



Effect Of Traffic Position Accuracy For Conducting Safe Airport Surface Operations

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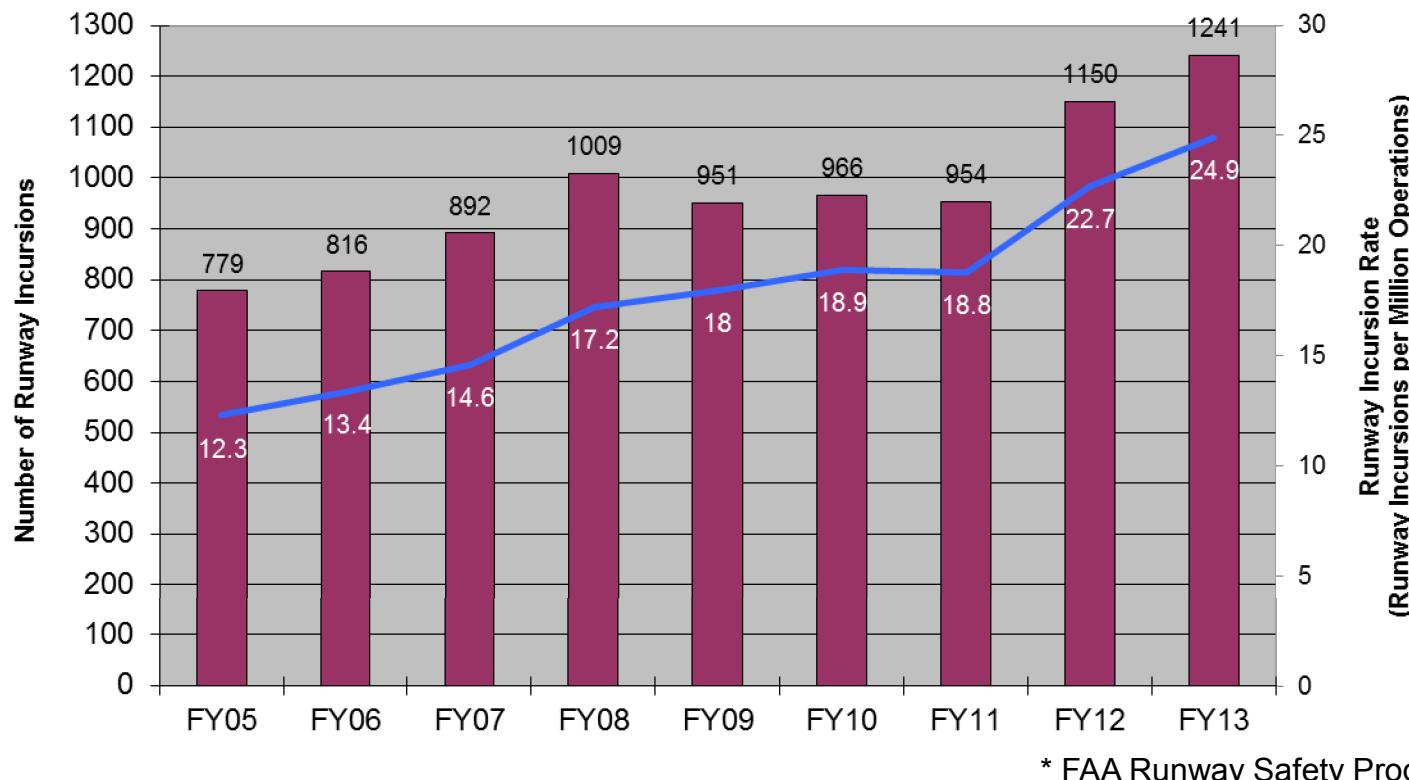
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Airport Safety



- NextGen proposes revolutionary operational concepts and technologies for overall increase in system capacity and safety
 - Cockpit display of traffic information and movements
 - Airport Moving Maps (AMMs)
 - Proactive alerts of runway incursions and surface traffic conflicts
- Runway incursion data:



Objectives



- Evaluate Conflict Detection and Resolution (CD&R) design criteria and assess the effect of traffic position accuracy on surface CD&R with humans-in-the-loop. (SURF IA focus)
- Evaluate ability to safely conduct airport surface operations while utilizing an Airport Moving Map (AMM) displaying traffic of various position accuracies. (SURF focus)

Definitions:

- CD&R – Conflict detection and resolution in the airport environment, within 3 miles from the runway threshold and below 1000 ft above field elevation
- SURF – *Airborne Traffic Situational Awareness for Surface Operations* - A traffic situation awareness application for reducing the potential for errors, runway and taxiway incursions, and collisions by providing enhanced situational awareness to the flight crew operating an aircraft on the airport surface (i.e. awareness derived from the cockpit display of traffic information (CDTI)). RTCA DO-322
- SURF IA – *Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts* - An application to reduce the likelihood and severity of runway incursions and collisions on or near the airport surface. Provides indications and alerts on a CDTI. Builds on SURF application. RTCA DO-323

Environment



- Research Flight Deck with motion
- Memphis (KMEM) airport
- 1800 ft RVR
- Transport category aircraft model
- Simulated ATC environment, human back-up
- ATC instructions via voice
- Head and eye tracking system
- ADS-B for traffic data

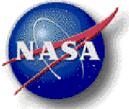


Research Flight Deck



- Electronic Flight Bags (EFB) – maximum primary field-of-view (AC 25-11A)





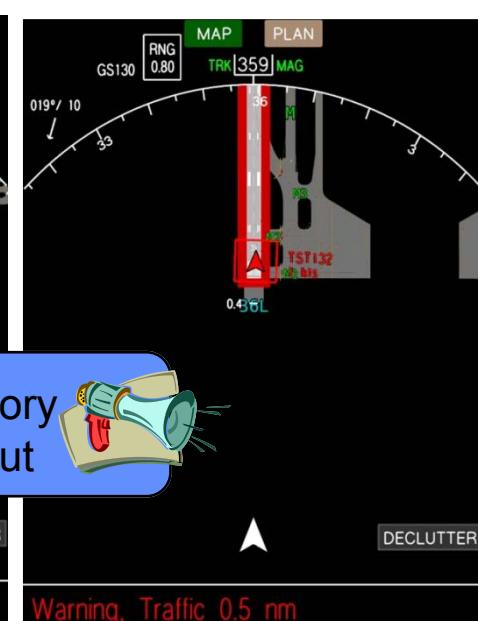
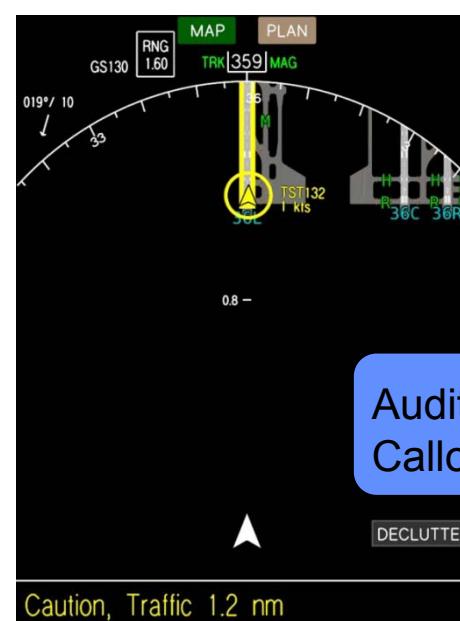
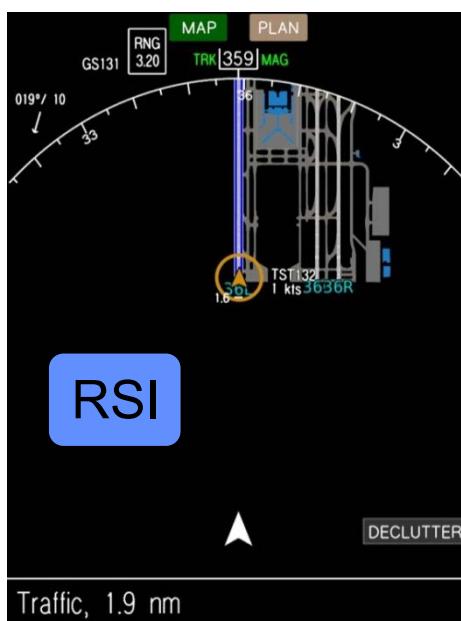
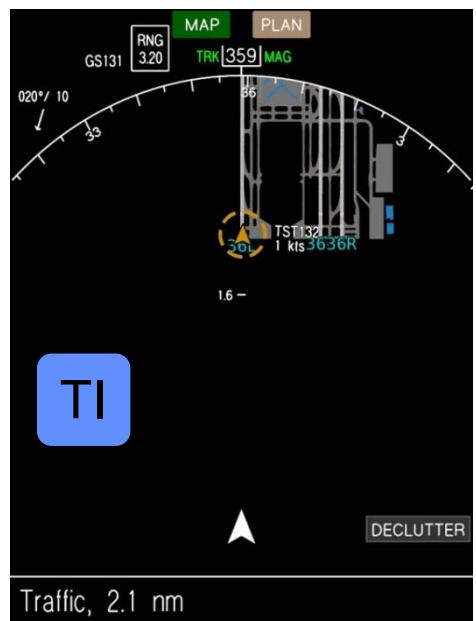
CD&R Capability

- SURF IA specifications used for runway conflict indication and alert (IA) generation
- Enhanced Traffic Situational Awareness on the Airport Surface with Indications and Alerts (SURF IA) application established by RTCA Special Committee 186
- Safety, performance, and interoperability requirements (SPR) published 2010, DO-323
- Identifies potential runway conflicts within 3 nm of the runway threshold and below 1000 ft above field elevation
- Utilizes traffic surveillance information from ADS-B In
- Generates IAs for a Cockpit Display of Traffic Information (CDTI)
- Same runway, very closely spaced parallel runway, and intersecting runway operating configurations
- *IAs only issued on traffic reporting accuracy equivalent to NACp 10 or 11*

Indications and Alerts (IA)



- Indications
 - Traffic Indication (TI) – highlights potential runway traffic collision/hazard that may emerge in the near future
 - Runway Status Indication (RSI) – identifies if runway is in-use or occupied by other traffic and not suitable for entering, takeoff, or landing
- Alerts
 - Caution – for conditions that require immediate flight crew awareness and subsequent flight crew response
 - Warning – for conditions that require immediate flight crew awareness and immediate flight crew response



ADS-B Model



- Gauss-Markov process to simulate time correlation between position measurement errors
- ADS-B transmission qualities and effects not modeled
- Positional data updated at 1 Hz rate
- NACp accuracy levels can be assigned to traffic individually

Definitions:

- NACp = Navigation Accuracy Category - Position
- 95% horizontal accuracy bound means that 95% of the time the horizontal position value will be within the bound listed
- EPU = Estimated Position Uncertainty
- FAA ADS-B Out Final Rule - NACp must be less than 0.05 nm (equivalent to NACp 8)
- SURF qualified traffic – traffic position accuracy of NACp 9 and higher
- SURF IA qualified traffic – traffic position accuracy of NACp 10 and higher

NACp	95% Horizontal Accuracy Bound (EPU)
8	EPU < 92.6 m (0.05 nm, 305.6 ft)
9	EPU < 30 m (99 ft)
10	EPU < 10 m (33 ft)
11	EPU < 3 m (9.9 ft)

Test Method



- 10 test trials per crew (8 nominal, 2 off-nominal)
- 2 AMM display conditions shown on EFB only
- Traffic position accuracy mix of NACp 8 to 11
- Auto-land approaches from 1600 ft HAT, land, taxi to ramp
- Departures begin at ramp, taxi to runway, and depart
- Taxi 15 kts whenever feasible
- Normal airport operations, follow ATC instructions
- 12 commercial flight crews
- Crews briefed and trained with concept

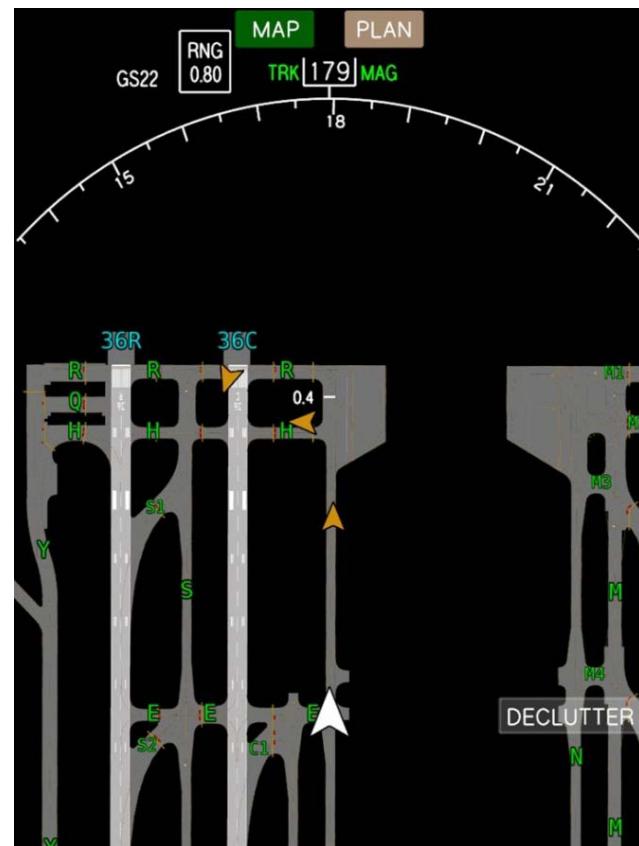
AMM Display Conditions



Map A



Map B



- Basic AMM
- Qualified traffic ($NACp \geq 9$)

- Basic AMM
- Qualified traffic ($NACp \geq 9$)
- Unqualified traffic ($NACp = 8$)

Experimental Design



Nominal Trials— Evaluate effect of displaying mixed traffic position accuracy on AMM during airport surface ops

	Approach Scenario 1	Approach Scenario 2	Departure Scenario 1	Departure Scenario 2
Map A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Map B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

- Map A showed qualified traffic only ($NACp \geq 9$)
- Map B showed all traffic on airport
- Within subjects, blocked by map type

Experimental Design Continued



Off-Nominal Trials- Test Runs 6 and 10 of 10 trials

Evaluate impact of displaying qualified vs. unqualified traffic on AMM during conflict situations

Crew	Scenario	Map Condition	Conflict Traffic Accuracy
1, 5, 9	Taxi crossing	A	8
	Departure	B	8
3, 7, 11	Taxi crossing	B	8
	Departure	A	8

- Map A showed qualified traffic only ($NACp \geq 9$), could only see conflict traffic out-the-window
- Map B showed all airport traffic, conflict traffic shown on map and out-the-window
- IAs not issued on conflict traffic

Experimental Design Continued



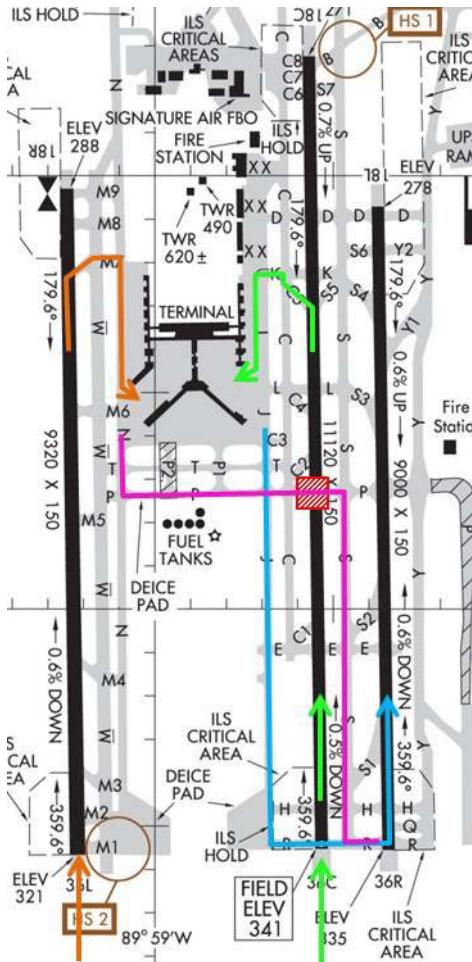
Off-Nominal Trials Continued -

Evaluate impact of receiving vs. not receiving IAs for traffic displayed on AMM during conflict situations

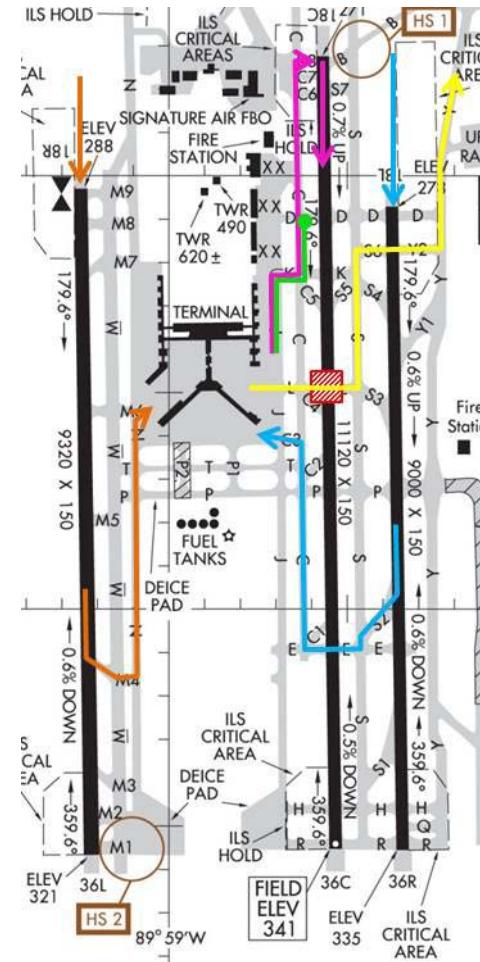
Crew	Scenario	Map Condition	Conflict Traffic Accuracy
2, 6, 10	Taxi crossing	A	9
	Departure	A	10
4, 8, 12	Taxi crossing	A	10
	Departure	A	9

- All conflict traffic shown on AMM since NACp 9 and 10
- No IA with NACp 9 accuracy
- IA with NACp 10 accuracy

Off-Nominal Scenarios



Taxi Crossing



Departure

- Magenta path represents ownship taxi clearance



For runway conflicts –

- Near collision
 - Horizontal distance < 300 ft
 - Vertical distance < 200 ft
- Collision
 - Horizontal distance < 150 ft
 - Vertical distance < 100 ft
- * Distance is between CGs (center-of-gravity)

Off-nominal Scenario Results



Evaluate impact of displaying qualified ($NACp \geq 9$) vs. unqualified ($NACp = 8$) traffic on AMM during conflict situations

	Taxi Crossing	Departure
Map A, NACp 8	3 crossed: 2 collisions, 1 near collision	2 departures, 1 high speed reject: 2 collisions, 1 near collision
Map B, NACp 8	1 crossed, 2 held short: 1 collision	1 departure, 2 held in position: 1 collision

- IA not issued on conflict traffic transmitting NACp 8
- Map A (conflict traffic not shown on AMM):
 - Action taken on 1 of 6 trials (17%) – not aware of traffic on 5 trials
 - 1 high speed reject (131 kt), stopped just before reaching traffic
- Map B (conflict traffic shown on AMM):
 - Action taken on 4 of 6 trials (67%)
 - 1 taxi crossing, unaware of traffic – checked AMM too early
 - 1 departure, saw traffic on AMM but not sure really on runway due to accuracy (symbol “dancing” on AMM)

Off-nominal Scenario Results



Evaluate impact of receiving vs. not receiving IAs for traffic displayed on AMM during conflict situations

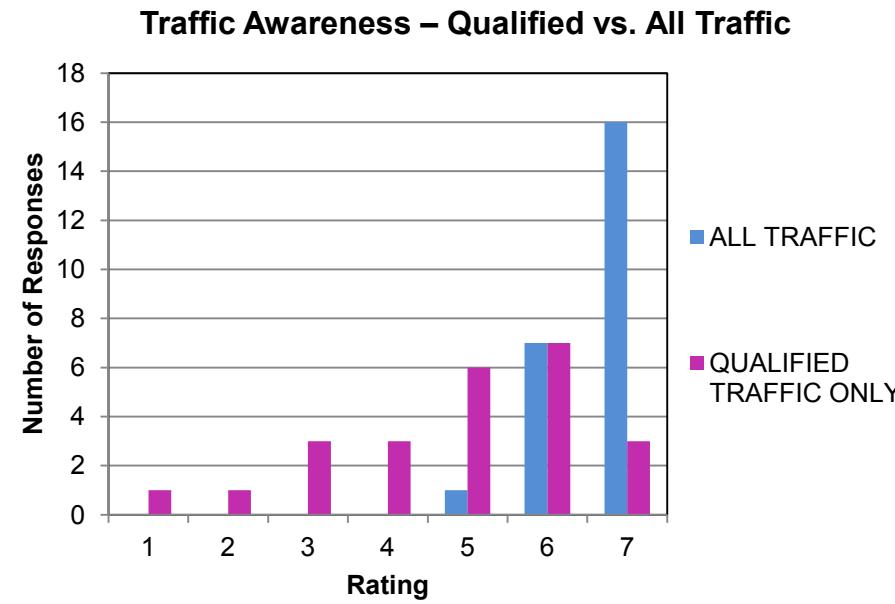
	Taxi Crossing	Departure
Map A, NACp 9	2 crossed, 1 held short: 2 collisions	1 departure, 2 crew rejected: 2 collisions
Map A, NACp 10	3 held short	1 held in position, 2 rejected

- All conflict traffic shown on AMM since NACp 9 or 10
- NACp 9 conflict traffic (no IA):
 - No action taken on 3 of 6 trials (50%) of trials
 - › 2 did not see traffic on AMM when crossing
 - › 1 saw traffic but not sure on runway due to accuracy
 - Action taken on 3 of 6 trials (50%) of trials
 - › 1 high speed reject (132 kt) and veer to right of traffic
- NACp 10 conflict traffic (IA issued):
 - Action taken on all 6 trials – 5 due to IA, 1 due to viewing traffic on AMM

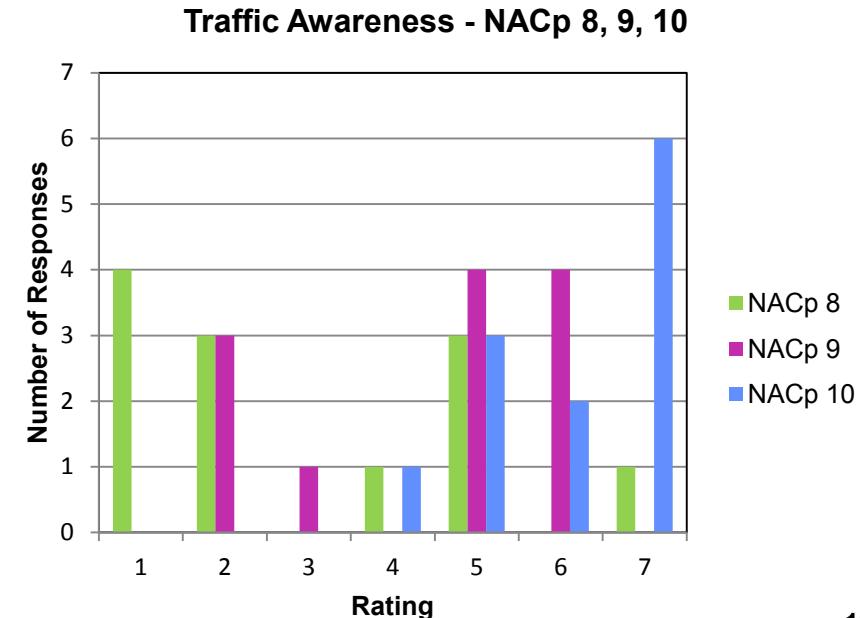
Traffic Awareness and Symbology Results



- Higher level of traffic awareness when all traffic displayed on AMM than when only qualified traffic ($NACp \geq 9$) displayed
- Statistically significant



- Traffic awareness greater when transmitting higher position accuracy
- Statistically significant

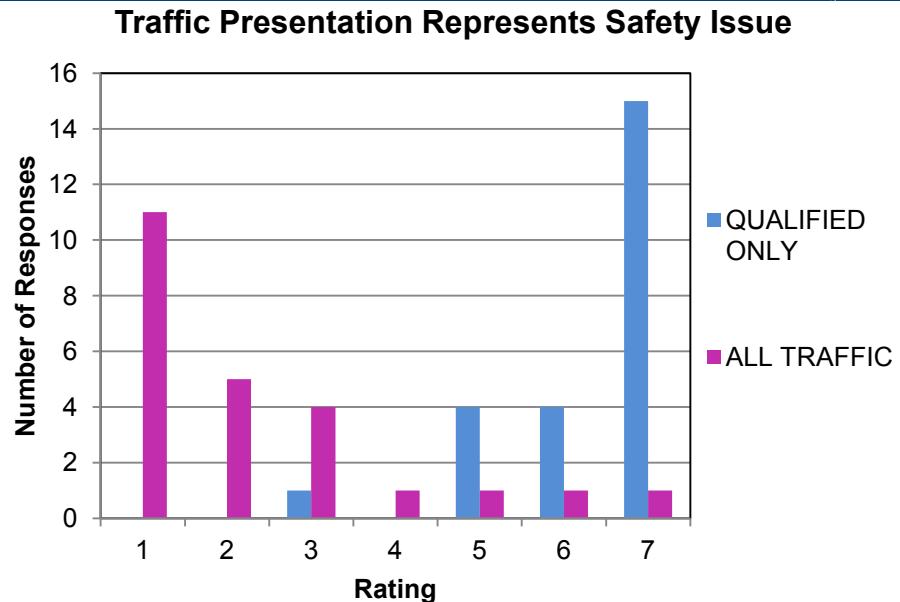


* Rating scale: 1 = strongly disagree, 7 = strongly agree

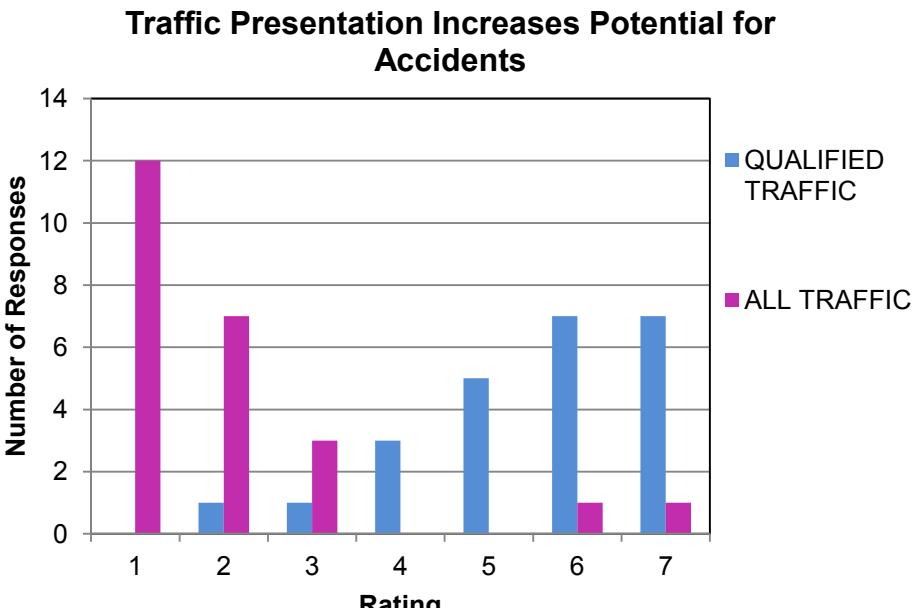
Traffic Awareness and Symbology Results



- Presentation of only qualified traffic ($NACp \geq 9$) on AMM is a greater safety issue than display of all traffic
- Statistically significant



- Presentation of only qualified traffic ($NACp \geq 9$) on AMM will increase potential for accidents
- Statistically significant

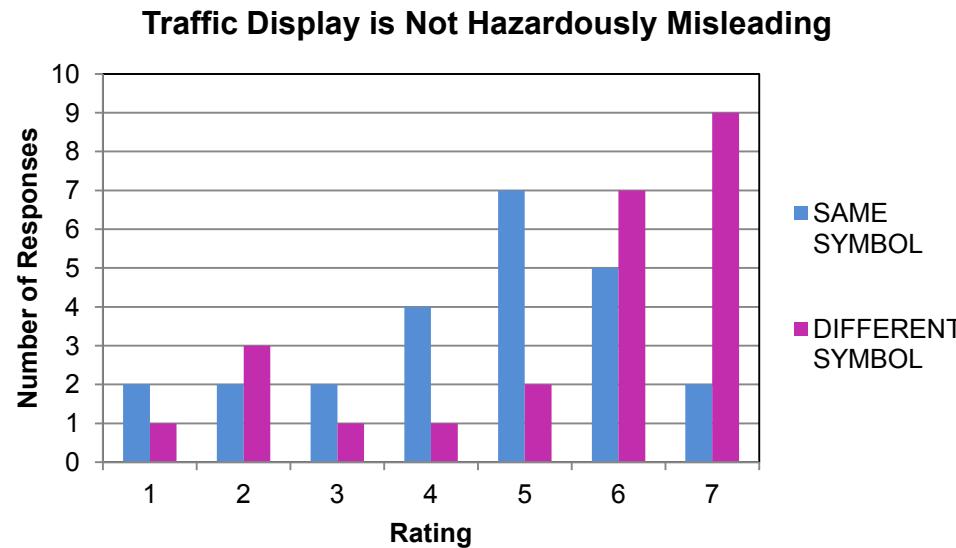


* Rating scale: 1 = strongly disagree, 7 = strongly agree

Traffic Awareness and Symbology Results



- Slight preference for using different symbology for qualified and unqualified traffic instead of the same symbology to avoid providing misleading information



- All traffic should be displayed on the AMM (23 of 24 pilots, confidence level of 6.4 mean, 0.6 SD)

* Rating scale: 1 = strongly disagree, 7 = strongly agree

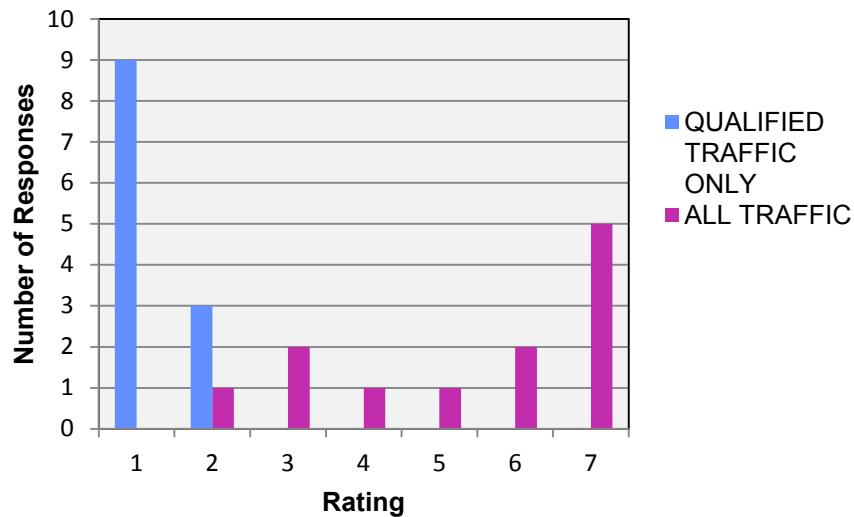
CD&R Symbology Results



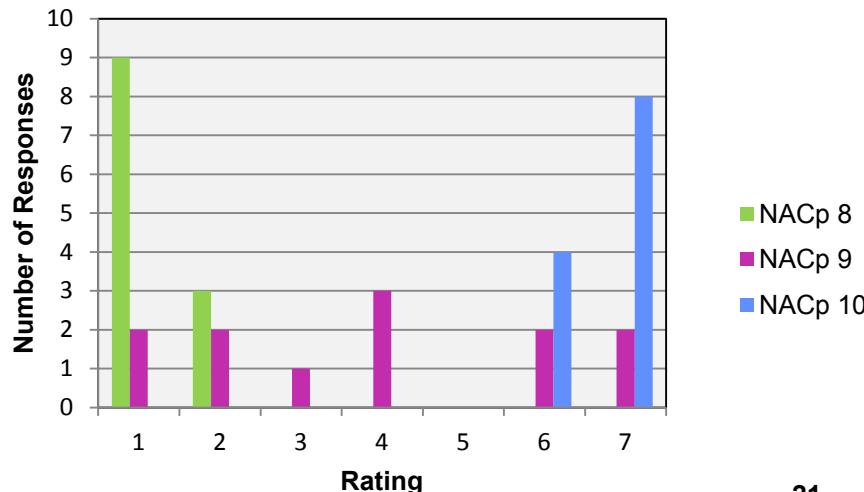
Detection of potential surface conflicts better when:

- All traffic displayed on AMM than when only qualified traffic ($NACp \geq 9$) displayed
 - Statistically significant
-
- Traffic transmitting higher position accuracy
 - Statistically significant

Potential Surface Conflict Detection Effectiveness – Qualified vs. All Traffic



Potential Surface Conflict Detection Effectiveness - $NACp 8, 9, 10$

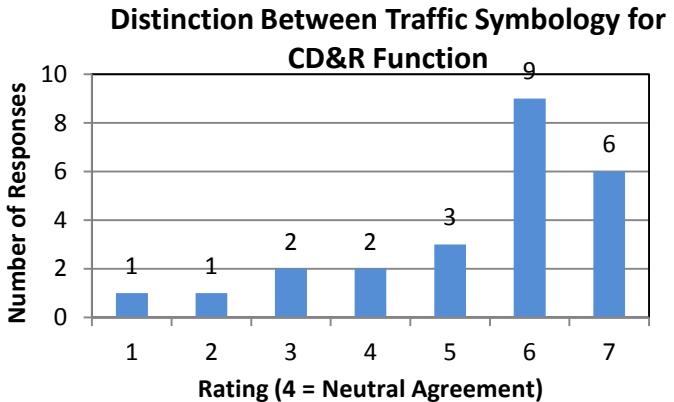
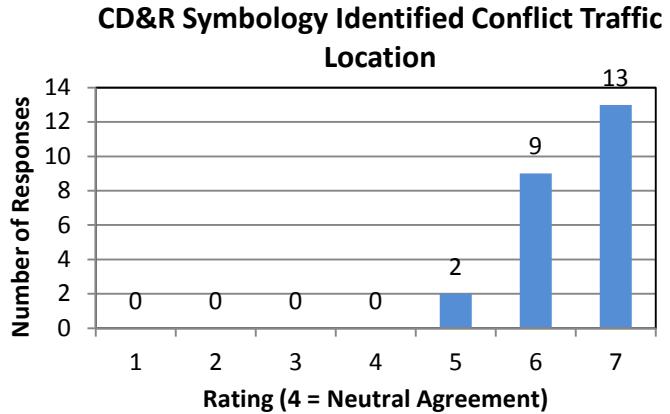
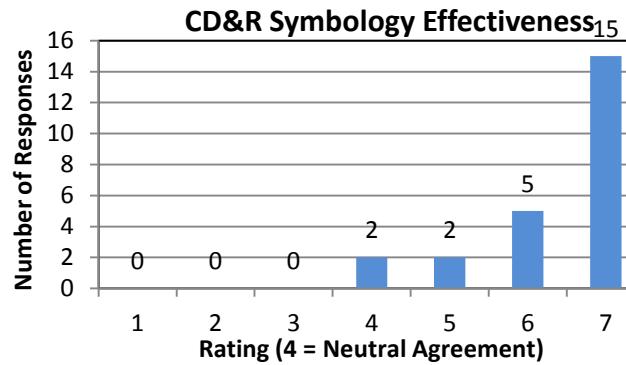


* Rating scale: 1 = strongly disagree, 7 = strongly agree

CD&R Symbology Results



- Effective in providing information on conflict traffic
- Provided a clear indication of the relative location of the conflict traffic
- Slight preference for using different symbology for traffic qualified for CD&R function



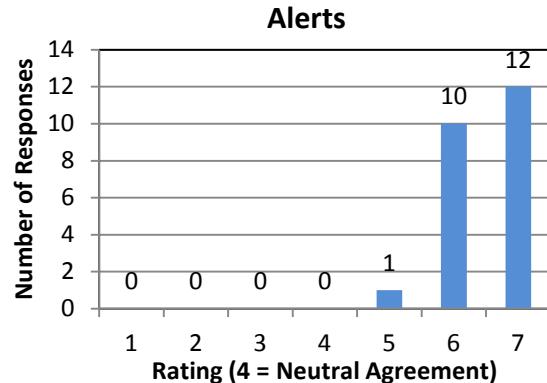
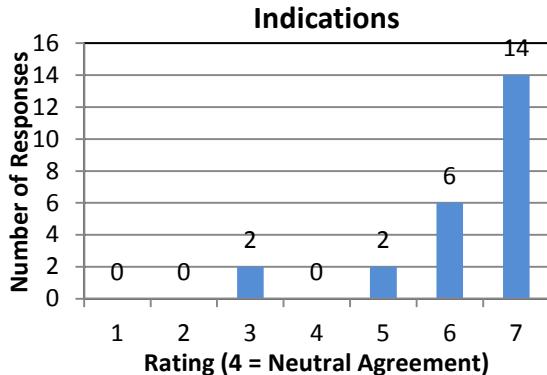
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CD&R Symbology Results

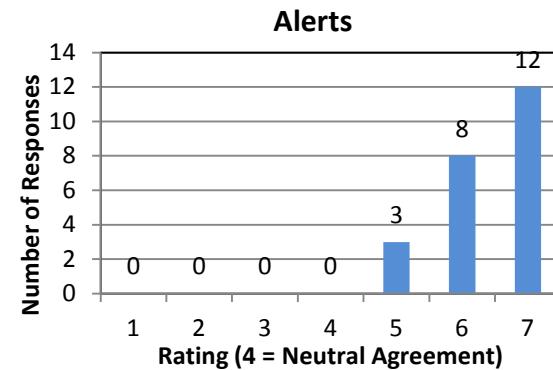
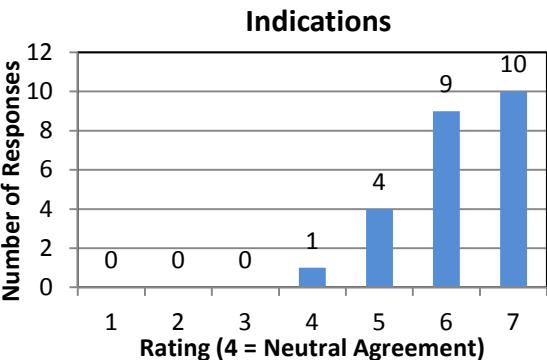


Indications and alerts were:

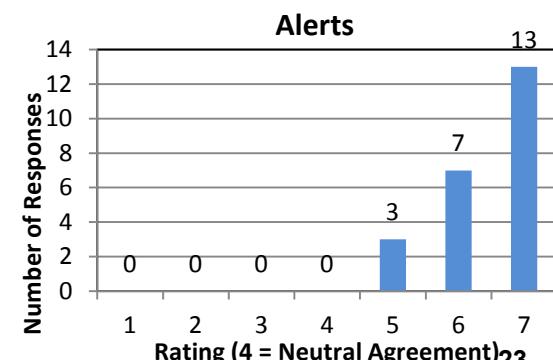
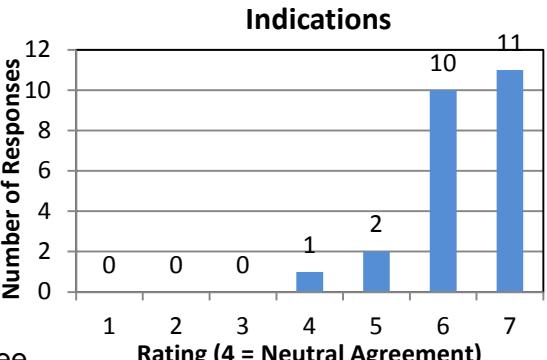
Helpful in determining critical runway safety information



Provided additional information over AMM traffic



Helped in determining location and movement of traffic relative to safety of own aircraft



Conclusions



- Display of all traffic on the AMM and increased position accuracy
 - Increased traffic awareness, including conflict traffic
 - Reduced collisions/near collisions
- Pilots indicated all traffic should be displayed on AMM
 - Increased safety
 - Reduce potential for accidents
- Display of NACp 8 traffic caused uncertainties, not sure if traffic a threat, further research necessary
- IAs were the most effective in preventing collision

Acronyms



ADS-B	Automatic Dependent Surveillance Broadcast
AMM	Airport Moving Map
ATC	Air Traffic Control
CD&R	Conflict Detection & Resolution
CDTI	Cockpit Display of Traffic Information
CG	Center-of-Gravity
EFB	Electronic Flight Bag
IA	Indications and Alerts
NACp	Navigation Accuracy Category for Position
RSI	Runway Status Indication
RVR	Runway Visual Range
SURF	Airborne Traffic Situational Awareness for Surface Operations
SURF IA	Enhanced Traffic Situational Awareness on the Airport with Indications and Alerts
TI	Traffic Indication