (16)

- Suitability for Ambient Environmental Conditions
  - I could read all control labels during the evaluations that occurred at night.
    - **4.6 (BED), 4.4 (PWM)**
  - Map display colors maintained their contrast, hue, and saturation (did not become lighter) during all daylight conditions that occurred during the evaluation.
    - **4.6 (BED), 4.4 (PWM)**
- Location of Controls
  - It was easy to locate the buttons that I needed to adjust the map display.
    - **4.6 (BED), 4.3 (PWM)**

Responses to Open-ended Questions

- **Do you believe that additional or different features should be included on the map display?**
  - 6 pilots responded “yes”
  - 10 pilots responded “no”
  - Suggestions for maximum detail at a range that encompasses entire airport - 4
  - Adding hold short lines - 3
  - Distinguish between “W” and “M”, and “H” and “I” - 2
    - Labels did not remain upright when the map rotated while in track up orientation.

Responses to Open-ended Questions (2)

- **Additional Comments**
  - Integrating map use into visual scan
    - fixated on map too much - 2
    - did not rely on map enough - 2
  - Comments by individual pilots
    - additional features: taxi route line, traffic, names of buildings (e.g., FBO), and ramps (FedEx, FSDO, GA), point at which to turn into ramp
    - problems: label blocked view of opposite end of runway, low angle of sun made map unusable for 20 s., slow response of range change function, ownship easier to find if different color from taxiways and runways.