



# **Enabling Strategic Flight Deck Route Re-Planning Within A Modified ATC Environment: The Display of 4/D Intent Information on a CSD**

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# Outline

- Air ground concept
  - Airspace
  - Roles and responsibilities
- CDTI design goals
- Full mission simulation
  - Objectives
  - Procedures
- CDTI and ATC displays
- Results
- Conclusions



# An Air-Ground Strategic Self-Separation Concept

- Free flight airspace in which current intent is shared between ATC and all aircraft
  - 3-D flight plans including waypoints for
    - start & top of climb
    - top & bottom of descent
    - changes to speed (*Not included in Present Study*)
  - State information (position, velocity, etc.)



# An Air-Ground Strategic Self-Separation Concept (cont.)

- Roles and responsibilities
  - The flight deck may identify and resolve strategic conflicts by submitting flight plan changes to ATC for approval (via data link), approved changes are broadcast
  - Under nominal conditions ATC allows flight deck to handle strategic self-separation
  - The controller has ultimate authority and responsibility for separation assurance



## Goals of CDTI Design

- Maintain at-a-glance viewing (low workload)
- Provide 4-D situational awareness
- Provide conflict alerting
- Provide a path replanning tool (conflict probe & graphical front end to FMS)
- Provide means to datalink revised flight plans to ATC for review



## Simulation Study Objectives

- To assess the value of 4/D intent information (flight plans) for flight crews performing strategic self separation during en route free flight operations.
- To obtain display usage measures for the various display tools.
- To obtain flight crew feedback on utility (effectiveness and workload) of specific display features and overall display design.
- \*\*\* To obtain measures of flight crew / ATC coordination
- \*\*\* To obtain measures of effectiveness of procedures emphasizing low and high ATC responsibility



# Tools & Procedures

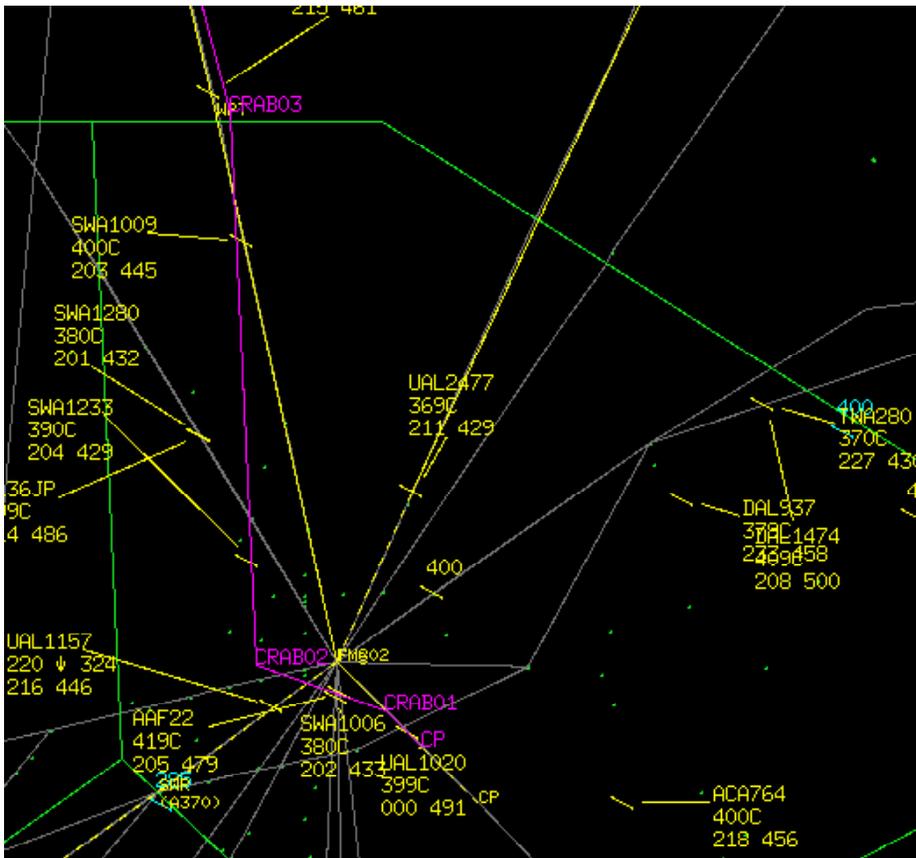
- Eight 747-400 flight crews managed separation utilizing CDTI
  - Basic Display
  - Alerting System
  - Advanced Route Analysis Tool
- Flight crew procedures
  - Develop resolutions
  - Data-link proposed resolutions to ATC
  - Implement upon agreement from ATC
- ATC Procedures - full authority and responsibility
  - Normal Operations ñ intervene at any time
  - Delay intervention ñ without adversely impacting sector operations, allow flight crews to self-separate







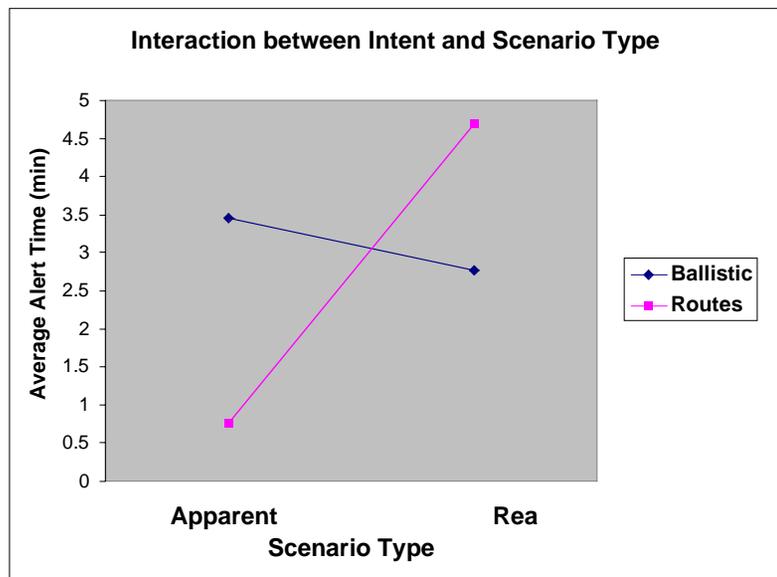
# Controller Approves Flight Plan Change



- ATC receives proposed de-conflicted flight path ñ graphic overlay on display
- Evaluates proposed routing and traffic
- Approves change



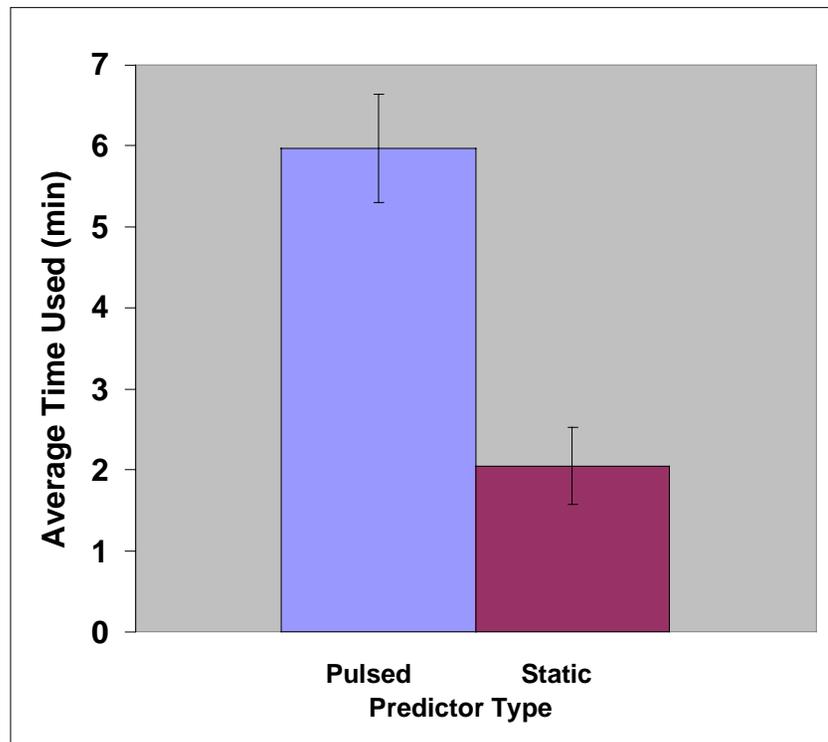
# Time in Alert By Intent And Conflict Type



- Apparent conflicts ñ alert duration was significantly reduced with 4-D routes information
- Real conflicts ñ alert duration was significantly increased with 4-D route information
- With 4-D flight plans crews were not subject to the false alarms that occurred when ballistic (non-flight plan based) alerting logic was used



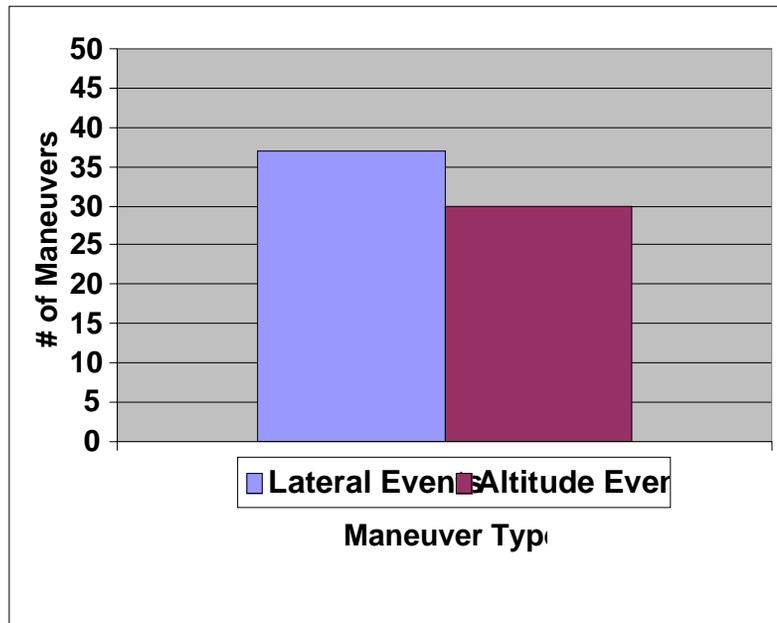
## Crew Use of Static VS Pulse Predictors



- Crews used the pulse predictor significantly more than the static predictor
- Comment: Crews reported a preference for the pulse predictor and suggested that it should be selectable for individual aircraft



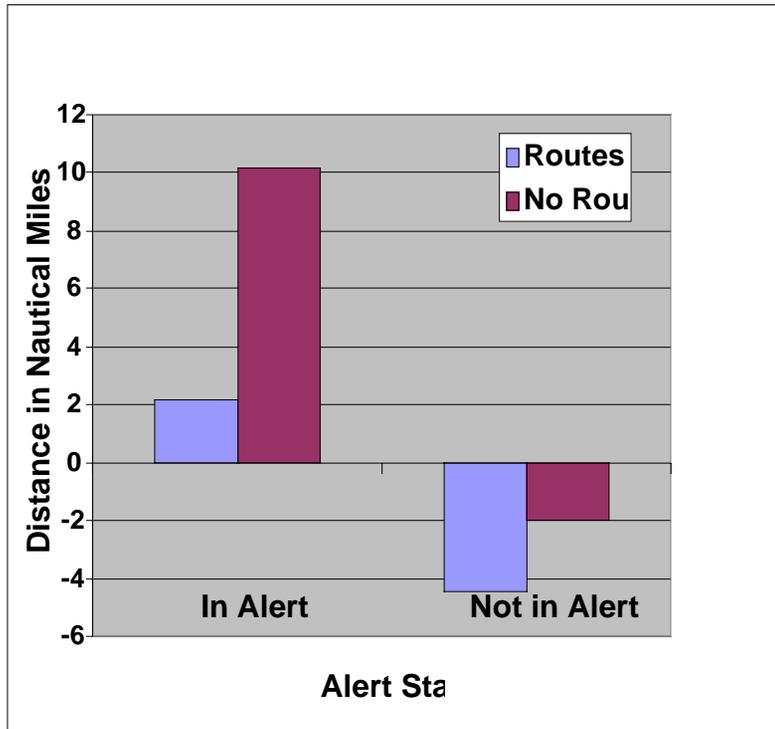
# Maneuvers Selection



- Flight Crews utilized both vertical and horizontal maneuvers during flight path re-planning
- Note: During the simulation the B-747 was normally below its flight economy ceiling.



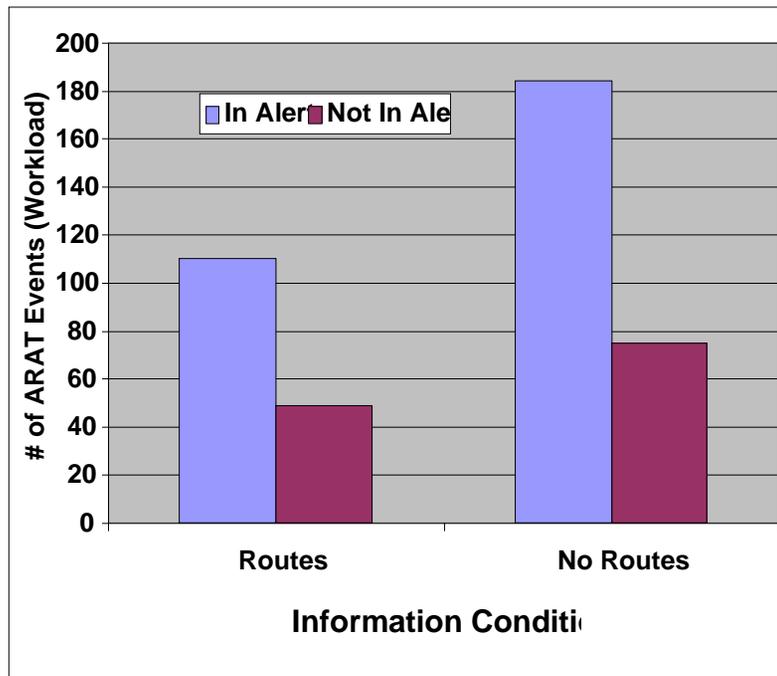
# Lateral Maneuver Distances by Route Condition



- Maneuvers made during alerts resulted in significantly smaller route deviations (distance) when crews had 4-D route information
- Maneuvers made during non-alert events resulted in significant reductions in trip length (distance) when crews had 4-D route information



# Number of ARAT Events by Routes Conditions



- During both alerts and non-alerts ñ crews performed significantly fewer ARAT activities when 4-D route information was available



## Results - Questionnaire

- Post simulation, crews responded to a Likert scale format (1-7 scale) - generally 1 negative, and 7 positive, or preferences with either choice anchoring the scale (e.g., 1- static and 7 - pulse predictors)
- A neutral position of 4 was used as an anchor to evaluate ratings that were significantly ( $p < 0.05$ ) above or below the anchor, on a two tailed t-test.



## Results: Display Clutter with and Without ARAT

- **Neutral** responses for clutter with both ARAT -M=4.13, and without ARAT -M=4.5
  - Flight crews reported that # of aircraft were the main cause of display clutter
  - They suggested that the ability to remove aircraft that were flying away at a different altitude (assumed no longer a threat) could help solve this problem



## Results: Text Size and Readability

- **Positive** response
  - Tail tags,  $M=5.69$
  - Aircraft ID blocks,  $M=6.0$
  - Flight plan waypoint names,  $M=5.78$
- **Neutral** response
  - ARAT waypoint names,  $M=4.44$



## Results: Aircraft Symbols

- Ownship and traffic (size, shape, altitude format, 1 minute predictor, & brightness), **positive** M=5.97
- Color coding of relative altitudes (blue -above, green - below, and white -same altitude), **Positive** M=6.37
- Comment:
  - The color coding allowed an instant recognition of the traffic situation.
  - Brightness levels were not as effective.



## Results: Flight Plans

- **Positive** response to flight plans (symbol size, shape, waypoints, & altitude segment),  $M=5.75$
- **Positive** response to the use of color in the flight plan,  $M=5.84$

**Comment: Broken (dotted ) line was very effective for showing altitude change segments**



## Results: Input Controls

- Predictor panel mounted controls
  - Ease of use, **positive**, M=5.61
  - Desirability, **positive**, M=5.47
- ARAT panel mounted controls
  - Ease of use, **neutral**, M=4.94
  - Desirability, **neutral**, M=5.33
- Touch Pad predictor and ARAT
  - Ease of use, **neutral**, M=4.69, & M=4.5
  - Desirability, **neutral**, M=4.47, & M=4.18



## **Results: Aircraft ID Blocks**

- 15 of 16 flight crew members reported that information in the flight ID block was necessary
- Comment: One addition to the current information set was suggested - final altitude for climbing and descending aircraft



## Results: Predictors

- Static, **neutral**  $M=4.44$
- Pulse, **very positive**  $M=6.66$
- Preference (1-static or 7-pulse), **positive**  $M=6.03$
- Input devices - controlling predictors
  - Control panel, **positive**  $M=5.56$
  - Touch Pad, **neutral**  $M=4.22$
  - Preference (1 - control panel to 7 - touch pad),  $M=3.28$



## Result: Alerts

- Alert Symbology
  - Overall (shape, sound and function), **positive** M=5.63
  - Effectiveness when ARAT engaged, **positive** M=5.82
  - ARAT symbology (size, shape, waypoints, altitude segment, and waypoint table), **positive** M=5.50
- Alert Resolution
  - Preference for vertical or lateral maneuver, **neutral** M=4.47
  - Location of initial maneuver (1 - near or 7 - away from ownship), **neutral** M=4.38
  - Value of flight plan, **positive** M=5.47
- Alert timing
  - Minimum desired time before loss of separation for alert level 3, M=5.63
  - Minimum amount of time needed to design, submit, approve and load flight plan changes, M=2.43 minutes ahead of ownship (current design is 1.50)



# Conclusions

- Flight crew efficiency and workload was reduced with 4-D flight plan information
  - Smaller deviations for traffic
  - Reduced trip length associated with non traffic related maneuvers
  - Fewer ARAT events (less workload)
- Crew responses to 3-D and 4-D traffic information, display clutter, and flight re-planning tools.
  - Positive response to 3-D flight plans
  - Positive response to pulse predictor
  - Positive response to altitude color coding (both flight plan & traffic)
  - Neutral response to clutter management tools
- Ratings showed that crews had difficulty with the ARAT controls.
  - Neutral ratings for both input devices, panel and touch pad