



Controller Managed Spacing Study

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Controller Managed Spacing Study

Objective

- Determine through fast-time and human-in-the-loop simulations how well controllers with and without an enhanced display based on nominal 4D trajectories can cope with disturbances and manage spacing of arrival aircraft on RNAV RNP routes with Optimized Profile Descents (i.e. Continuous Descent Arrivals - CDAs).



Controller Managed Spacing Study

Motivation

Enable quiet, fuel efficient Optimized Profile
Descent operations with high throughput.



Road Map

- Airborne Merging and Spacing ... DAG-CE-11
- Trajectory Oriented Operations With Limited Delegation
- Continuous Descent Arrival (CDA) analysis (TASAT) and field studies
- **This series of studies focuses on controller procedures, displays and tools for managing spacing of arrival aircraft in a mid-term time frame**
- Future studies will focus on super-density operations with controller tools and a proportion of aircraft equipped for airborne Required Time of Arrival, Flight Deck Merging and Spacing and/or Close Spaced Parallel Approaches



Background

- TIMER and FASA
- FAST ... speed and heading advisories
- CTAS / FMS ... uplink of a FAST computed path
- DAG CE-11 ... flight deck merging and spacing & history circles
- Ghosting displays ... CRDA, RPI, ...
- CDA ... TASAT design tool and operational trials at SDF, ATL & LAX
- TRUST ... speed advisories on RNAV procedures
- TOOWiLD ... RNAV procedures, CDAs & FDMS
- SPACR



Operational Concept for Controlling Arrival Aircraft on RNAV RNP / CDA routes

Time-based metering provides runway arrival schedule and time constraint for inbound aircraft.

En route speed assignments delivers aircraft so they are correctly spaced for descending on the RNAV RNP/CDA route.

Flight crews fly VNAV descents along RNAV RNP route – largely without controller intervention.

Aircraft are delivered to TRACON boundary according to a time schedule. Aircraft arrive with spacing errors that need to be reduced to maximize throughput and minimize spacing violations.

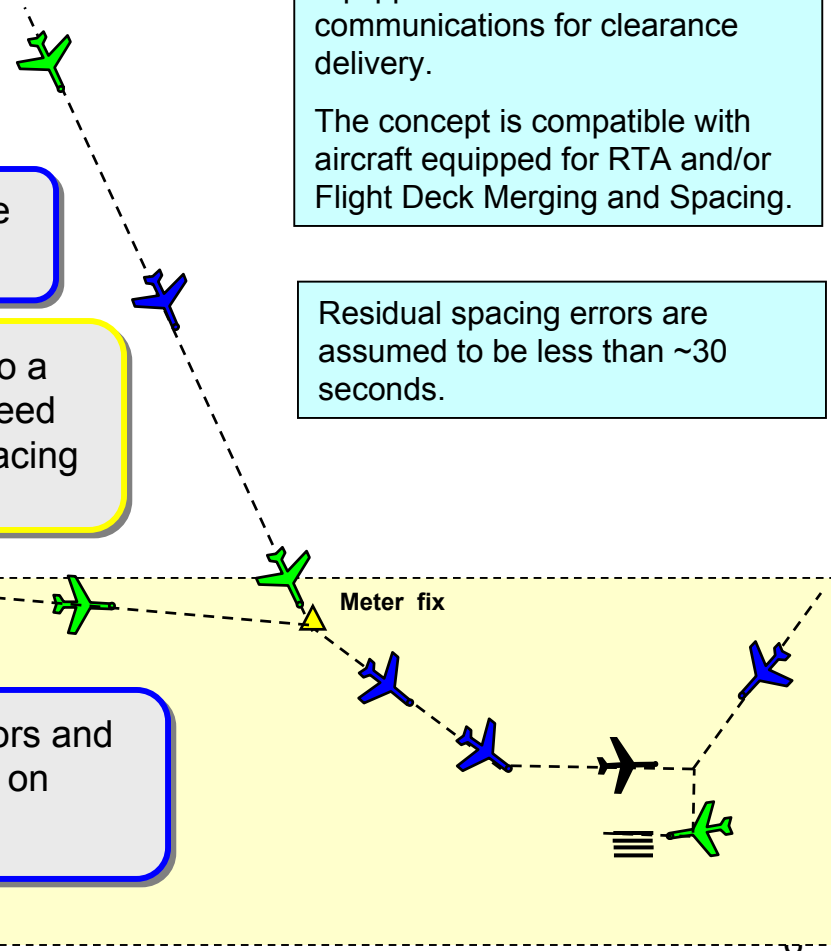
Focus of this study:

TRACON controllers correct residual spacing errors and cope with disturbances using a display aid based on nominal 4D trajectories.

Aircraft are assumed to be FMS equipped but generally not equipped with data communications for clearance delivery.

The concept is compatible with aircraft equipped for RTA and/or Flight Deck Merging and Spacing.

Residual spacing errors are assumed to be less than ~30 seconds.





RNAV RNP / CDA Design Goals and Issues (CDA = Optimized Profile Descent)

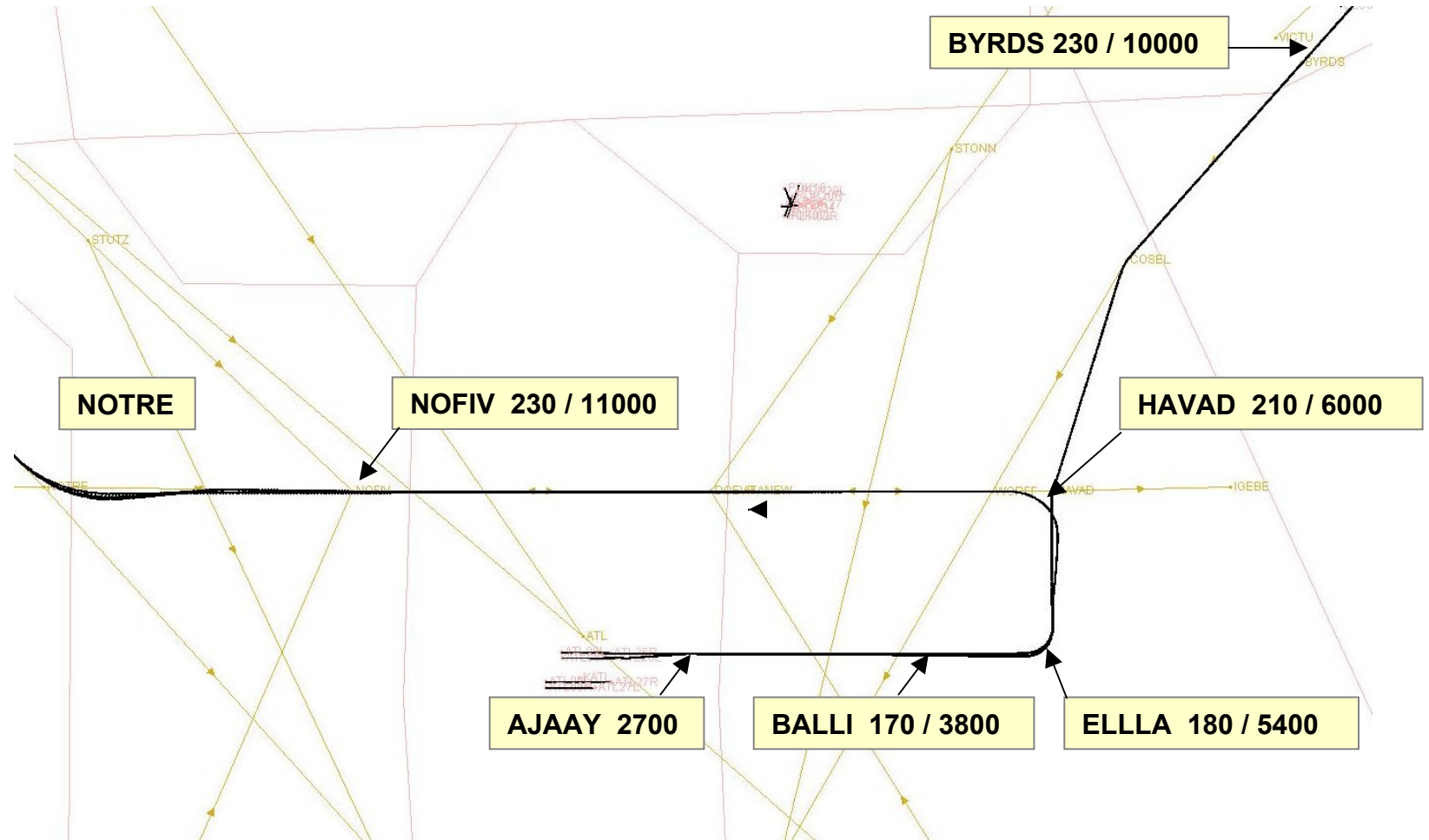
- Altitude and speed restrictions to regularize the vertical profiles of arriving aircraft ... like the LAX RIIVR ONE
- Non-idle profile sections to allow speed control for adjusting spacing
- Airspace provided to allow lateral path adjustments
- Video map markers and/or range rings to aid controllers in no tools conditions ... like the LAX RIIVR ONE

Collaborating with the ASDO Flight Management System (FMS) tasks (Dave Williams) and FAA CDA ATL 2.0 Field Trials (John-Paul Clarke) on RNAV RNP / CDA procedure design.



NOTRE1 and DIRTY1 RNAV Procedures

(Based on the RNAV procedures proposed for ATL 2.0 CDA Study)

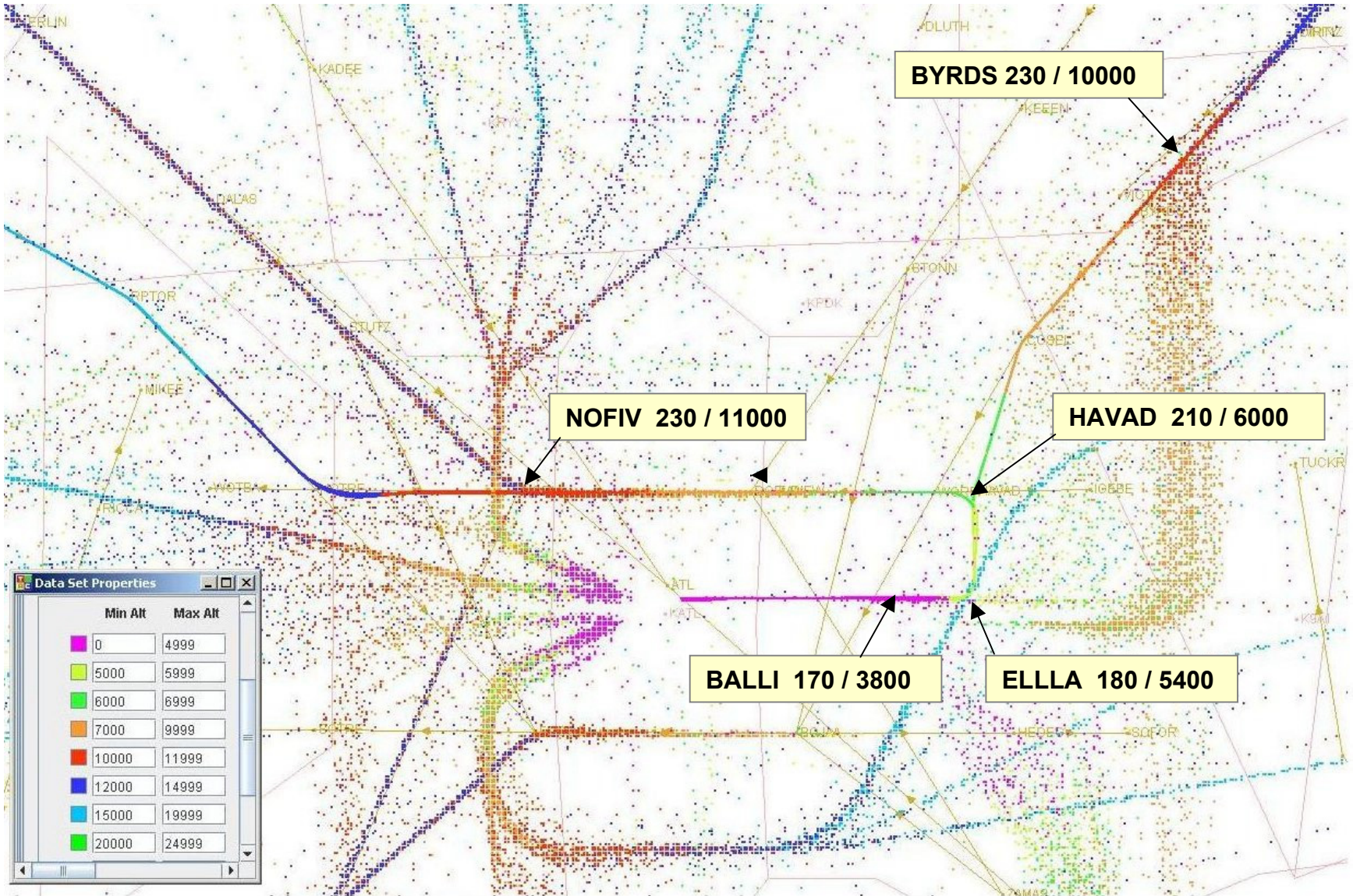


The altitude restrictions at NOFIV & BYRDS provide descent angles to HAVAD of -2.24 & -2.46 degrees.

ELLLA is 4.7nm east of BALLI and positioned so that it is aligned with HAVAD.

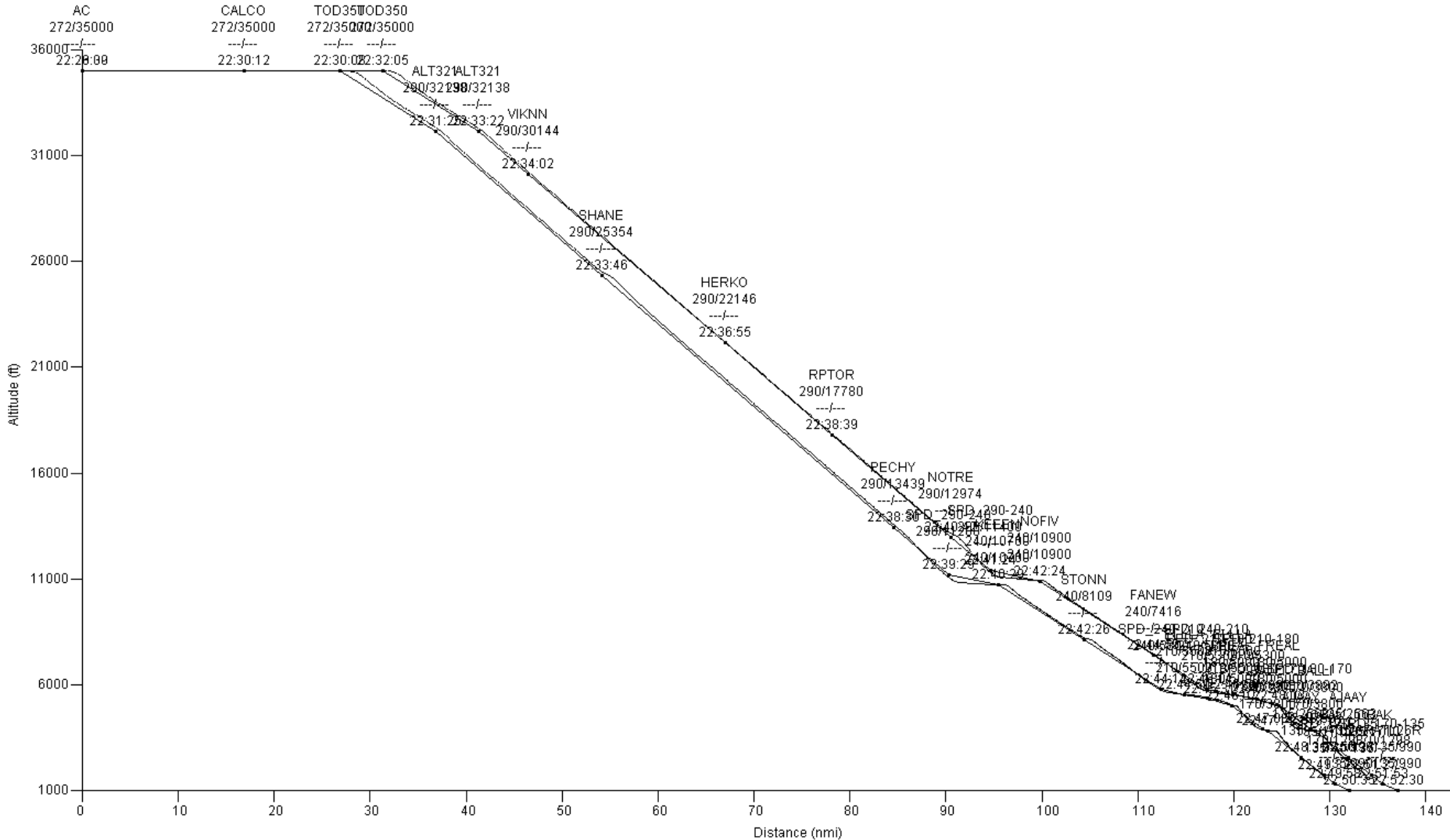


NOTRE1 and DIRTY1 RNAV Procedures (With track data from Atlanta Center)





MACS FMS Vertical Profiles as Depicted in TRAC



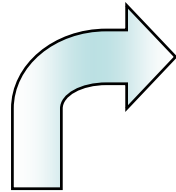
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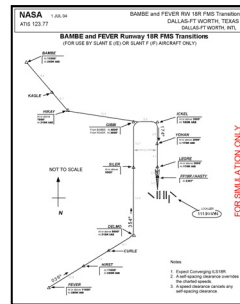
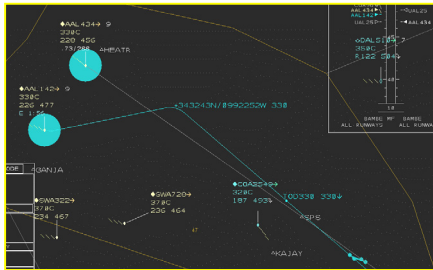


Human-in-the-Loop Simulation

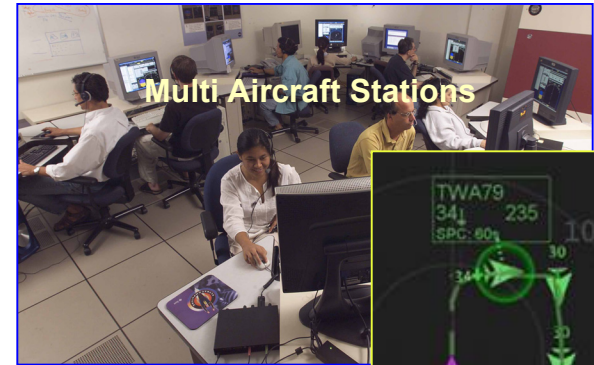
Multi-Aircraft Control System (MACS)



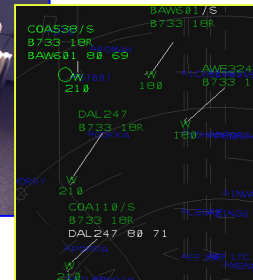
Pilot stations with FMS and advanced CDTI, ASAS and data link



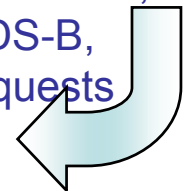
FMS procedures



Controller stations emulating current and advanced surveillance, automation, and data link capabilities



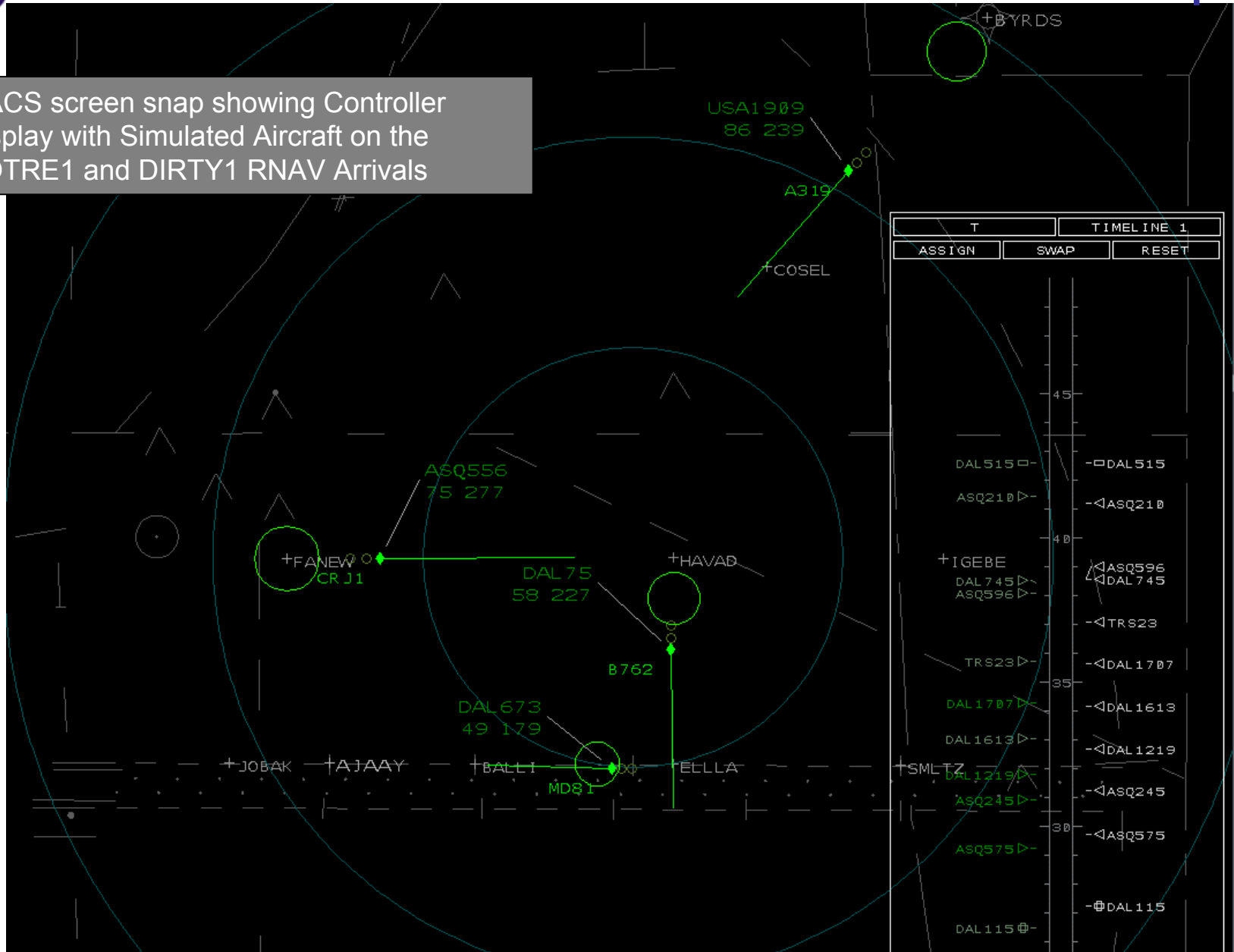
Standard voice com., DataCom, ADS-B, Trajectory requests





MACS Emulated TRACON STARS Display

MACS screen snap showing Controller Display with Simulated Aircraft on the NOTRE1 and DIRTY1 RNAV Arrivals



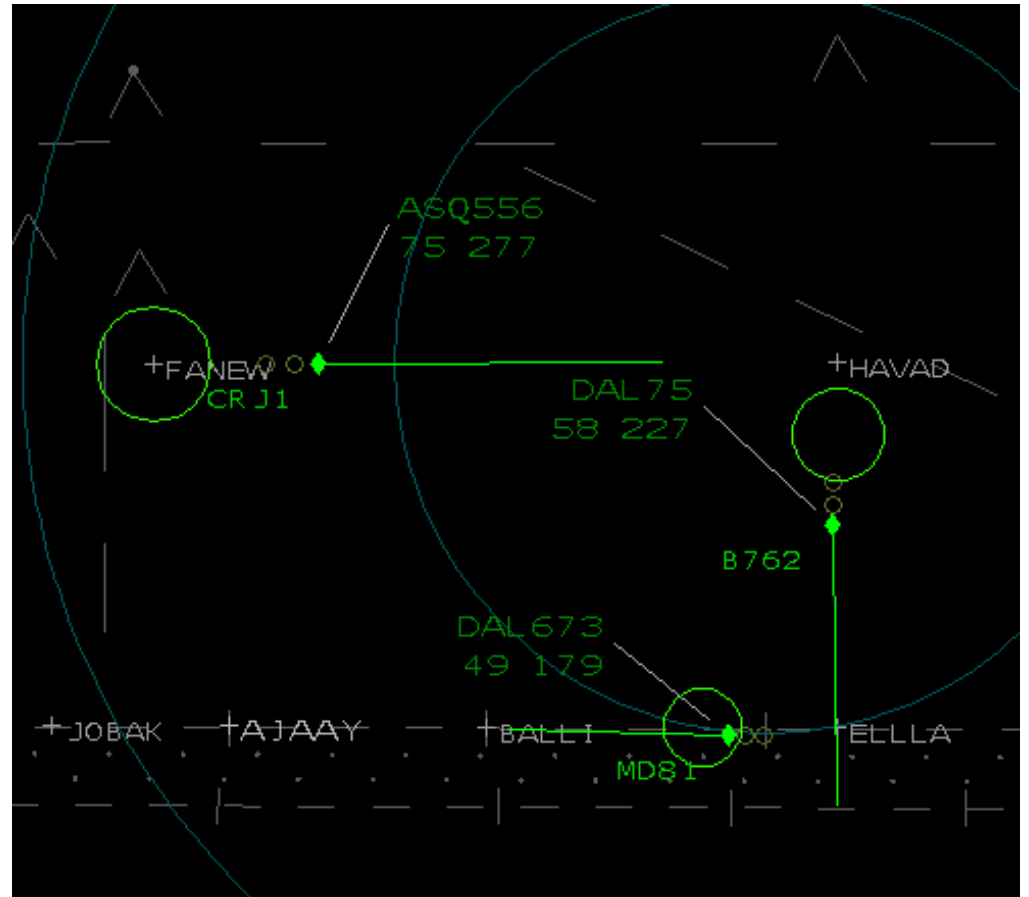


Controller Display with Slot Markers

Enhanced controller display showing a mockup of slot markers of desired aircraft position based on each aircraft's nominal 4D trajectory.

The slot markers show where the aircraft should be if it flies the nominal RNAV arrival procedure through the estimated wind field and arrives at the runway threshold on schedule correctly spaced behind the aircraft ahead of it.

The display provides a reference that allows the controller to assess each aircraft's progress and intervene as necessary to deliver the aircraft on schedule.



The radius of the slot marker circle is 10 seconds.



Slot Marker Calculations

- Calculate ETAs for the schedule point (the runway)
- Calculate STAs for the schedule point (the runway)
- Calculate nominal 4D trajectory for the aircraft that will arrive at the schedule point at the STA
- Display the “now” position for the aircraft’s nominal 4D trajectory on the controller’s display

Why this concept:

- Compatible with OPD / CDA concept
- Minimize uncertainties due to trajectory prediction errors
- History spacing circles did not support merging task
- Compatible with monitoring self-spacing or RTA aircraft.



Multi-Pilot Station

The screenshot displays the Multi-Pilot Station (MBS) software interface for flight DAL 115. The interface is divided into several panels:

- Top Bar:** Shows system information including "Developer-Lite: guest", "Pilot-Config: plan_b(Enabled)", "ATC-Sector: ZTL_256(Enabled)", "ADRS: offline (offline)", and "16 flights". The current time is 18:16:30. Control buttons for A/C, MULTI (selected), DSR, STARS, ATM, VIEW, and ADMIN are visible.
- MBS ABOUT Panel:** Lists flight numbers and aircraft types, such as ASQ210 (CRJ1 ARR), ASQ245 (CRJ1 ARR), ASQ556 (CRJ1 ARR), ASQ575 (CRJ1 ARR), ASQ596 (CRJ1 ARR), DAL 115 (B762 ARR - highlighted), DAL 1219 (MD81 ARR), DAL 1613 (MD81 ARR), DAL 1707 (B735 ARR), DAL 515 (B752 ARR), DAL 673 (MD81 ARR), DAL 689 (B752 ARR), DAL 745 (B735 ARR), DAL 75 (B762 ARR), TRS23 (B735 ARR), and USA1909 (A319 ARR).
- MBS Pilot Handoff Panel:** Shows flight parameters: 110.0, 119.87, 120.0, and CONTROL.
- MBS Mode Control Panel:** Displays current speed (230), heading (226), altitude (9911), and vertical speed (-1345). It includes controls for speed selection (SPD SEL, VNAV, SPACING, MACH), heading selection (HDG SEL, LNAV), and altitude selection (FLCH, VNAV, VS). Vertical speed is set to 6000 and -1338.
- MBS PFD Panel:** Shows a Primary Flight Display with "FINAL DESCENT" mode. It includes altitude (280 to 180), speed (230), heading (210 to 240), and vertical speed (10500 to 1928) scales. A central heading indicator shows 001.
- MBS FMS VNAV Panel:** Shows vertical navigation settings: CRZ ALT (35000), CLB SPD (280), CRZ SPD (Mach .80), and DES SPD (300). It also includes RTA (RTA AT, RTA) and RTA ACTIVE controls.
- MBS CDU Panel:** Displays the active route (RTE 1 LEGS 1/2) with waypoints: 223°/7 NM COSEL (230/7795), 199°/7 NM HAVAD (210/6000), 151°/5 NM ELLLA (180/5400), 272°/5 NM BALLI (170/3800), 271°/3 NM AUAAY (140/2669), and AUAAY. It includes a keyboard interface for entering data.
- MBS MAP Panel:** Shows a map view with flight path, heading (223), magnetic heading (MAG), and time to go (GS 243, TAS 265, 254/25). Waypoints include ATL26R, AUAAY, ELLLA, HAVAD, COSEL, and BYRDS.
- MBS Flaps/Gear Panel:** Shows speed brakes (Off), landing gear (Auto), and flaps settings (Auto).

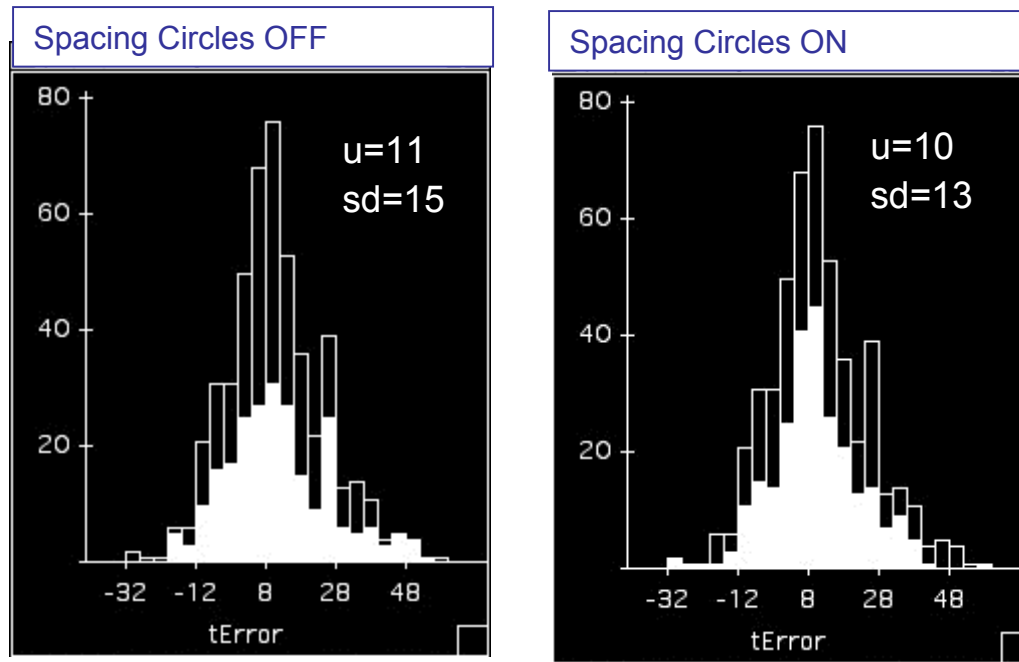


Study Design

- Run each team for 4 days
- 4 30 minute scenarios per half day
- Data runs: 4 ... 8... 8... 4
- 3 experimental conditions → 8 different conditions
 - Display / Tool ... 2 levels
 - Wind uncertainty ... 2 levels
 - Control method ... 2 levels
- 3 replications per condition → 24 runs per team
- 4 teams



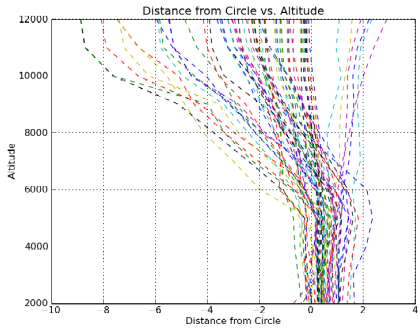
Preliminary Results



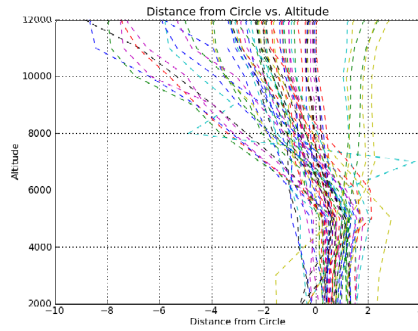
Histogram of aircraft spacing error at the outer marker (AJAAY)



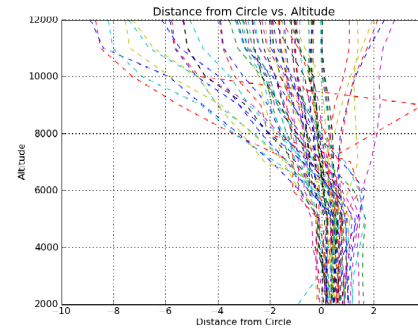
Distance from aircraft to the slot marker vs. altitude



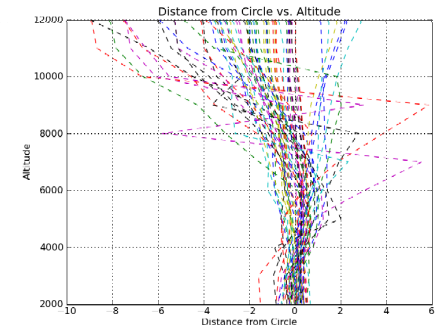
tool ON Team A



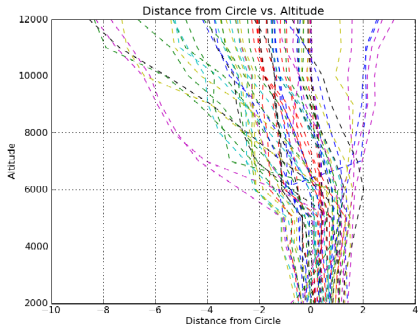
tool ON Team B



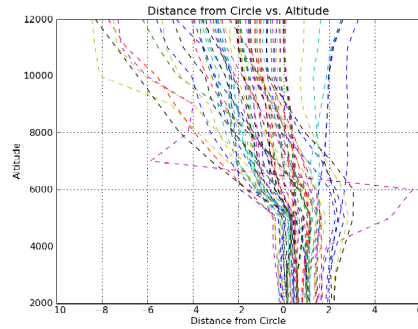
tool ON Team C



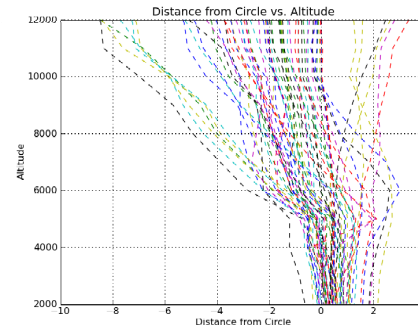
tool ON Team D



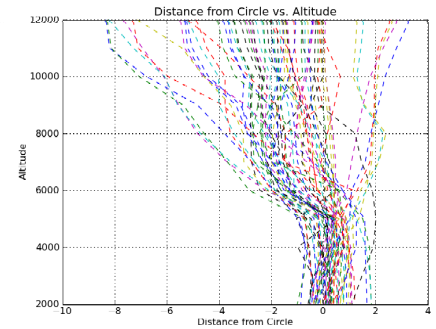
tool OFF Team A



tool OFF Team B



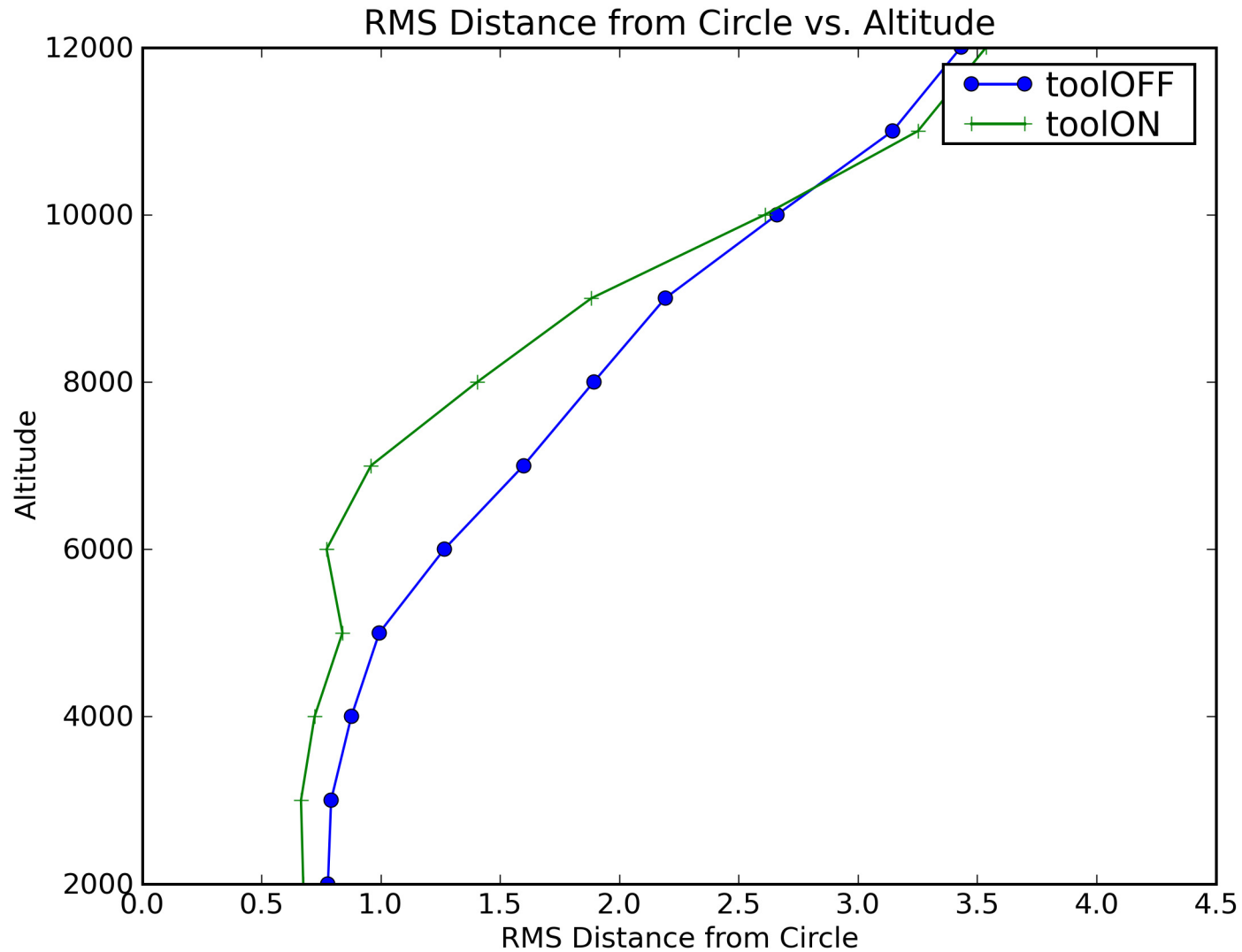
tool OFF Team B



tool OFF Team B



RMS of distance from aircraft to the slot marker vs. altitude





Plans

- Follow up study with slot markers and training on control strategies
- Fast-time simulation and control power / delay buffering analysis of routes for next study
- Study with path and speed advisory tools in June 2009
- Study with some aircraft equipped for Flight Deck Merging & Spacing in June 2010



Questions!

