Prototype ADS-B System in the Midwest: Description and Lessons Learned

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Topics

- Overview
- Background
- Midwest ADS-B System
  - System
  - Equipment
  - Features
  - Data Conversion
- ADS-B and Radar Fusion
- Beacon Code and Flight ID Correlation Process
- Lessons Learned
- Questions

Overview

- **Period: 2007 to Present**
- **Participants: FAA, Volpe, WJHTC, MITRE**
- **Objectives**
  - Deploy a prototype 1090 MHz ADS-B monitoring system in the Midwest of the United States
  - Develop and implement a correlation process that provides a Flight ID (e.g. UPS1251, USA110, etc) based on a Beacon Code
  - Provide a stable “Test Bed” that distributes surveillance data to the UPS Global Operations Center (in Louisville, KY) for use in a Merging and Spacing Application

Background

- FAA, in coordination with UPS, sponsored development of a merging and spacing tool
  - Airline Based En-route Sequencing and Spacing (ABESS)
  - Development of analytical tools within ABESS are ongoing
- Most UPS aircraft are equipped with Mode S Extended Squitter transponders
- In addition to ADS-B, radar is also used as a supplement surveillance source
- Five radars and five ADS-B ground stations data are fused and provide:
  - Position information
  - Altitude
  - Velocity
  - Beacon Code or Flight ID (depending on the data source)
- Reports with Beacon codes are correlated with an additional data feed called the Traffic Flow Management Data to Government (TFMDG)
  - Used to Identify a corresponding Flight ID

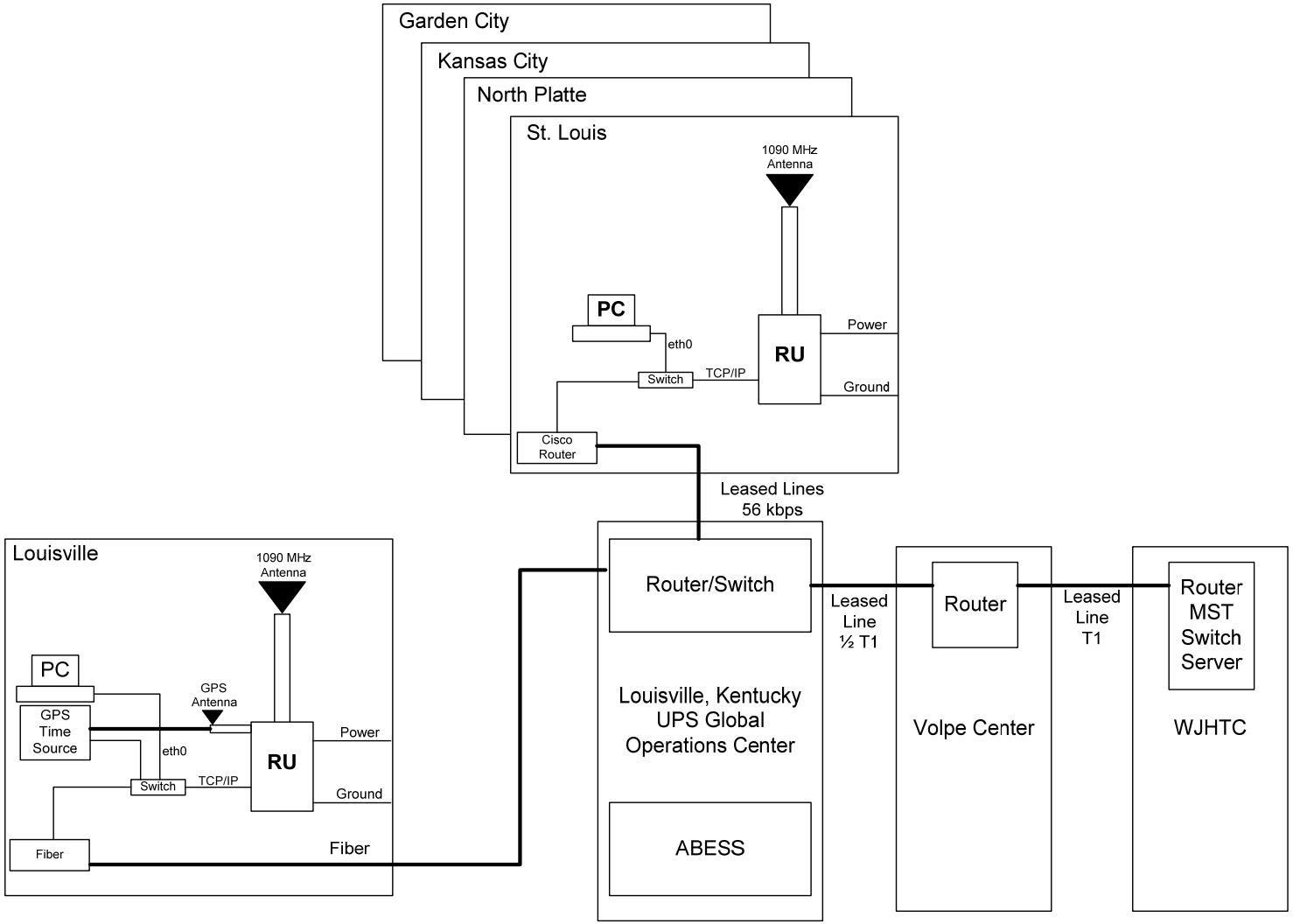
ABESS Surveillance Needs

- Midwest system designed around needs of ABESS
- Requires coverage 90 minutes west of SDF
  - Coverage above 20,000 ft MSL
- Include most major air routes into SDF from the west
  - Distance of approximately 1,000 nmi miles
- Surveillance Data:
  - Frequent Update Rate
  - Accurate Position report
  - Altitude report
  - Aircraft Velocity
  - Aircraft Flight ID

System Features

- **Hardware**
  - Sensis Corporation Multilateration RU (Mode S receiver)
  - Miniature PC (ADS-B Processor)
  - Network Time Protocol (NTP) — syncronizes systems to Coordinated Universal Time (UTC)
- **Software**
  - Operating System on the Mini-PC is Windows XP Professional
  - Cygwin: UNIX emulation program under Windows
    - Allows for Windows and UNIX operating features
    - Code Written in C
    - Allows for use of GNU g++ compiler
    - Includes libraries for socket communications
    - High-precision calculations
    - Small compiled executables
- **Output**
  - ASTERIX Category 33 (CAT-33) messages
  - Well defined and easy to implement
  - Identified for use in the ADS-B National Deployment

ADS-B Midwest System



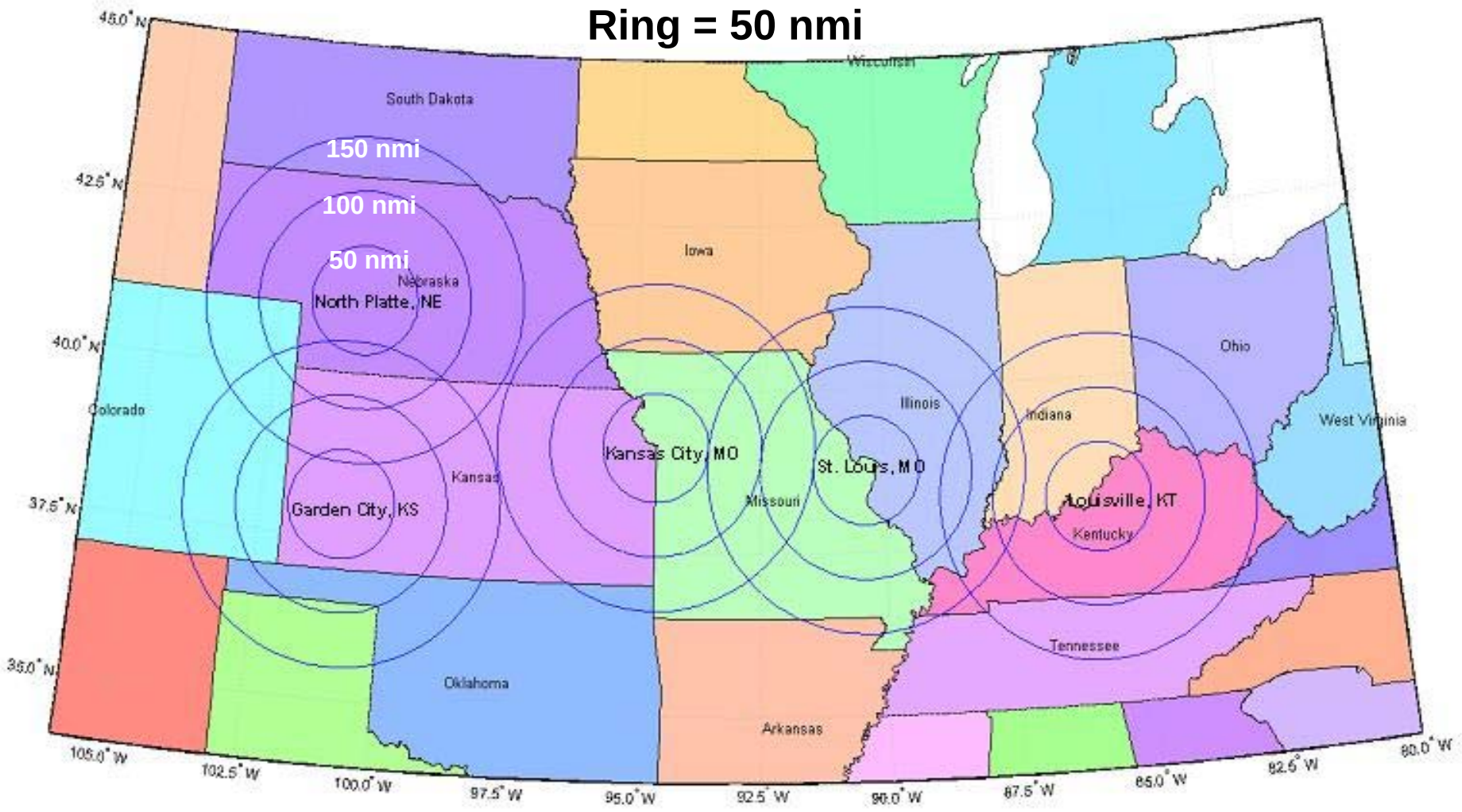
ADS-B Ground Station Equipment

ADS-B Ground Station

Switch, Router and Mini-PC

ADS-B Omni Directional Antenna

ADS-B Coverage



DF-17 to CAT-33 Format Conversion

- Executable running on Mini-PC converts multiple DF-17 messages to a single output message (not a one-one conversion)
- Output format is (ASTERIX) Category 33 (CAT-33)
  - Version 1
- RU performs error correction on received DF-17 messages
  - Four output conditions:
    1. Too many low confidence errors to correct
    2. Error detected and not corrected
    3. Error detected and corrected
    4. Decoded in the clear
  - Only use 3 and 4

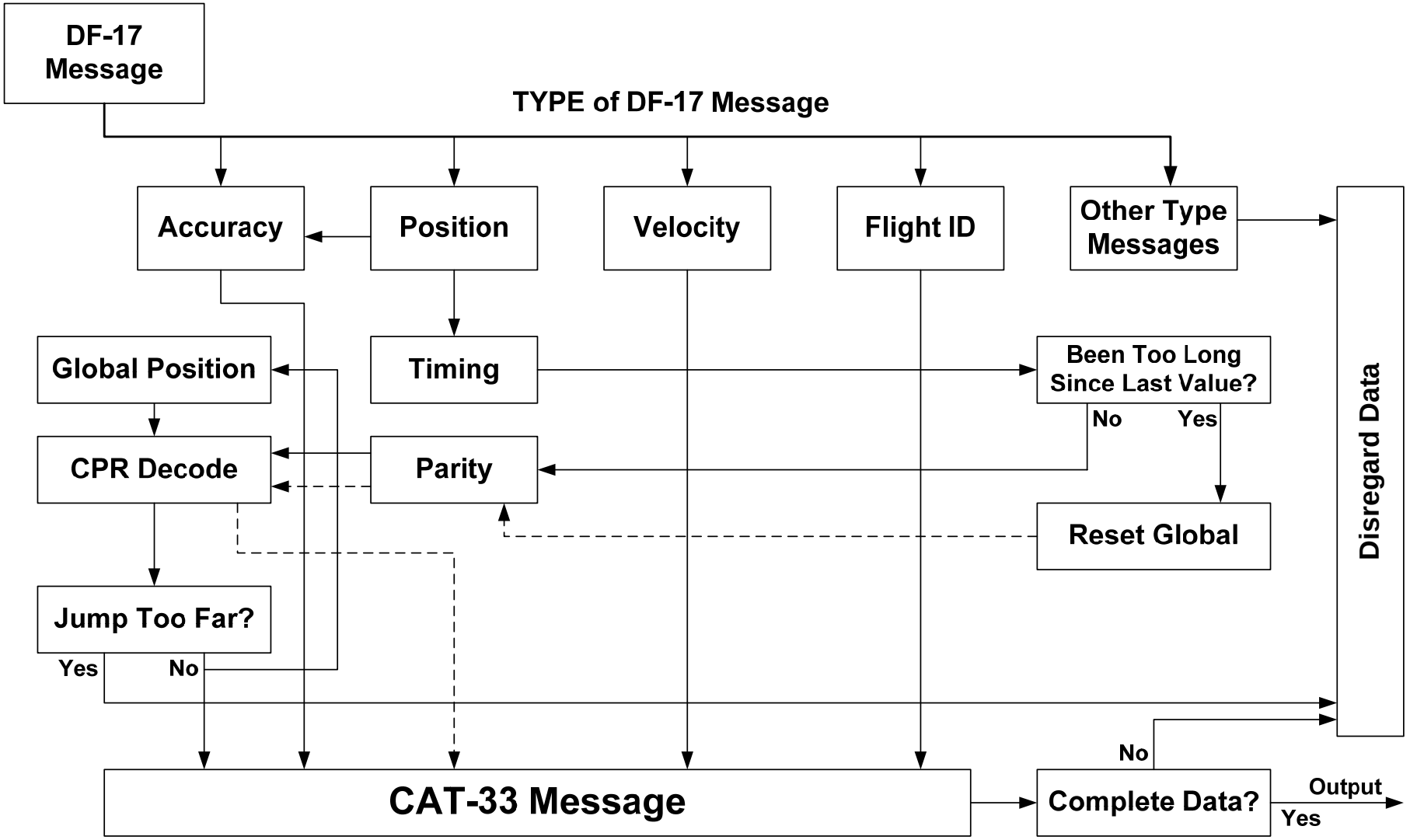
DF-17 to CAT-33 Format Conversion (cont.)

- Decode DO-260 *and* DO-260A compliant aircraft messages
  - Beacon Code
    - DO-260: Is not included
    - DO-260A: Included but not used in CAT-33 output
  - Integrity and accuracy parameters
    - DO-260: Look-up table based on DF-17 Type 9-18, 20-22 messages and NUC_P
    - DO-260A: Uses the values in DF-17 Type 31 message for NIC, SIL, and NAC_P
- Included in output CAT-33 message:
  - Time, Position, Altitude, Velocity, Flight ID, Mode S ID
  - Integrity and accuracy values
  - Other system information such as Version number, System Area Code, System ID Code, etc.

Latitude and Longitude Decoding

- Dominant DF-17 messages
  - Types 9-18 and 20-22 contain position information
  - Formatted as Compact Position Reports (CPR).
  - Individual CPR message give 1/3 of the total information
  - Not a one to one conversion
- Required Information for CPR Decoding
  - Even Parity Message
  - Odd Parity Message
  - Base Position (e.g. Antenna location)
- Using Even and Odd Parity
  - Decoded results in “locally unambiguous” position report
  - Within 160 nmi diameter zone
  - The actual position of the aircraft may be in the same relative position but within a different 160 nmi diameter zones
  - 15 Zones
- “Globally unambiguous” position report is found by using “Base Position”

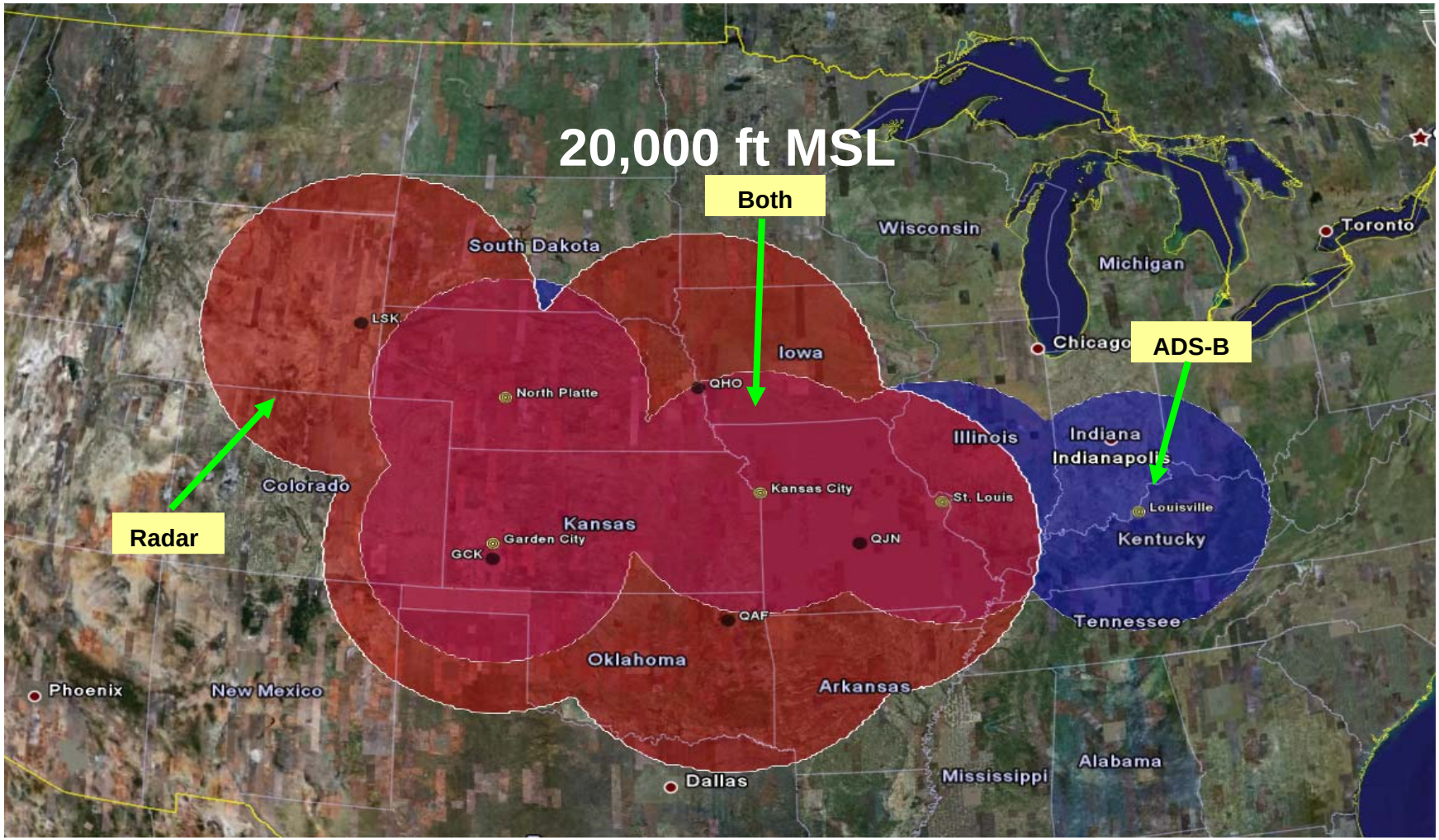
Format Conversion Process



Radar Fusion

- Radar data is required
  - Many non UPS Aircraft are not Mode S Extended Squitter Equipped
  - ADS-B Ground Stations do not encompass the total required coverage
- ADS-B and Radar data are fused and provided in CAT-33 format
- Fuse with 5 Radars
  - Garden City, KS (GCK)
  - Croker, MO (QJN)
  - Omaha (Offutt AFB), NE (QHO)
  - Chelsea, OK (QAF)
  - Lusk, WY (LSK)

ADS-B and Radar Coverage



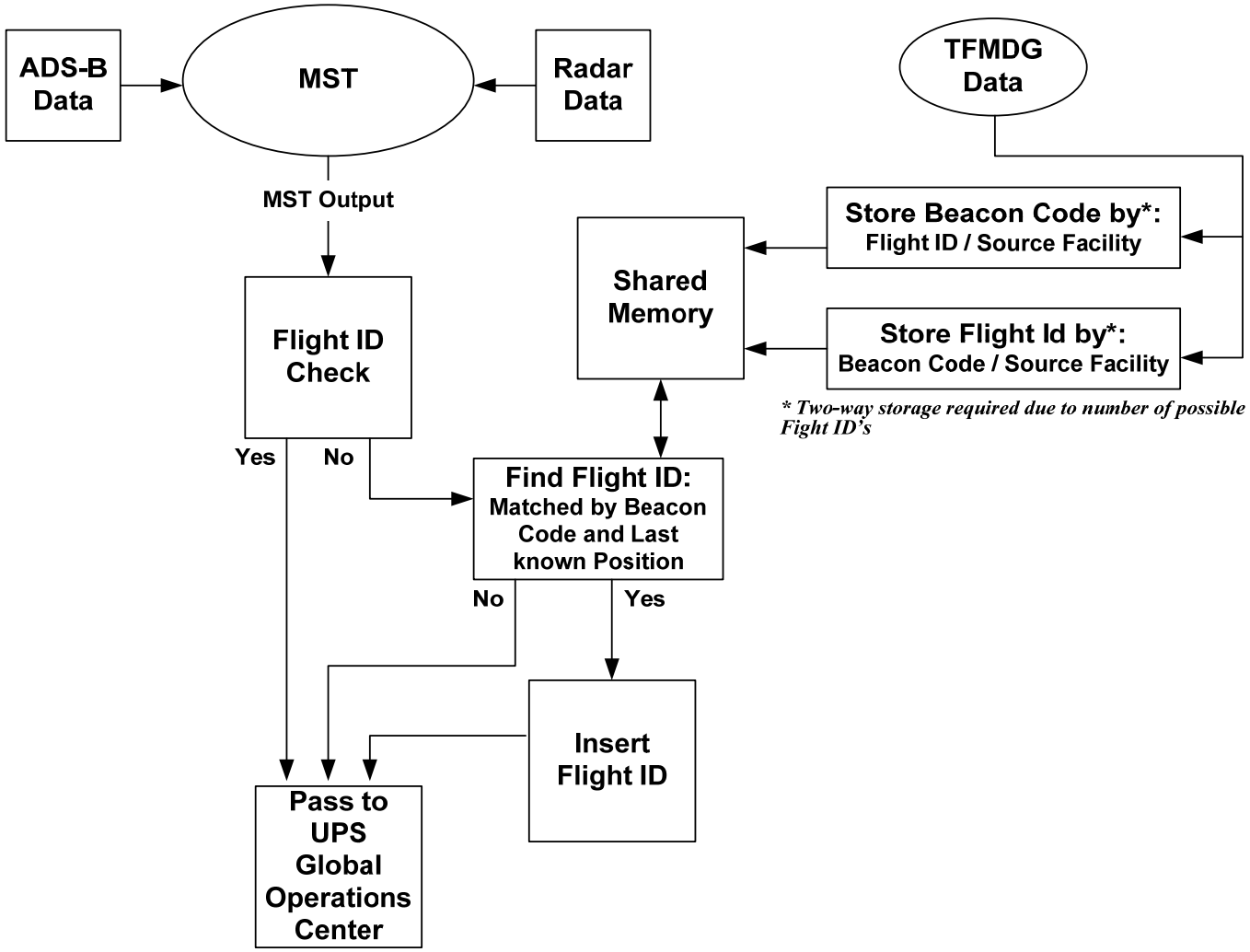
Radar Fusion

- Fusion is performed based on 3D position information
  - ADS-B and ADS-B/Radar fused targets:
    - Position
    - Velocity Vector
    - Altitude
    - Mode S ID
    - ***Flight ID***
  - Radar only Targets
    - Position
    - Velocity Vector
    - Altitude
    - Unique track file identifier
    - ***Beacon Code***

Flight ID and Beacon Code Correlation

- ABESS requires the use of Flight ID's to filter and associate aircraft
- Correlation process must be performed
  - Use Traffic Flow Management Data to Government (TFMDG) as data correlation source
  - Includes Flight ID's
  - Includes Beacon Code's, unlike Commercial ETMS data
- TFMDG is comprised of the entire NAS surveillance data including flight plan information, boundary crossings, flight cancelation messages, etc.
- TFMDG can not be used alone because of the infrequency of position updates (once every minute)

Flow Diagram for Flight ID Correlation



Observations or Items of Importance (1/2)

- No standard relationship between the number of received DF-17 messages and the number of CAT-33 messages produced
  - DF-17 to CAT-33 conversion is not one to one — it's several to one
  - Acceptable DF-17 messages tend to be 10% to 50% of those received
  - CAT-33 report interval varies between 1 second down to 2-5 seconds
  - Aircraft further from the receiver tend to have fewer CAT-33 reports
- Identified a modified CPR decoding technique
  - Find "globally unambiguous" solution
  - ADS-B receivers' location should only be used as the first "base position"
  - Subsequent CPR solutions should use the last known "globally unambiguous" position as the new "base position".
  - This eliminates
    - Large jumps and stitching near boundaries
    - Track swaps

Observations or Items of Importance (2/2)

- Observed jumps in position
  - Due primarily to uncorrected “bit swaps”
  - Corrected using a jump filter
- The Mode S ID is unique to an aircraft and therefore very useful in identifying, monitoring and associating data belonging to an aircraft
- UDP Socket Communications can significantly reduce communications delays due to the volume of data sent from the ADS-B Receiver
- A “zero” value in DF-17 data indicates the numerical value of zero, whereas in CAT-33 nomenclature a “zero” value may indicate missing or null data

Questions