

Separation Accuracy of Mixed Surveillance Technologies with Microprocessor En route Automated Radar Tracking System Targets in Alaska

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**Federal Aviation
Administration**



Outline

- **Introduction and Objective**
- **Processing and Approach to Data Analysis**
- **Approach to Targets of Opportunity (TOO)**
- **Radar position error results**
- **MEARTS Display Algorithm**
- **Method for Analysis of Separation Error**
- **Separation error results**



Objective of Targets of Opportunity Analysis

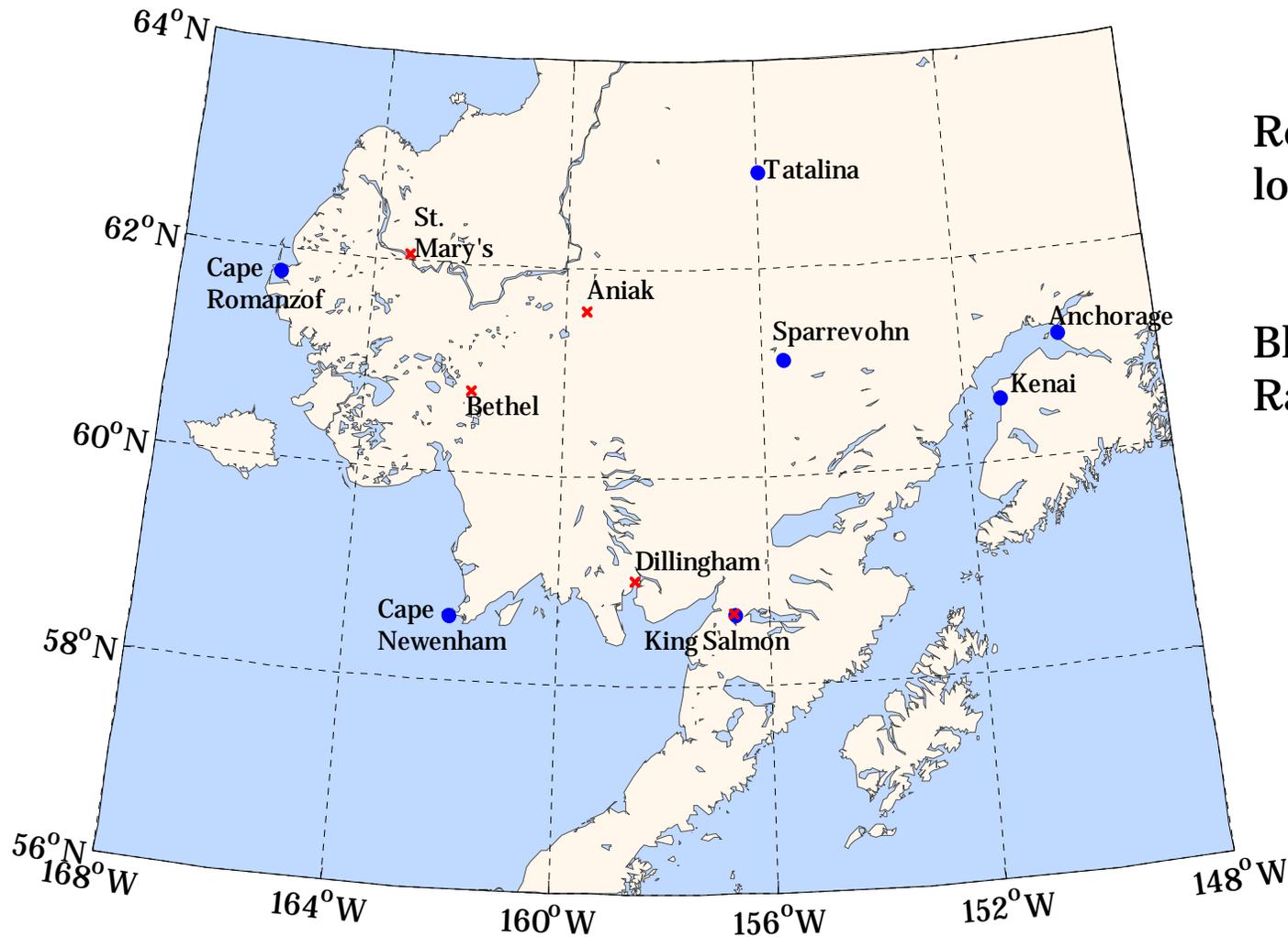
An objective of the Operational Evaluation in Alaska is:

- **To assess the end-to-end ADS-B system's performance in a mixed environment while applying a ADS-B-to-radar separation standard to validate that the ADS-B system supports a 5nm separation standard between ADS-B and radar targets**

Our part of that objective is:

- **To analyze current operational data and formally document them. Of primary concern are:**
 - Targets of opportunity (TOO) – whatever is flying now
 - Displayed Separation Error between an ADS-B target and a Secondary Radar target using ADS-B as the “true” separation measure.
 - Displayed Separation Error between two Secondary Radar targets using ADS-B as the “true” separation measure.

Map of the Sensors

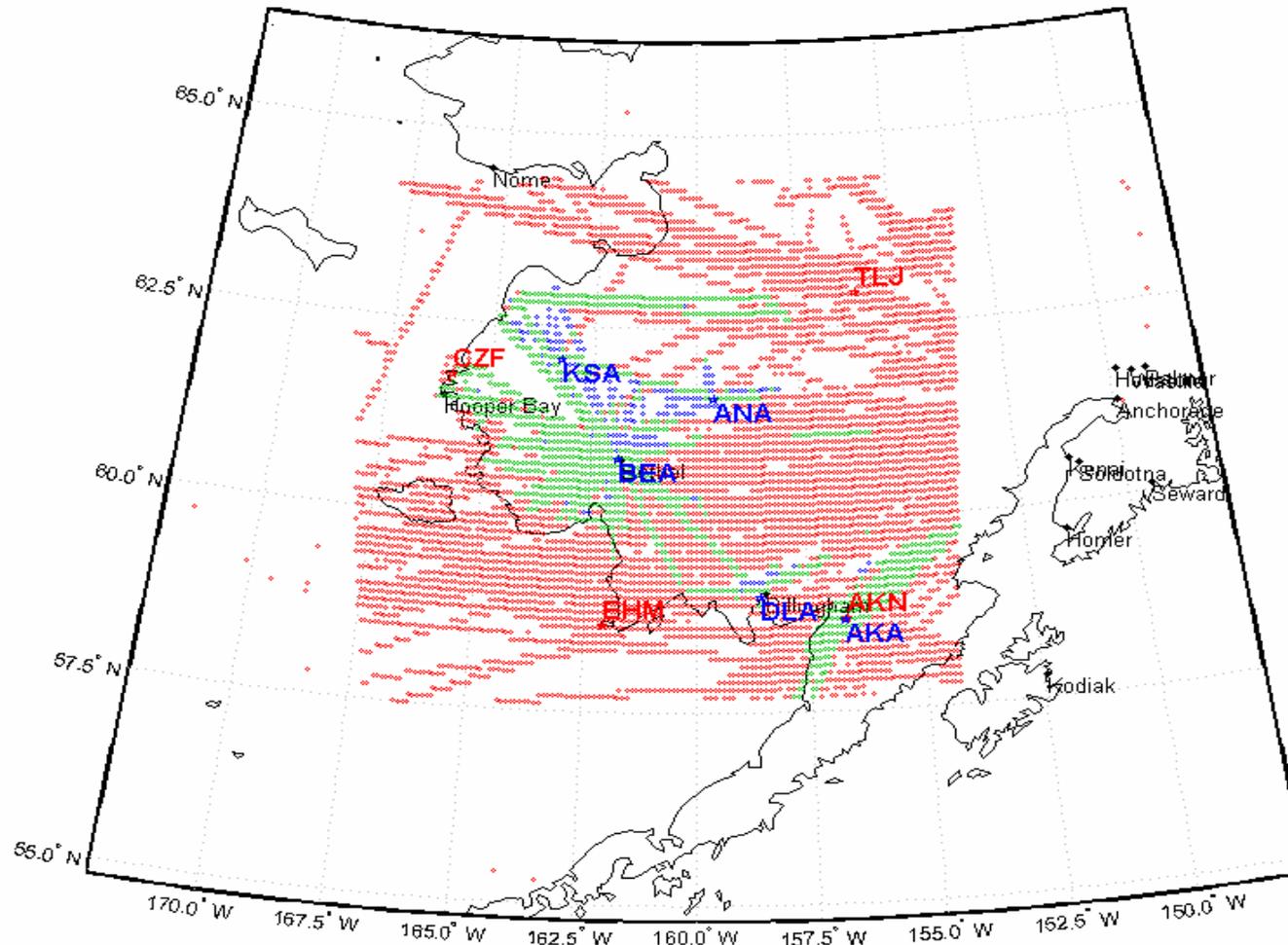


Red 'x' – GBT locations

Blue Circle - Radar locations



Mapping of Received Sensor Data from June 15, 2006



Red = areas where only radar targets are seen

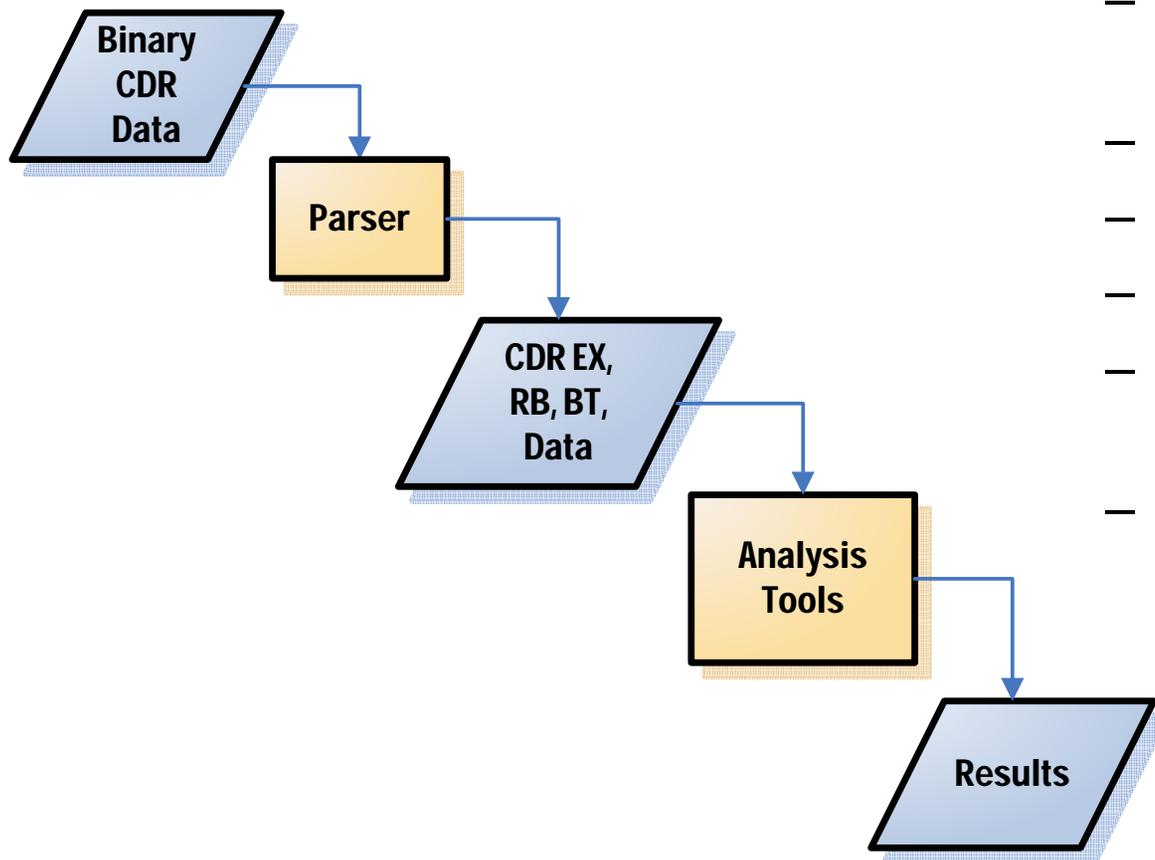
Blue = areas where only ADS-B targets are seen

Green = areas where both are seen

Data Pre-Processing

- **ZAN ARTCC uploaded data regularly to JHU/APL ftp site**
 - Provides binary Continuous Data Recording (CDR) files
- **JHU/APL performs CDR extraction from this data**
 - Data is now in various classes
 - EX class has ADS-B data
 - RB class has radar data that is reinforced (S+B)
 - BT class has radar data that is beacon-only
 - TD class has the source-level tracking data
 - Others that are less useful (ST, CA, ...)
- **Data must be parsed from document format into a common data format**
 - break out individual data items in each class
- **Once data is parsed, it can be input into analysis tools**

Analysis Methodology

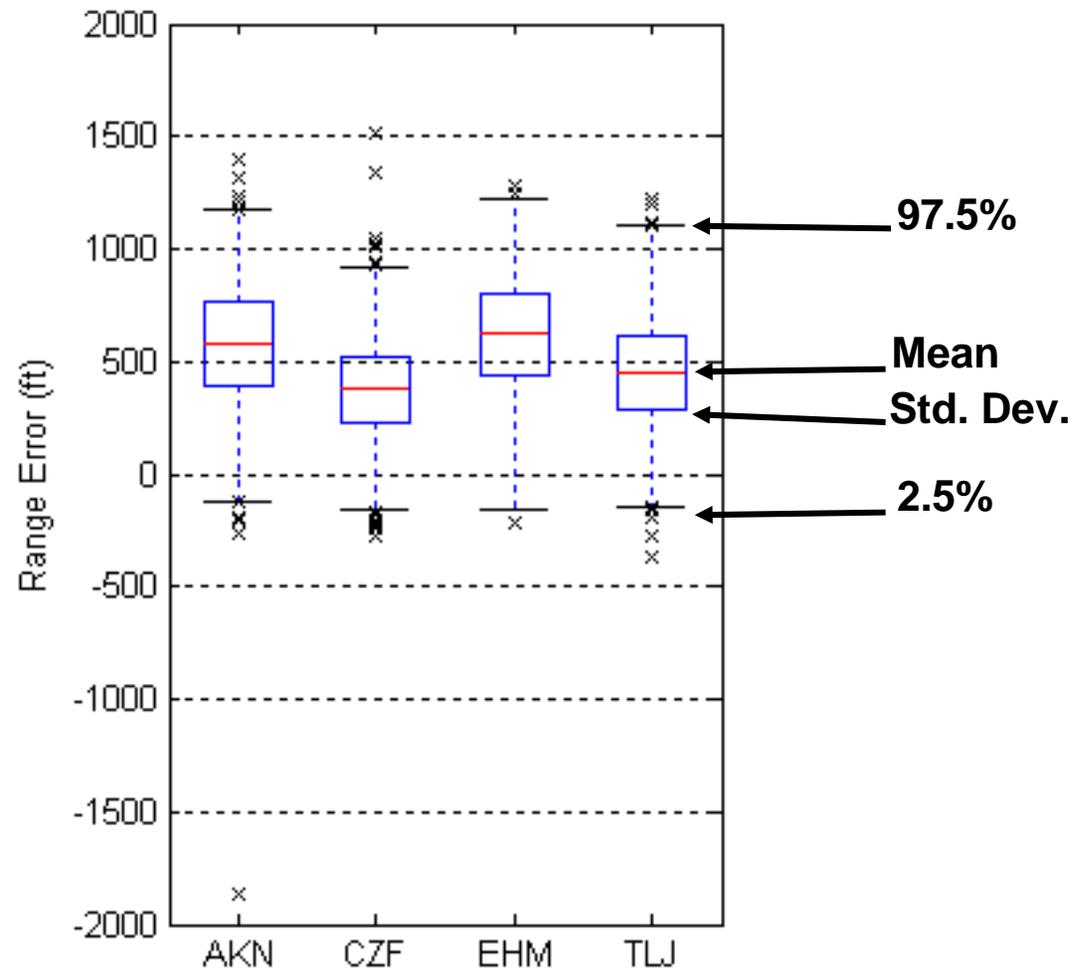
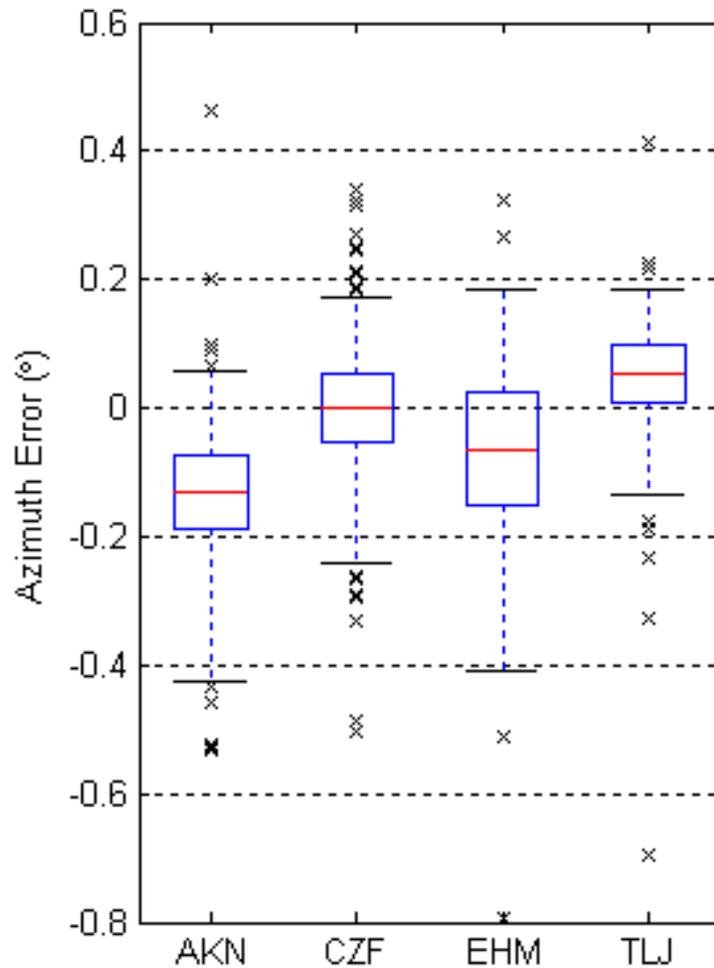


- **Results include:**
 - Map of radar and GBT locations
 - Target frequency maps
 - Observed NIC/NAC_p tables
 - Selected Flight Profiles
 - ADS-B to Radar reported position differences
 - Approach for separation error calculations

Method for Calculating ADS-B to Radar Reported Position Differences

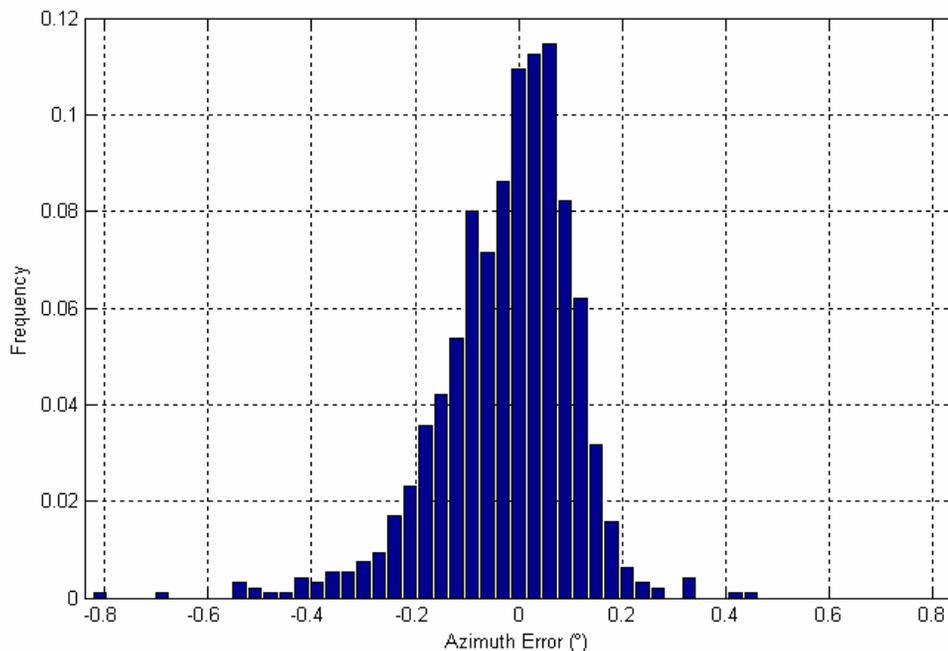
- **Identify beacon codes present in CDR EX data**
- **Match with beacon codes in CDR RB/BT data**
 - Plot tracks or check times to make sure same aircraft
- **Recreate boresight time of radar report from radar test targets and azimuth data**
- **Interpolate the ADS-B position to the time of boresight**
- **Take difference and break into scalar distance, and range and azimuth components from radar**

Radar ADS-B Error Components for IFR Traffic on June 15th

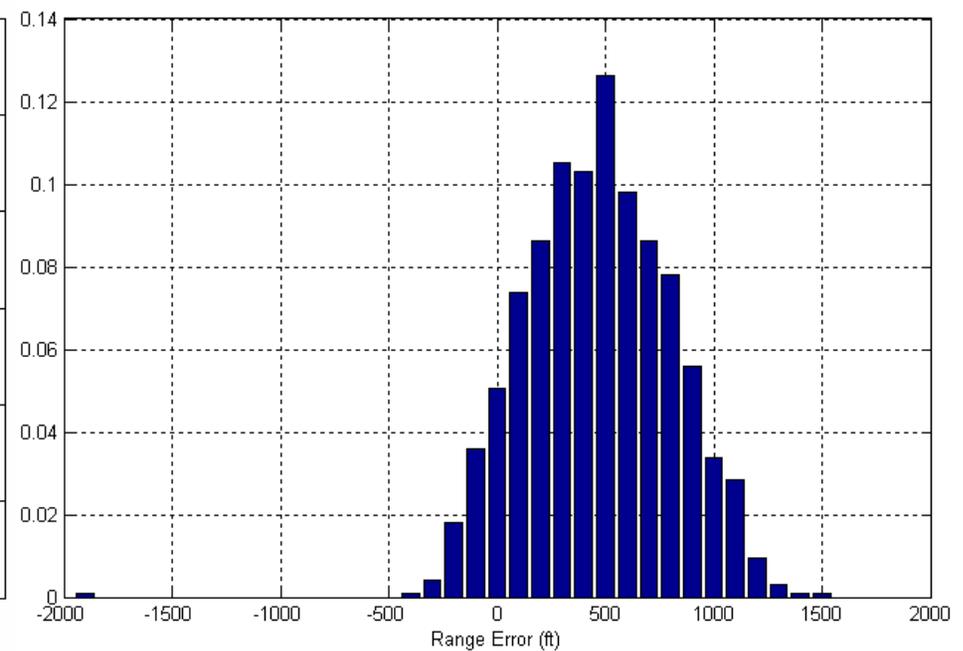


Radar ADS-B Error Distributions for IFR Traffic on June 15th

Azimuth Error

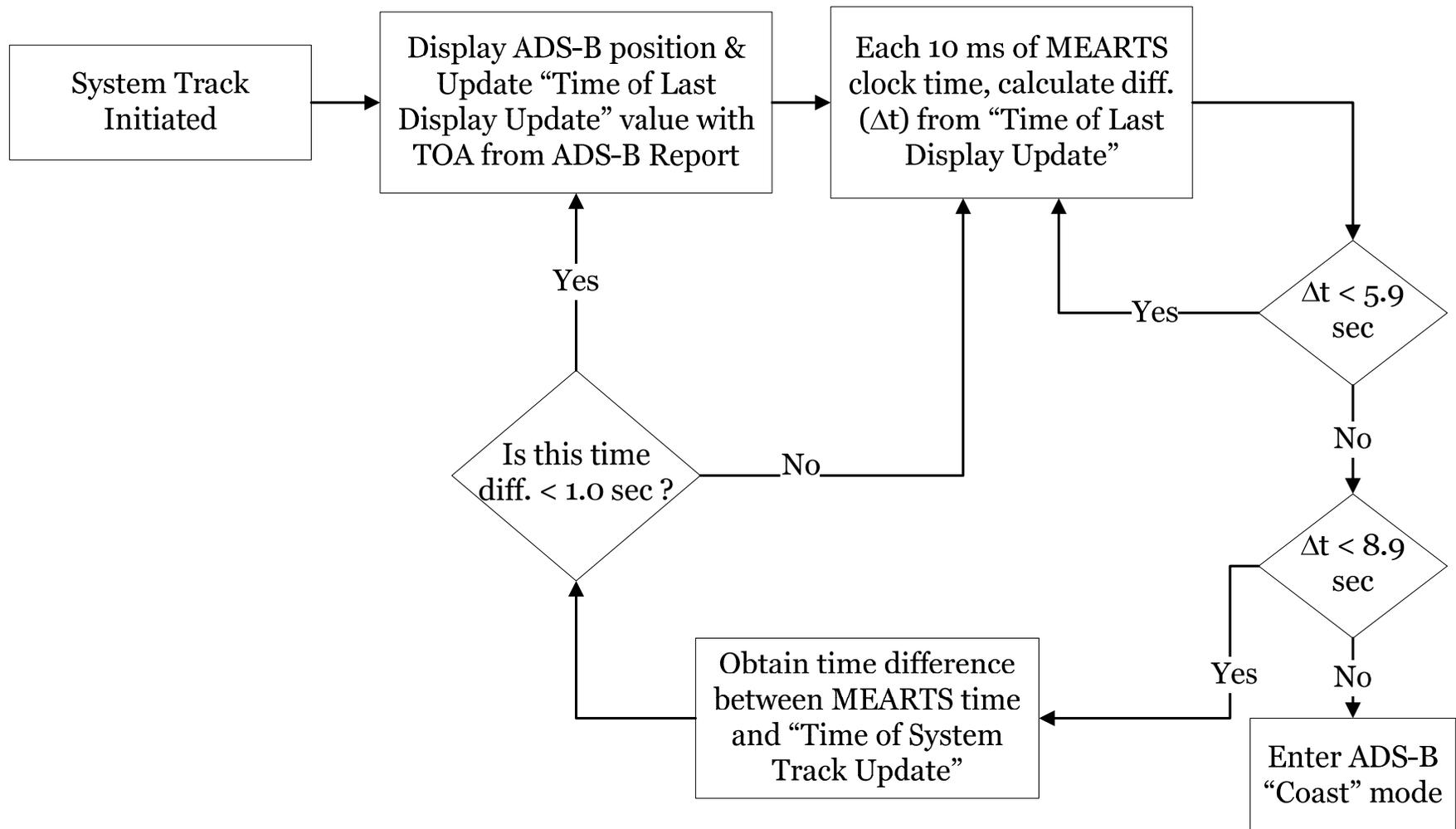


Range Error

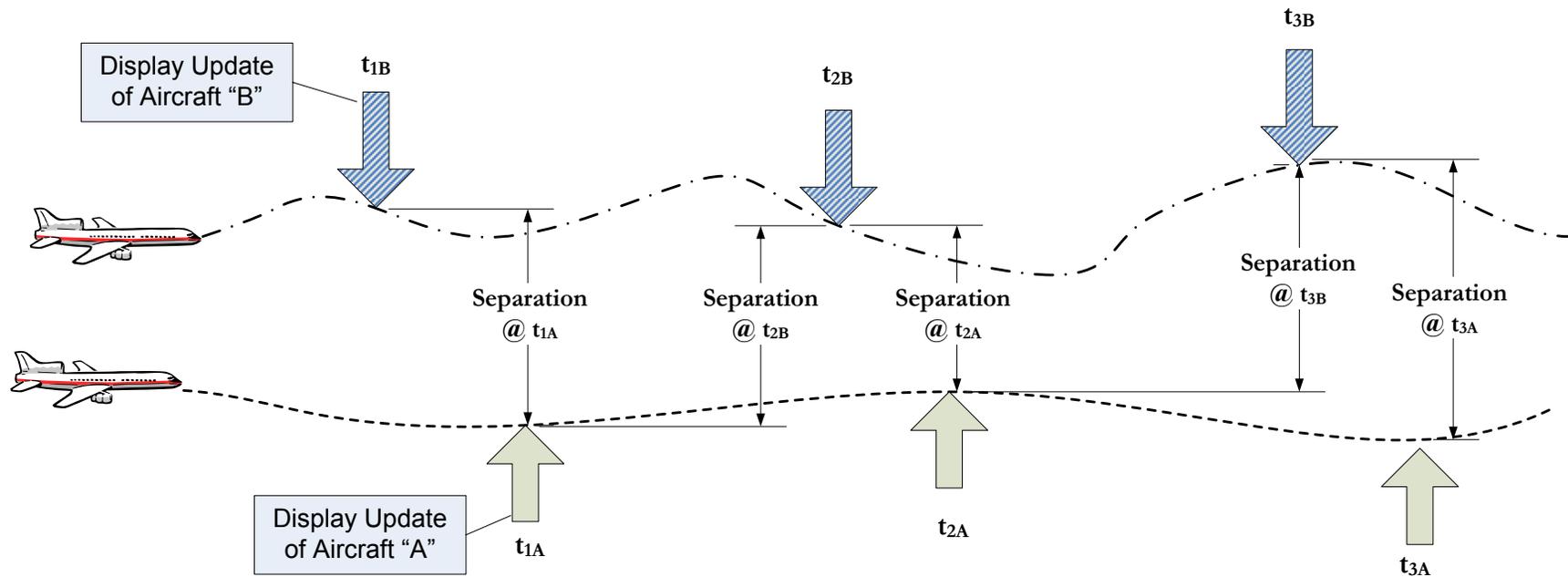


	Count	Mean	Std Dev	-2.50%	97.50%	Min	Max
Total Azimuth	950	-0.02 °	0.13 °	-0.32 °	0.18 °	-0.80 °	0.46 °
Total Range	950	460 ft	340 ft	-150 ft	1110 ft	-1870 ft	1520 ft

MEARTS Algorithm for Display of ADS-B Data



When is separation error calculated?



- Whenever display is updated – separation is calculated
- Alternates between aircraft

Method for Analysis of Separation Error

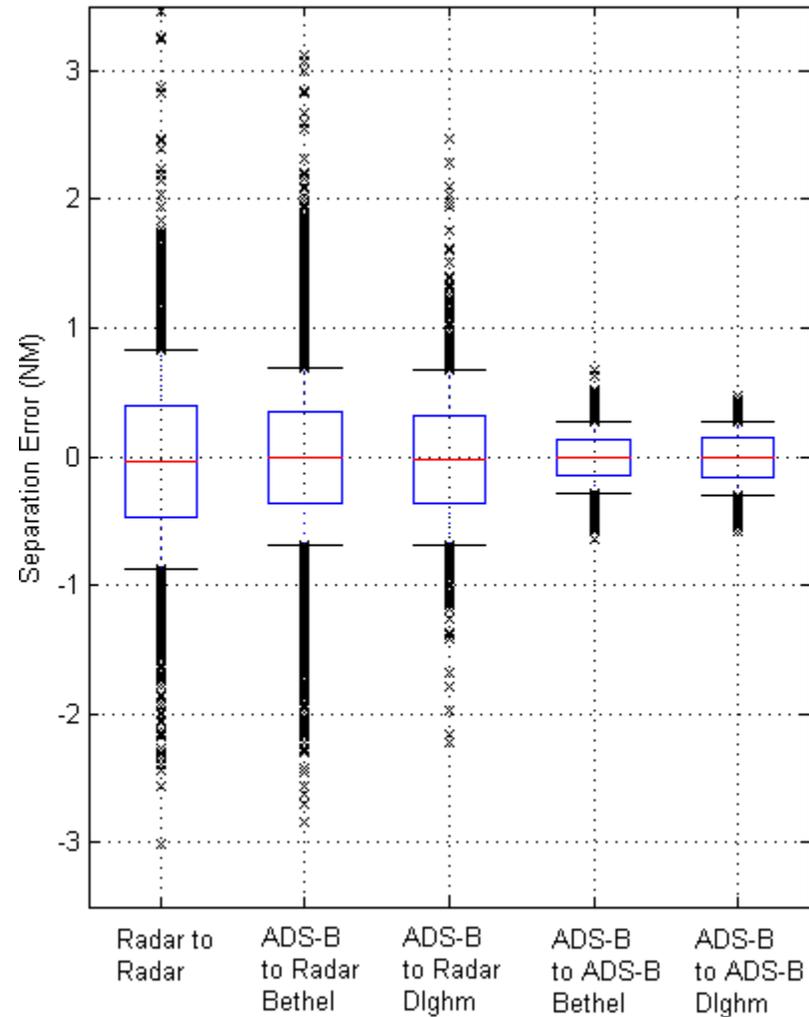
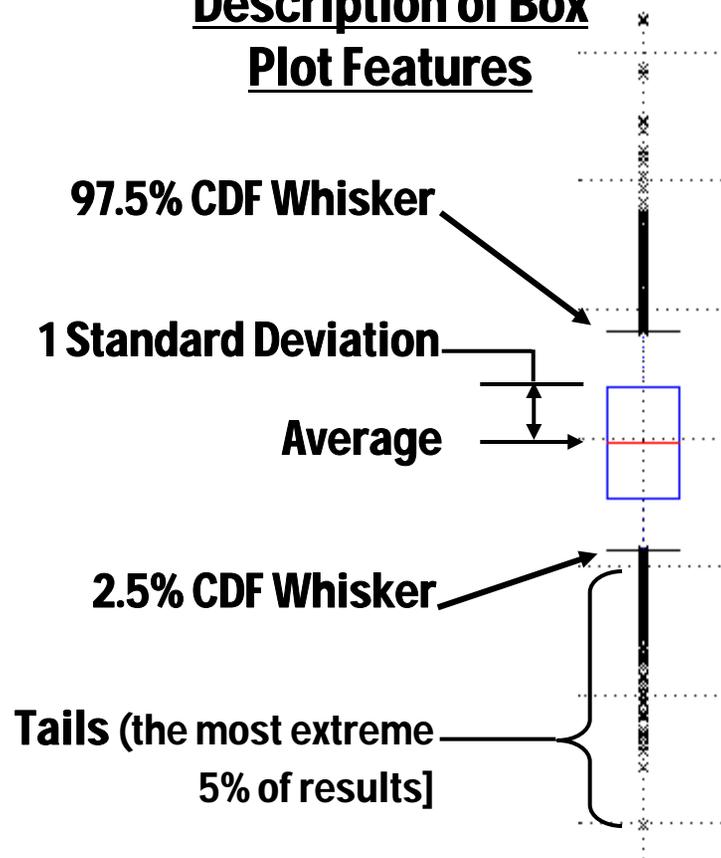
- All radar reports are displayed, assume t_{disp} occurs 575 ms delay after CDR timestamp
- ADS-B data is displayed based on output of MEARTS ADS-B display algorithm
 - $t_{\text{disp}} \geq 100$ ms delay after CDR timestamp
- Use System Plane projected X/Y data item in CDR data to calculate separation (Δ_{mix}) using classic “distance formula”
- Prepare “Truth” data at t_{disp}
 - Constructed from ADS-B TOA data
 - position is linearly interpolated to t_{disp}

Separation Error Metric

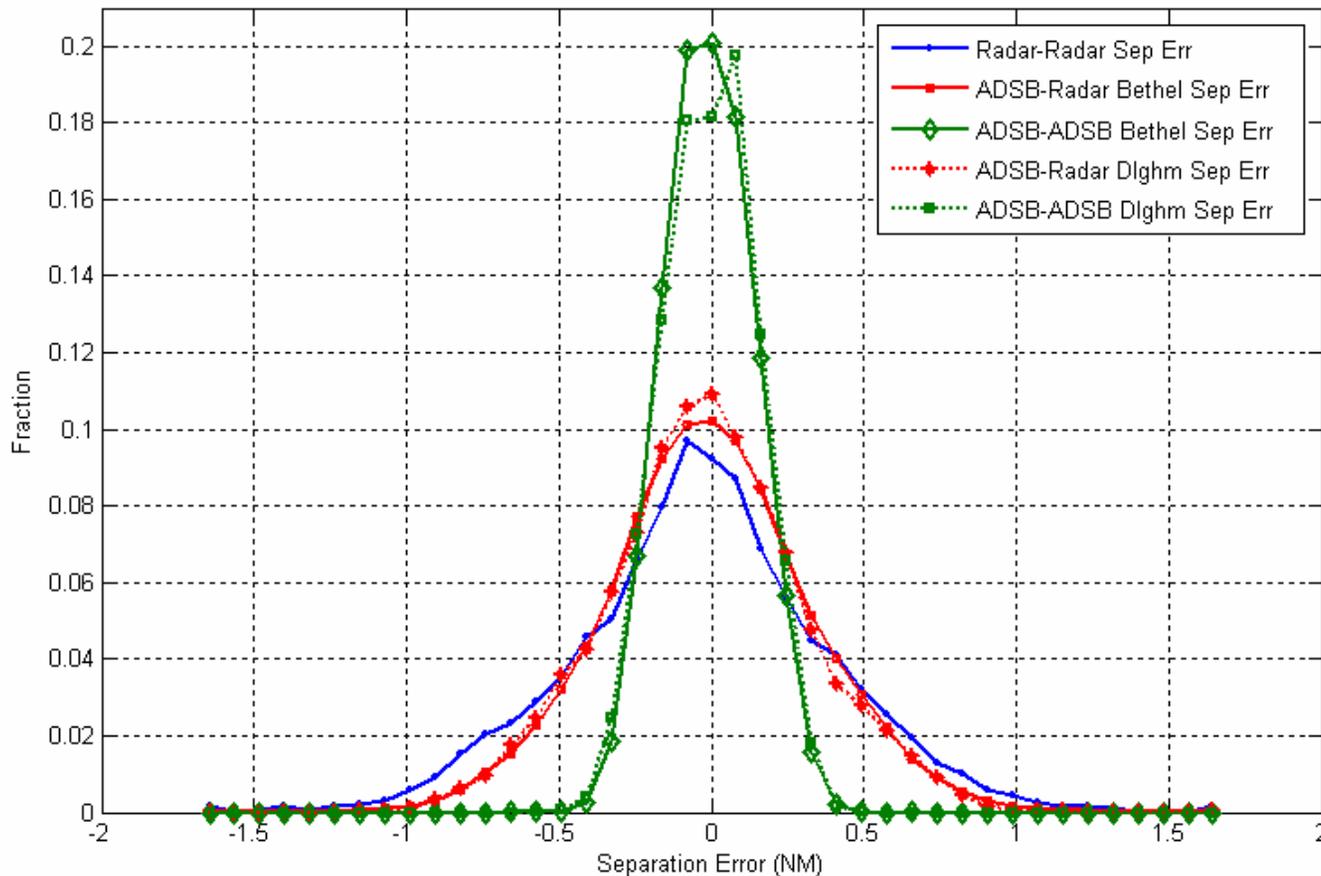
- **Calculate separation difference (Δ_{mix})**
 - “Truth” – “Displayed”
 - If the data for the other target (not being updated) is too old, skip to the next display update opportunity
 - skip if ADS-B data is older than 8.9 seconds, or
 - skip if radar data is older than 13 seconds

Box Plot Visualization of Separation Error Statistics

Description of Box Plot Features



Comparison of Distributions of the Bethel and Dillingham Evaluation Areas



“ADSB-Radar Dllghm” refers to ADS-B to Radar Separation Error results from the Dillingham Operational Evaluation Area.

Comparison of Separation Error Statistics of the Bethel and Dillingham Areas

Statistic (All Errors in NM)	Radar to Radar	ADS-B-to-radar		ADS-B to ADS-B	
		Bethel	Dlghm	Bethel	Dlghm
Count	21,948	125,332	11,063	487,486	43,550
Mean Error	-0.03	-0.01	-0.02	-0.01	0
Std Dev	0.43	0.35	0.34	0.14	0.15
2.5th Percentile	-0.88	-0.70	-0.68	-0.28	-0.30
97.5th Percentile	0.82	0.69	0.67	0.27	0.28

*Bethel Area incl. ANA, KSA, and BEA. Dillingham Area incl. AKN and DLA

Frequency of Reported NIC/NAC_P

- **3 months of data yielded:**
 - 27,110,765 reported NIC values and
 - 6,733,355 reported NAC_P values.
- **Velocity Filtered:** All reports where velocity < 20 knots were removed from consideration (to remove GPS initialization)
- **Over 99.5% NIC equal to or greater than 7,**
- **Over 99.9% NAC_P reports equal to or above 7**

NIC		NAC _P
0.10%	0	-
-	1	-
-	2	-
0.01%	3	-
0.01%	4	-
0.02%	5	-
0.09%	6	0.01%
0.19%	7	0.04%
3.36%	8	2.79%
46.19%	9	66.88%
50.01%	10	30.28%

Conclusions

! These conclusions are limited by the assumptions stated in previous slides and the accompanying ICNS paper.

- **TOO analysis shows that ADS-B to long-range radar separation errors are less than or equal to separation errors from two long-range radars**
- **Largest separation errors are eliminated when ADS-B to ADS-B case is examined**
 - Radar errors appear to dominate the ADS-B to radar Separation Error results
- **The Dillingham Operational Evaluation Area (DLA and AKN) exhibits comparable separation error to the Bethel area (BEA, KSA, ANA).**
- **The majority of reported ADS-B Integrity and Accuracy values are 7 and above ($R_c < 0.2$ Nm, $EPU < 0.1$ Nm)**
- **ADS-B reported positions from the GDL-90 UAT have greater accuracy than beacon reports from current radar sites in the evaluation area**