Session 84-GNC-49: "Highlights from the FAA Support of the National Airspace System"

Paper AIAA-2009-6080:

"Improving Ground- Based Trajectory Prediction Through Communication of Aircraft Intent"

Presented to: AIAA GNC, Chicago, IL

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Federal Aviation Administration

The Boeing FAA CRDA TBO

Boeing FAA CRDA

No. 02-CRDA-0171

Five-year collaboration designed to facilitate technology development in Trajectory-Based Operations

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Duration: 2007- 2011

2007/2008:

- **Proof of Concept**
- **The outcome was published last year at AIAA**
  - "A Demonstration of an Aircraft Intent Interchange Specification for Facilitating Trajectory-Based Operations in the National Airspace System"

2009 :

- **Demonstration**
  - Study accuracy of trajectory prediction with and without using AIDL.

2010/2011:

- **Further expand the efforts in demonstration and validation of AIDL**

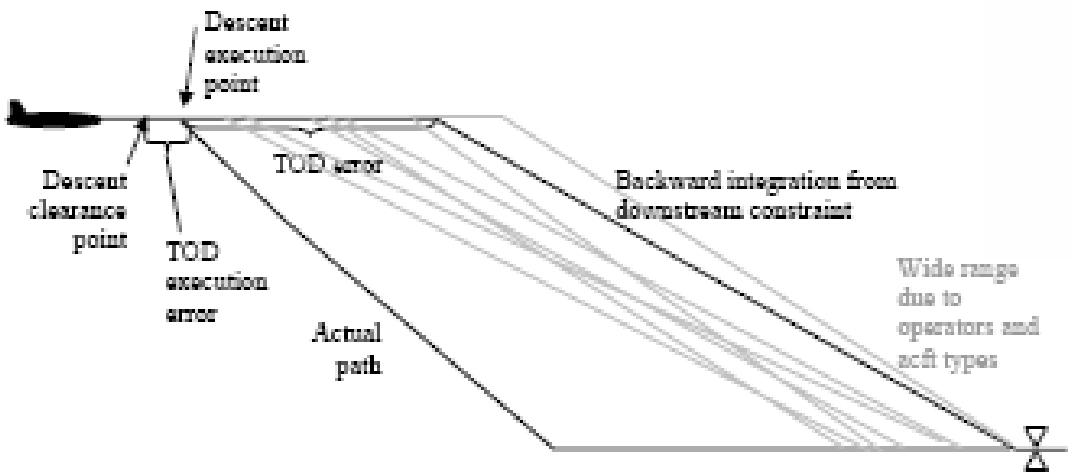
Motivation

- **Supporting the *NextGen Implementation Plan and SESAR***
  - SESAR concept of operations requires a system that relies on coordinated, strategic trajectory deconfliction
  - NextGen focused on equipage of three core avionics capabilities for the midterm (2012-2018)
    - Area Navigation (RNAV) and Required Navigation Performance (RNP)
    - Automatic Dependent Surveillance-Broadcast (ADS-B)
    - Data Communications.

Technical Overview

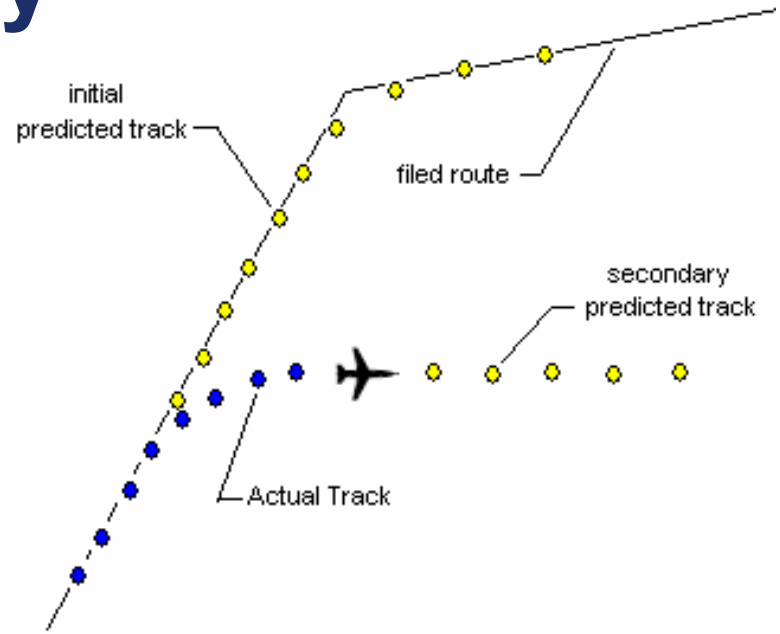
- **Experiment Design**
  - Examine Common Trajectory Prediction Problems
  - Emulating Ground-Based Prediction of a Real Flight
  - Improving with Aircraft Intent Communication
- **Experiment Results**
  - Comparing the Predictions
  - Common TP Metrics Put to Use
- **Conclusion**
  - Aircraft Intent Communication Greatly Improves Trajectory Prediction

Common Sources of Trajectory Prediction Uncertainty



Top-of-Descent Uncertainty

(source: Mondoloni[8])



Unknown lateral change

Research Objectives

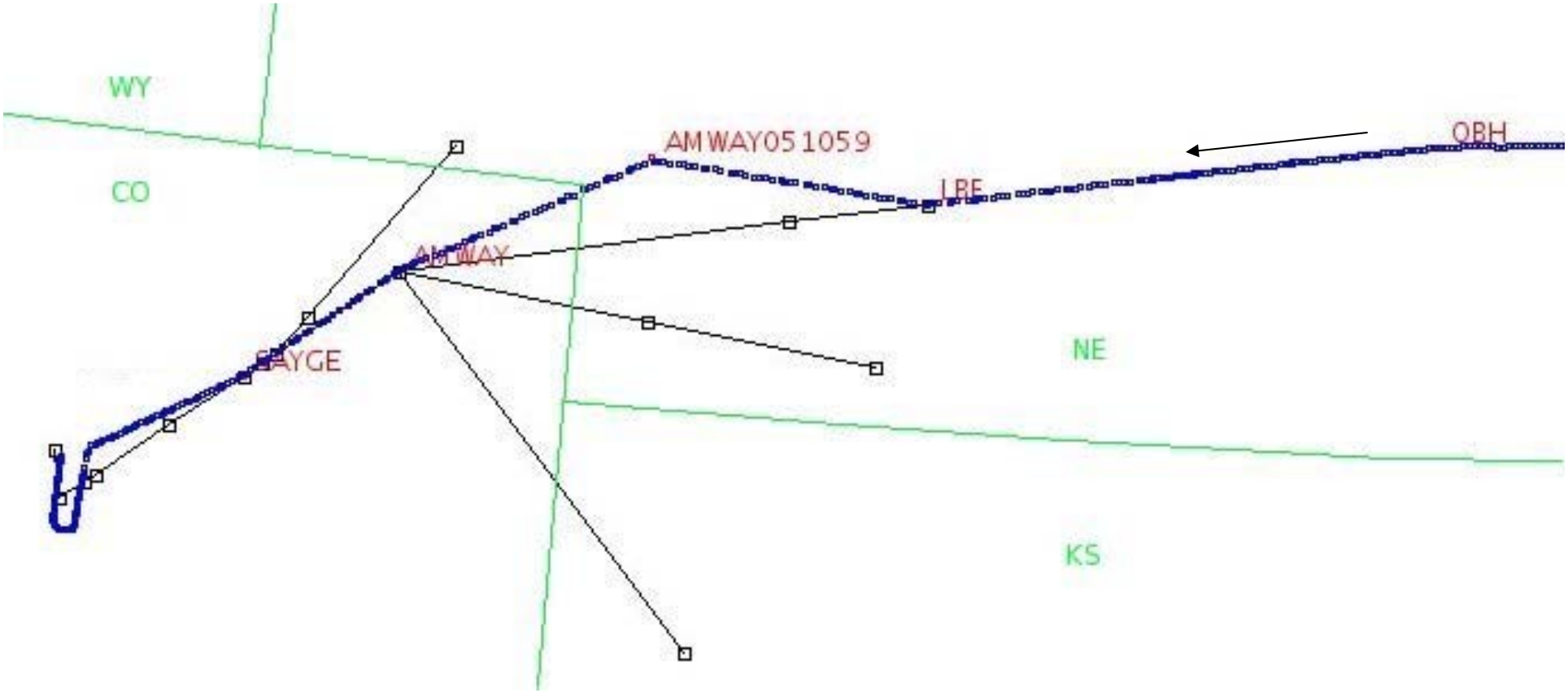
- **Identify a Real Flight to Use for Test**
  - Contains examples of identified sources of uncertainty
  - Cleveland to Denver flight with an Optimized Profile Descent
- **Emulate Ground-Based TP**
- **Reverse Engineer the Aircraft Intent**
- **Generate the Trajectory**
- **Compare the Accuracy**
  - predicted vs. generated
  - using standard TP metrics
  - expect improvements in cross-track error, vertical error, time error, and speed error

Experiment Tools

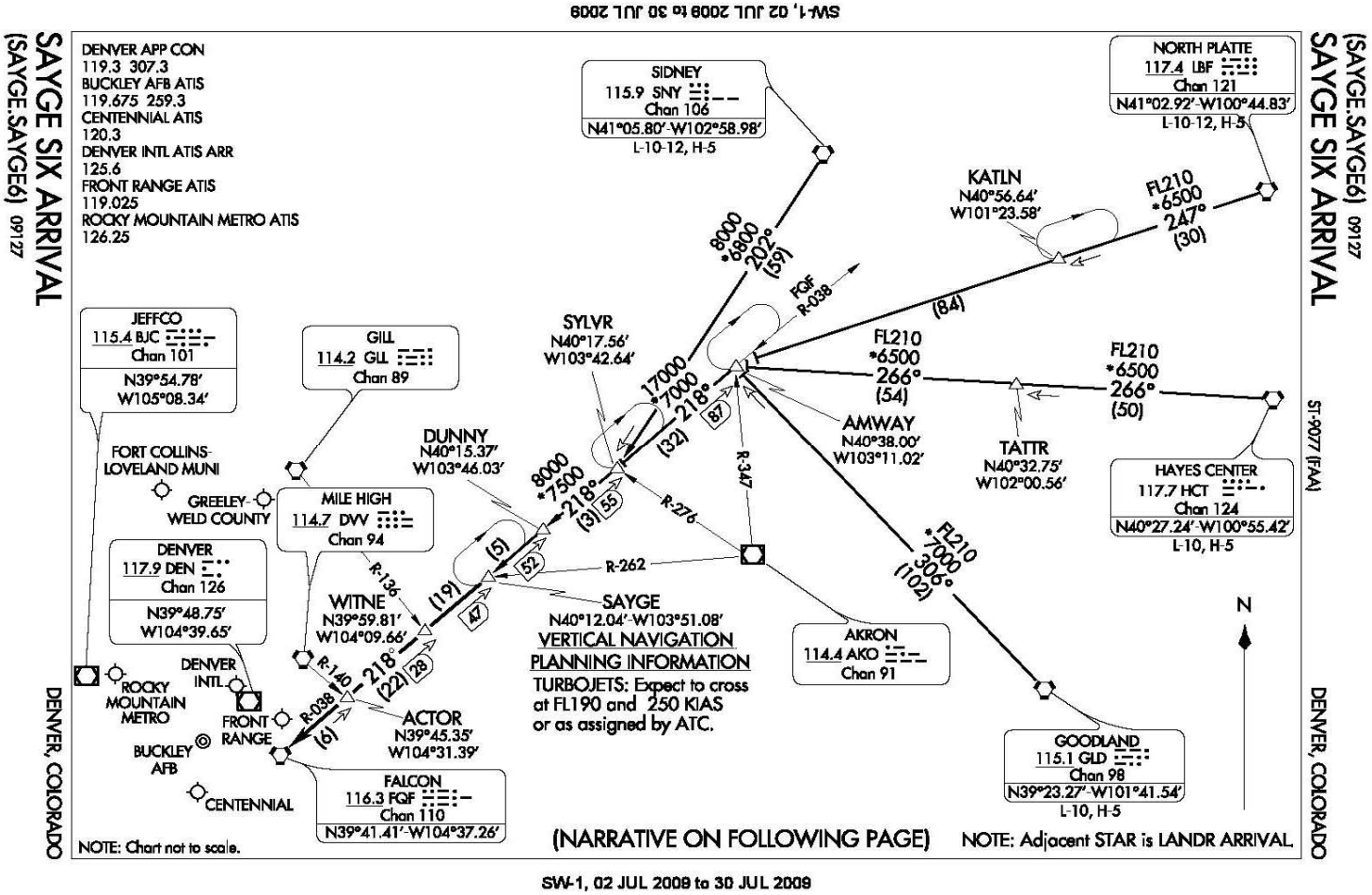
- **Trajectory Predictor - URET**
  - **U**ser **R**equest **E**valuation **T**ool
  - Developed at MITRE's Center for Advanced Aviation System Development (CAASD)
  - Deployed and fully operational at all 20 en route air traffic control facilities
  - Laboratory prototype version used for this study
- **Trajectory Generator – TGF**
  - **T**arget **G**eneration **F**acility at FAA Technical Center
  - Real Time, Controller-in-the–Loop simulator
- **Intent Communication – AIDL**
  - **A**ircraft **I**ntent **D**escription **L**anguage
  - Developed at Boeing Research & Technology Europe
  - Formal language designed to describe aircraft intent information in a rigorous but flexible manner

CMS Track of Test Flight

In Denver Airspace

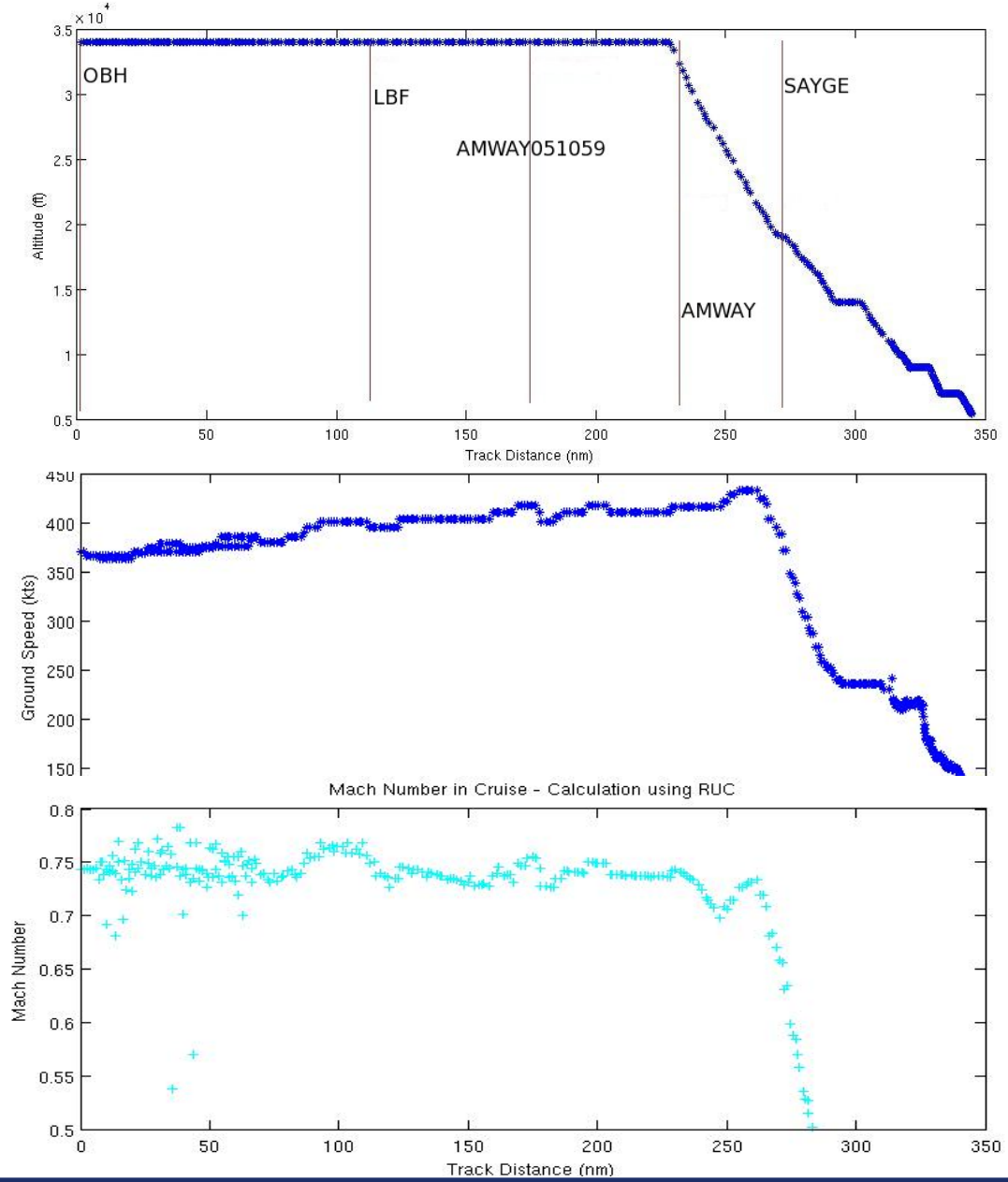


SAYGE SIX Approach Plate

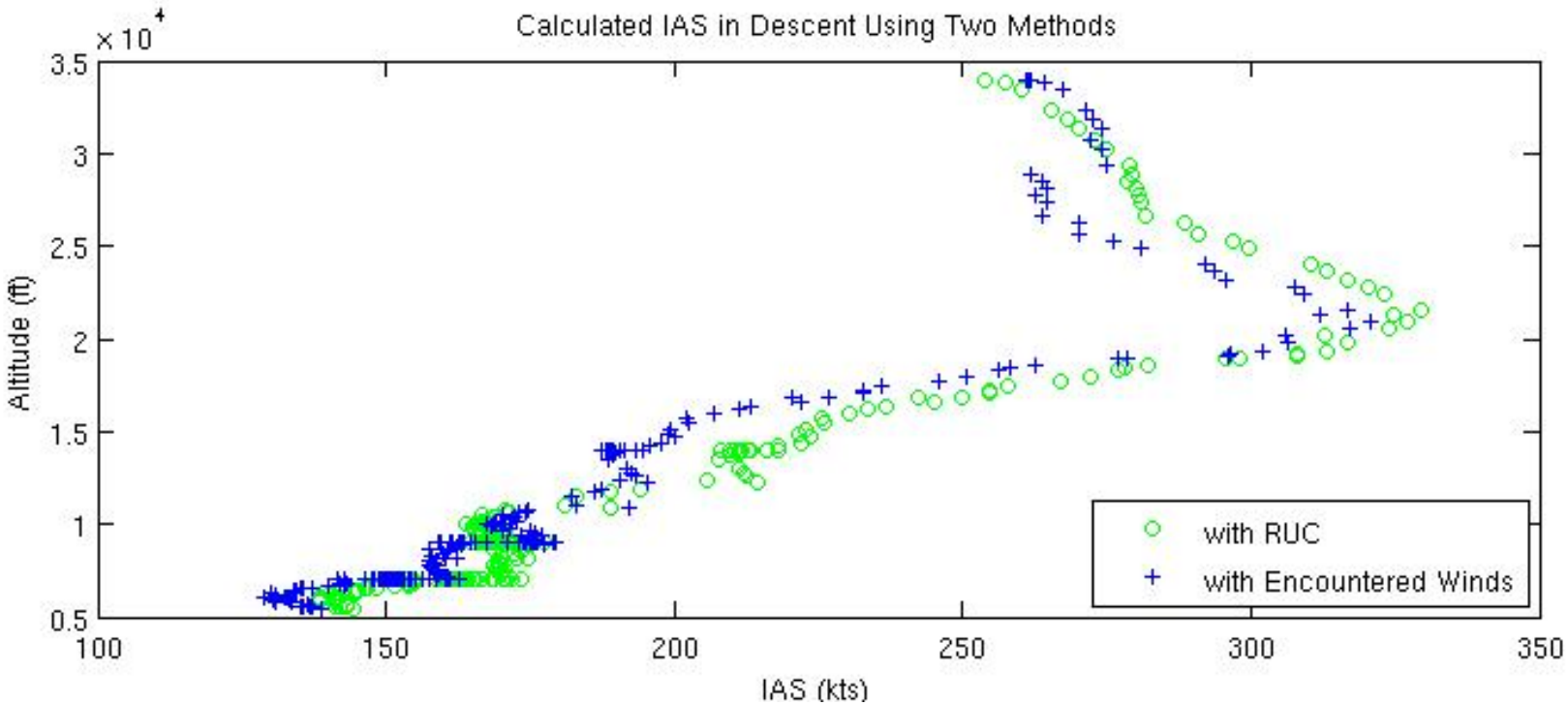


Source: U.S. Terminal Procedures Publication

Analysis of Test Flight



Indicated Airspeed in the Descent

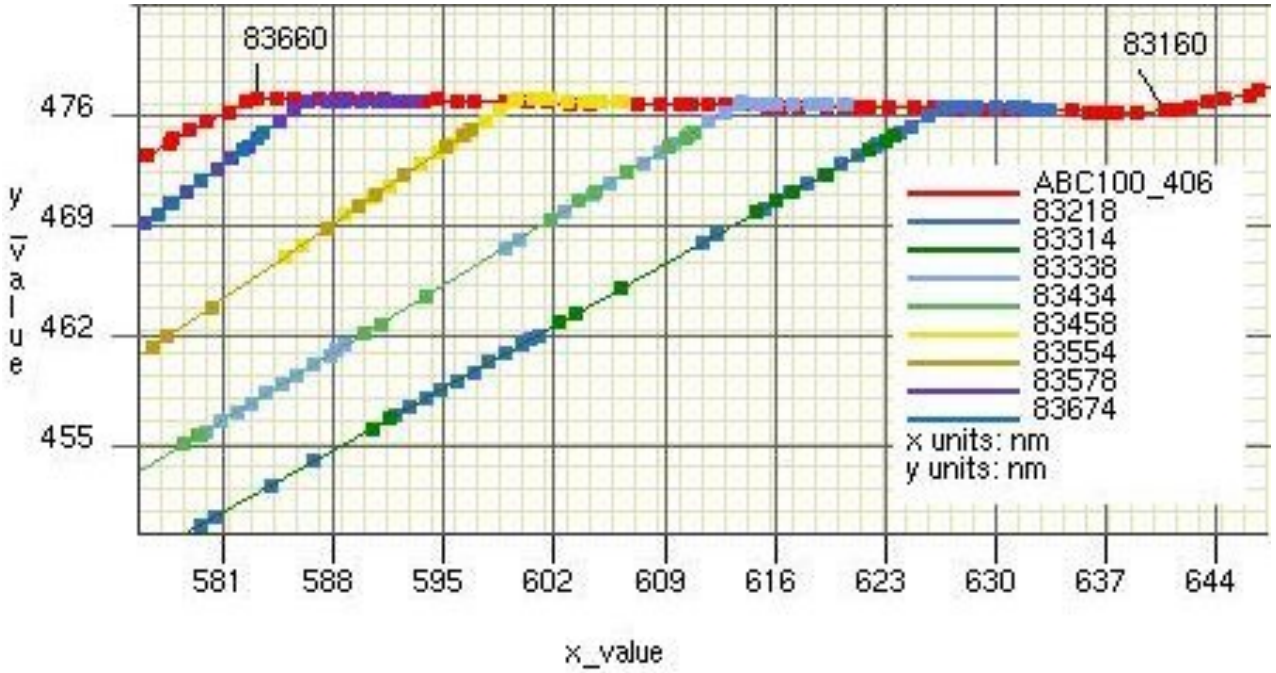


Extracting Aircraft Intent

- **Assumptions**
  - Lateral path is known, including path stretch
  - Weight is known
  - TOD is known (2.9 nm before AMWAY)
  - Idle thrust descent along a geometric path angle

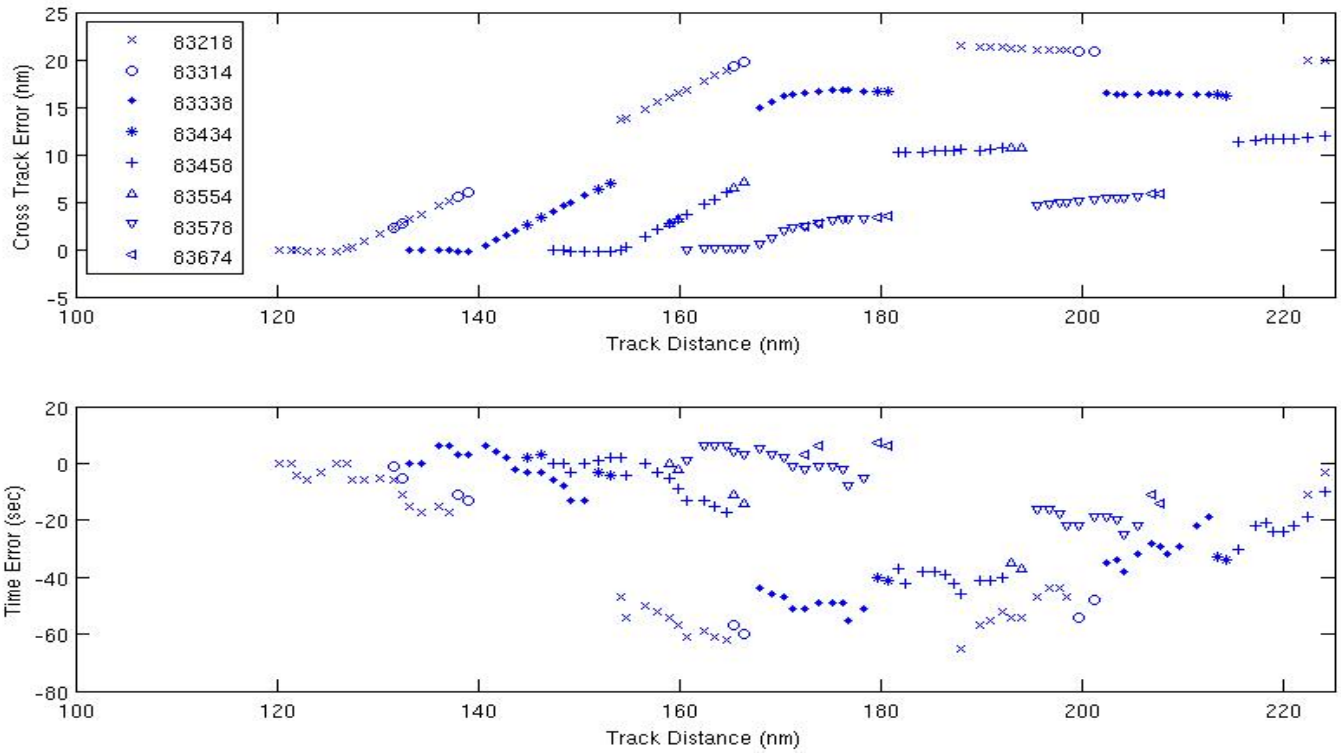
URET prototype

- **Path Stretch**



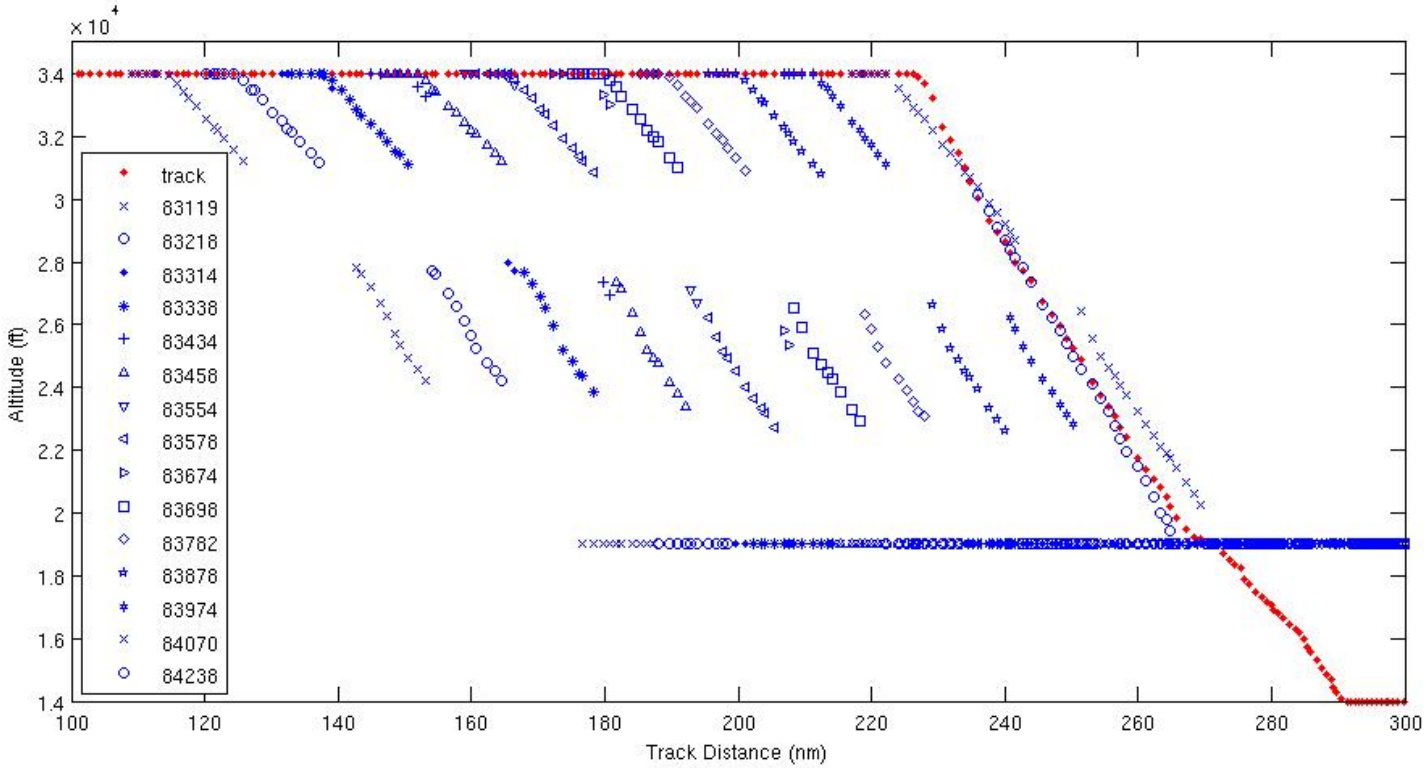
URET prototype

- **Path Stretch**



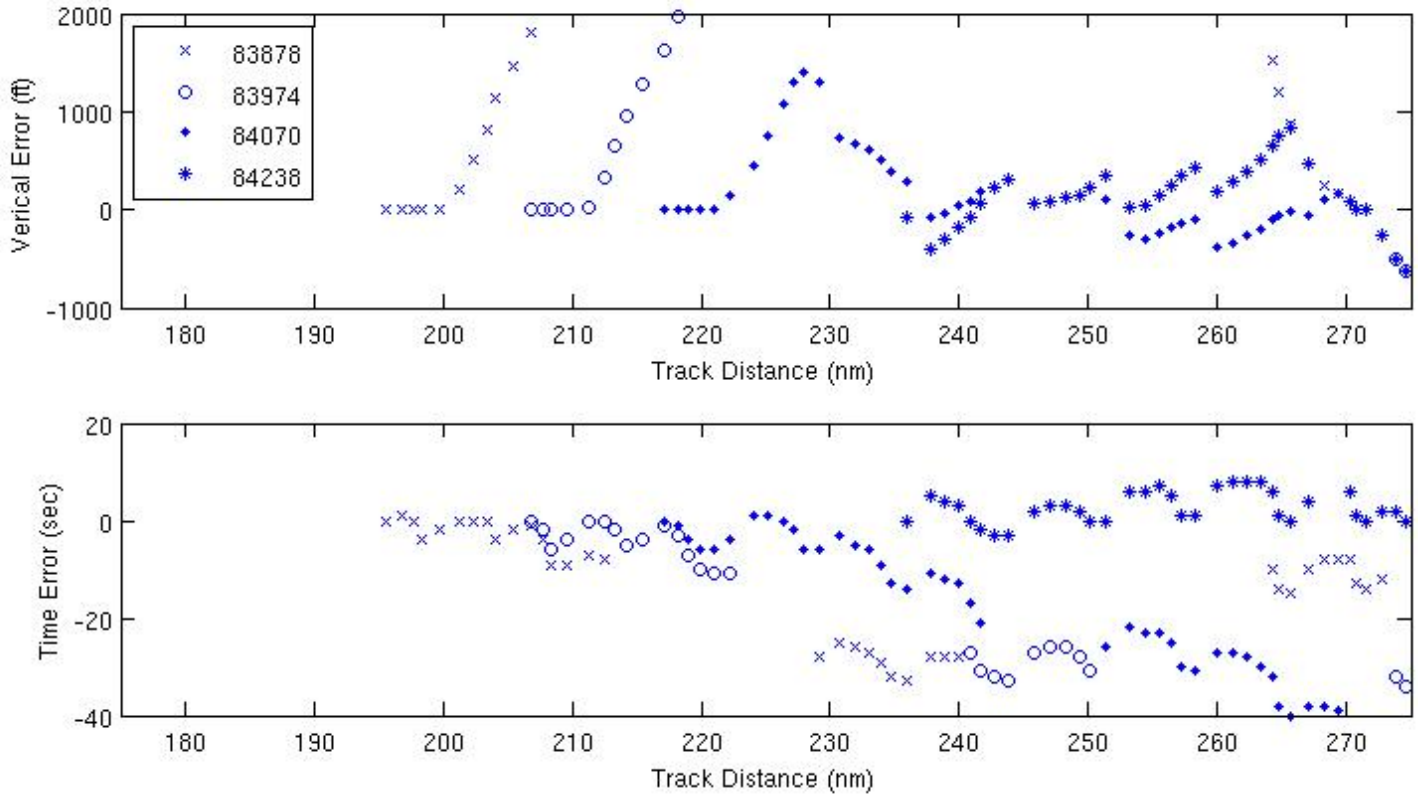
URET prototype

- **Initial Descent**



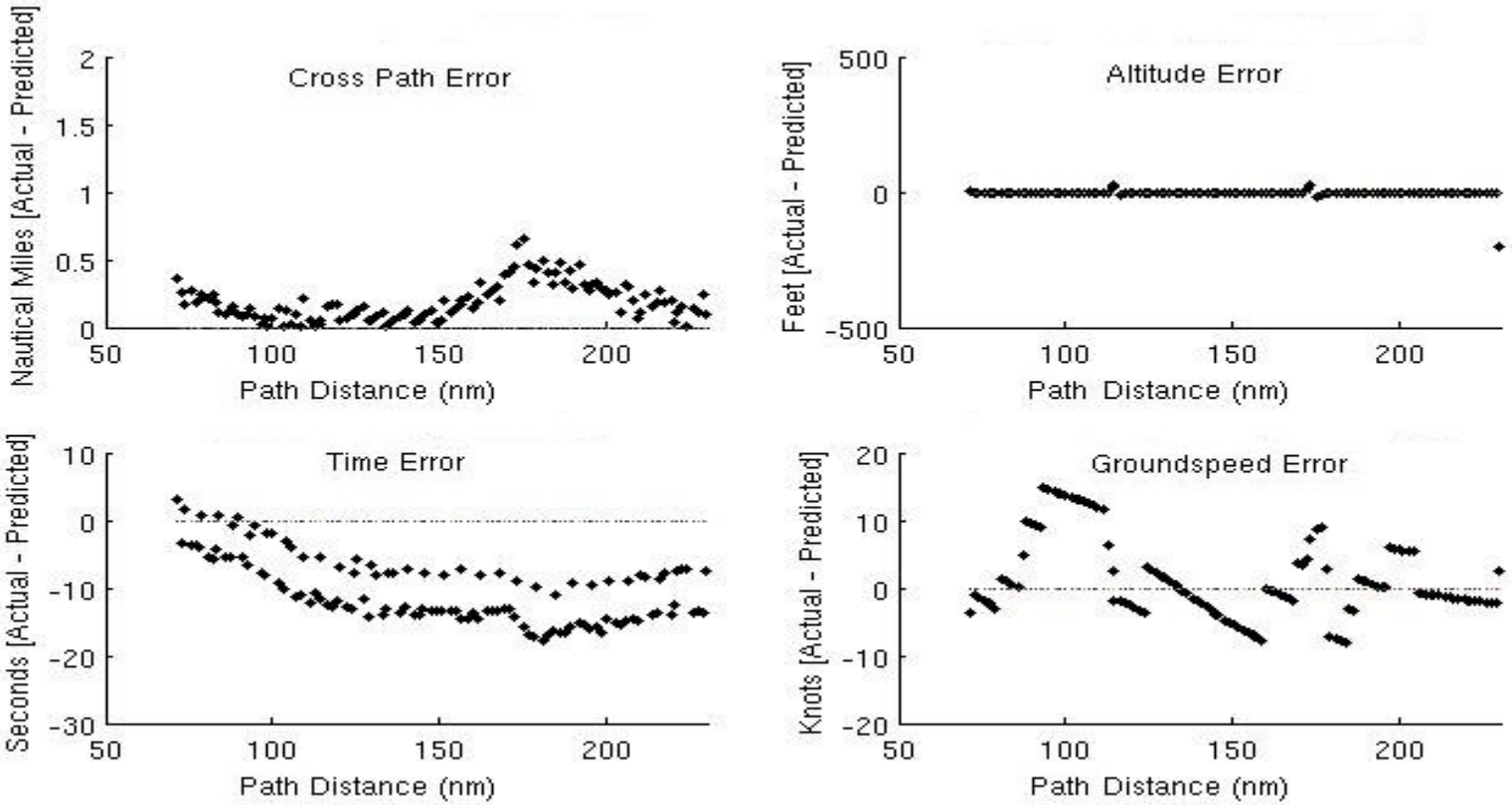
URET prototype

- **Initial Descent**



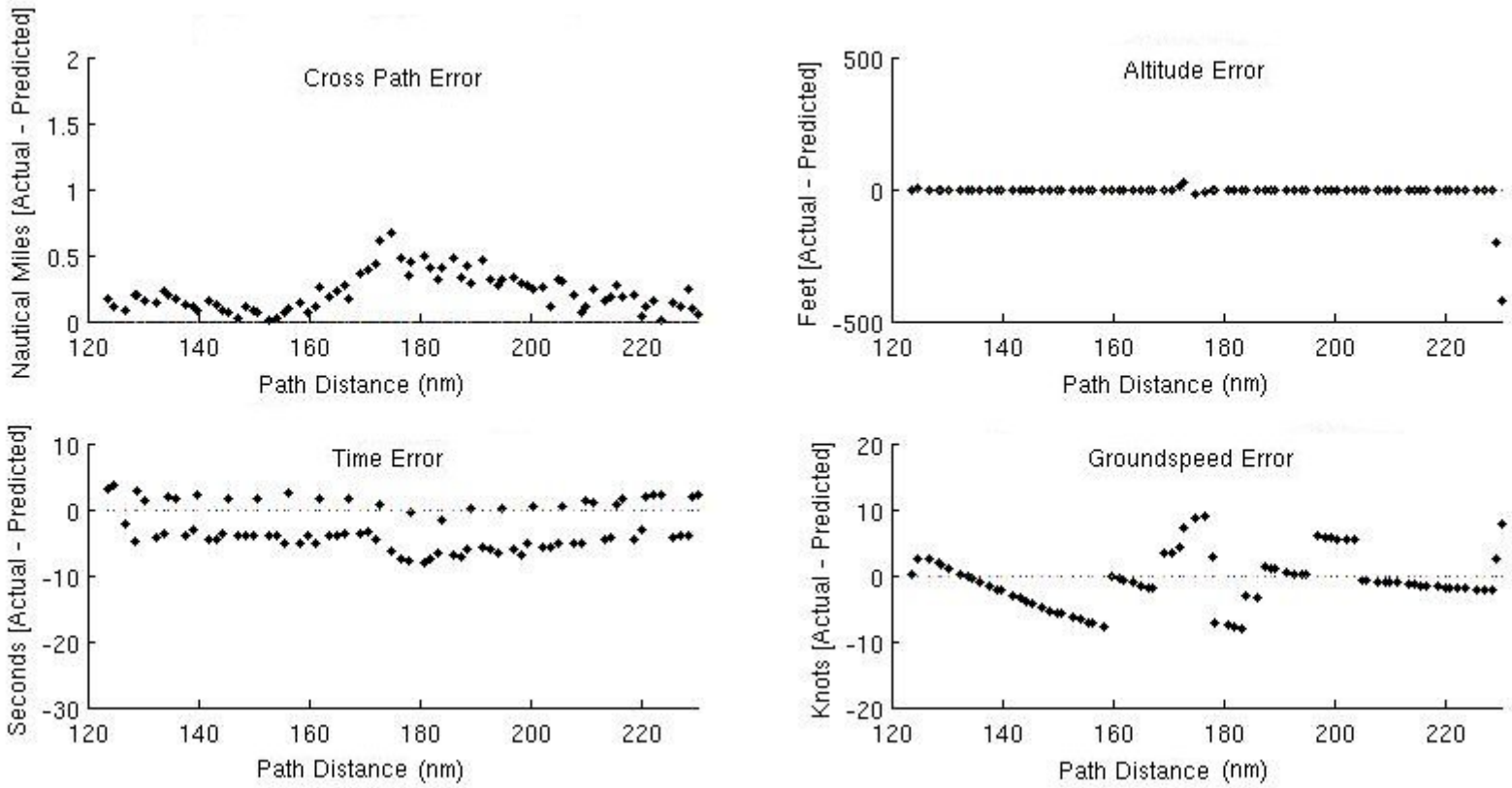
Post-AIDL Trajectory

- **Path Stretch - clearance to AMWAY**



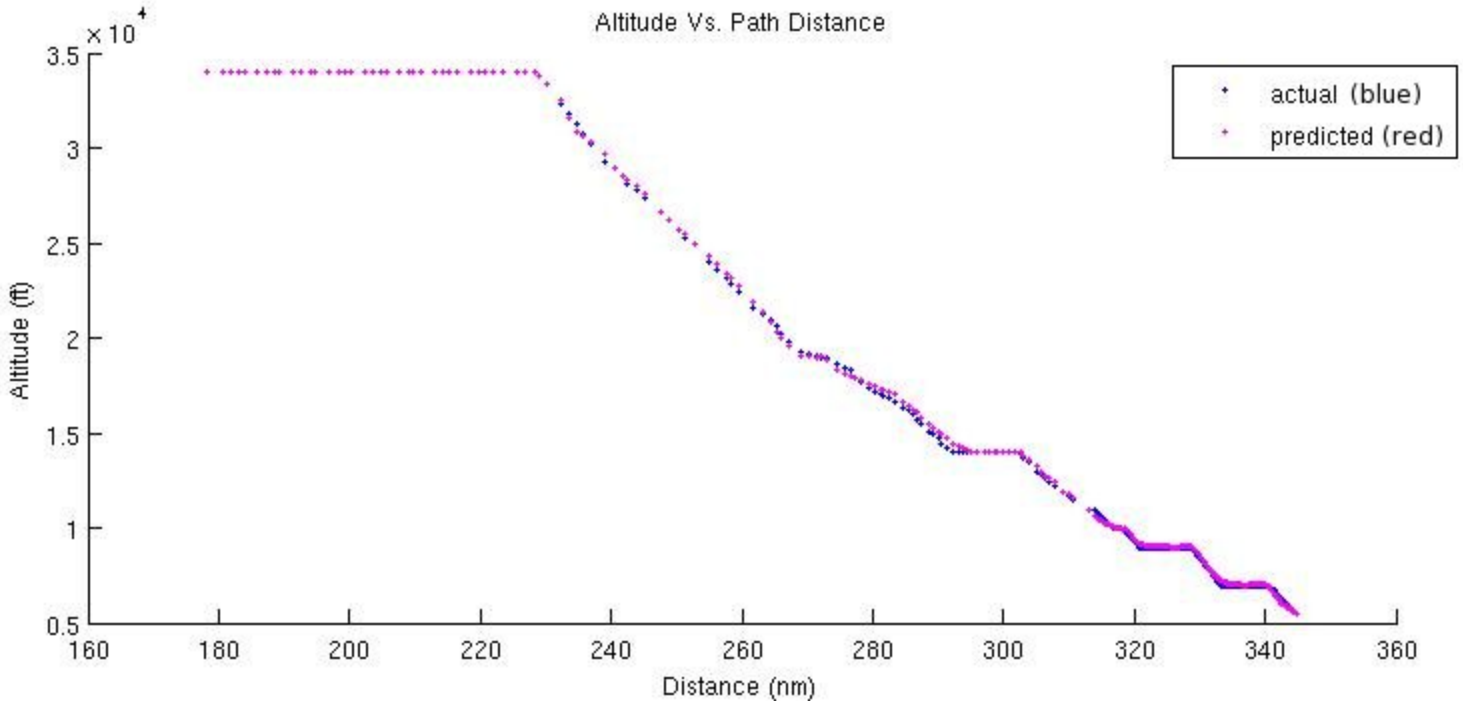
Post-AIDL Trajectory

- **Path Stretch - LBF to AMWAY**



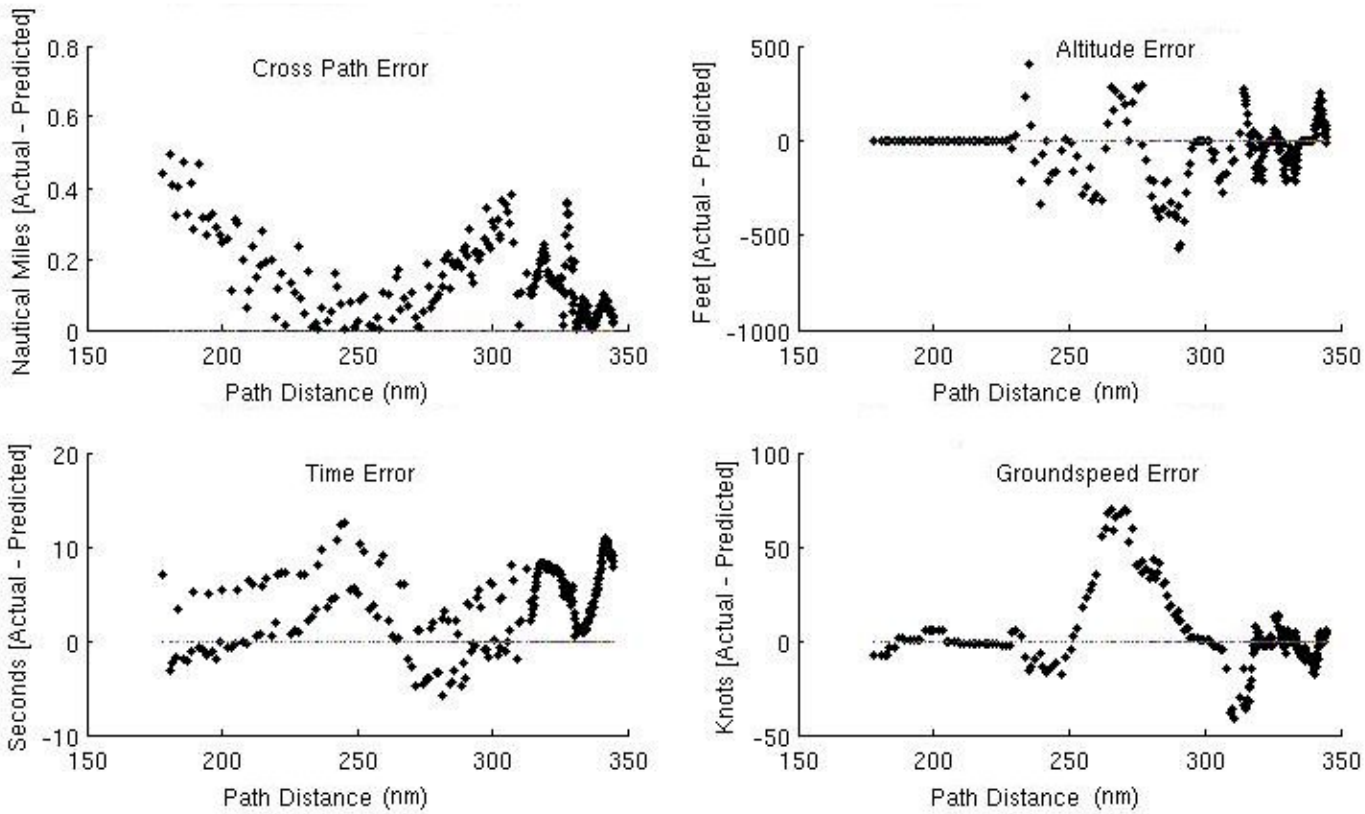
Post-AIDL Trajectory

- **Initial Descent**



Post-AIDL Trajectory

- **Error Metrics for Initial Descent**



Concluding Remarks

- **Communicate Aircraft Intent - errors reduced**
  - cross-track, time, and vertical
- **Improvements in speed error not realized**
  - accurate weather modeling needed
- **Without Aircraft Intent Communication**
  - In steady-state flight, accuracy comparable to a trajectory generator using aircraft intent
  - Frequent monitoring required to maintain tolerable accuracy
- **With Aircraft Intent Communication**
  - Stable representation of the flight
    - little variation with large look-ahead times

References

1. "Concept of Operations for the Next Generation Air Transportation System Version 2.0," Joint Planning and Development Office, 13 June 2007.
2. Mondoloni , S., "Flight Object - A Recommendation for Flight Script and Trajectory Description," FAA/Eurocontrol Action Plan 16 Common Trajectory Prediction Capability - Team Publications [online database], URL: http://acy.tc.faa.gov/cpat/tjm/index.html [cited 3 August 2009].
3. "SESAR Definition Phase Deliverable 3 - The ATM Target Concept, D3," SESAR Consortium, DLM-0612-001-02-00a, September 2007.
4. Peters, M., and Konyak, M. A. (2003), "The Engineering Analysis and Design of the Aircraft Dynamics Model for the Target Generation Facility" November 2003, TGF Public Documentation [online database]. URL: http://public.tgf.tc.faa.gov/, [cited 3 August 2009].
5. Gallo, E., and Lopez-Leones, J., "Aircraft Intent Description Language (AIDL) Specification v1.3 r1," BRTE-ATT0810-AIDK1301-SPEC, Boeing Research & Technology Europe, Madrid, Spain, 10 August 2008.
6. Konyak, M. A., Warburton, D., Lopez-Leones, J., and Parks, P. C., "A Demonstration of an Aircraft Intent Interchange Specification for Facilitating Trajectory-Based Operations in the National Airspace System," AIAA-2008-7145, AIAA Guidance, Navigation and Control Conference and Exhibit, Honolulu, Hawaii, Aug. 18-21, 2008
7. Wichman, K.D., Klooster, J.K., Bleeker, O.F., and Rademaker, R.M., "Flight Validation of Downlinked Flight Management System 4D Trajectory," ISBN: 978-1-4244-1108-5, 26th Digital Avionics Systems Conference, Dallas, TX, 21-25 October 2007.
8. Mondoloni, S. (2006), "Aircraft Trajectory Prediction Errors: Including a Summary of Error Sources and Data (Version 0.2)." FAA/EUROCONTROL Action Plan 16, July 2006, Common Trajectory Prediction Capability - Team Publications [online database], URL: http://acy.tc.faa.gov/cpat/tjm/index.html [cited 3 August 2009].
9. Paglione, M. M., and Oaks, R. D., "Implementation and Metrics for a Trajectory Prediction Validation Methodology", AIAA 2007-6517, AIAA Guidance, Navigation, and Control Conference, Hilton Head, South Carolina, August 20-23, 2007.
10. Paglione, M. M., and Oaks, R. D., "Memorandum to the Conflict Probe Assessment Team (CPAT) File Re: CMS_ASCII Format Definition, Revision D," (unpublished), Federal Aviation Administration William J. Hughes Technical Center, Atlantic City International Airport, NJ
11. U.S. Federal Aviation Administration William J. Hughes Technical Center, ARTCC Host Computer System (HCS) Air Traffic Management (ATM) Applications Interface Requirements Document (IRD), NAS−IR−8217−0001, Atlantic City International Airport, NJ, 2007.
12. Benjamin, S.G., Brown, J.M., Brundage, K.J., Schwartz, B.E.. Smirnova, T.G., and Smith, T.L., "RUC-2 - The Rapid Update Cycle Version 2 Technical Procedures Bulletin – draft," [online database] URL: http://ruc.noaa.gov/ruc2.tpb.html, [cited 1 July 2009].
13. Kirk, D.B., and Ricker, M.L., "User Request Evaluation Tool (URET) D3 Automated Problem Detection Algorithmic Detection," MITRE Technical Report MTR 96W00000038R1, Center for Advanced Aviation System Development, McLean, VA, December 1997.
14. Ryan, H.F., and Paglione, M.M., "State Vector Based Near Term Trajectory Prediction," AIAA 2008-7144, AIAA Guidance, Navigation, and Control Conference, 18-21 August 2008, Honolulu, HI.
15. BR&TE, DFS and Avtech. COURAGE: Domain Analysis. 2006. EUROCONTROL Technical Interchange Meetings [online database], URL: http://www.eurocontrol.int/moc-faa-euro/public/standard_page/TIMS.html, [cited 3 August 2009].
16. Klooster, J.K., Wichman, K.D., and Bleeker, O.F., "4D Trajectory and Time-of-Arrival Control to Enable Continuous Descent Arrivals," AIAA 2008-7402, AIAA Guidance, Navigation, and Control Conference, 18-21 August 2008, Honolulu, HI.

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