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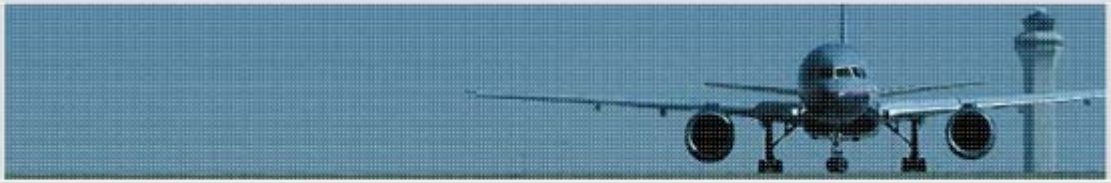

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System Wide ADS-B Back Up and Validation

Rannoch Corporation

May 2006

Rannoch Overview

Air Traffic Control

- Multilateration
- ADS-B & TIS-B
- A-SMGCS
- Vehicle Tracking
- Precision Runway Monitor
- Reduced Vertical Separation
- Collision Avoidance

Airport Management

AirScene

- Noise & Emissions
- Revenue Management
- Gate Management
- Airport Operations

Military & Homeland Security

- Passive Surveillance
- Range Management
- Aircraft Identification
- Mobile Solutions

Surveillance Today

RANNOCH CORPORATION

- **Primary and Secondary Radar**
  - Secondary often limited to airport areas
- **High cost to deploy and maintain**
- **Performance Limitations**
  - Accuracy, availability
  - Line of sight limited
  - Update rate (5 to 12 seconds)
- **Inadequate coverage in some areas**
  - Reduces airport throughput and capacity
  - Significant commercial impact

Current Avionics

RANNOCH CORPORATION

- **Mode A/C transponders**
  - General Aviation
  - Transmits Mode A beacon code for identification
  - Transmits Mode C altitude
  - Transmissions on 1090 MHz
- **Mode S transponders**
  - Commercial and business aviation
  - Transmits unique 24 bit ICAO that is unique to the aircraft
  - Replies to discreet or addressed interrogations from TCAS and SSR
  - Transmissions on 1090 MHz
- **Supports surveillance**
  - Replies to TCAS interrogations to support airborne surveillance
  - Replies to Secondary Surveillance Radar (SSR) interrogations to support ground based surveillance

ADS-B Overview

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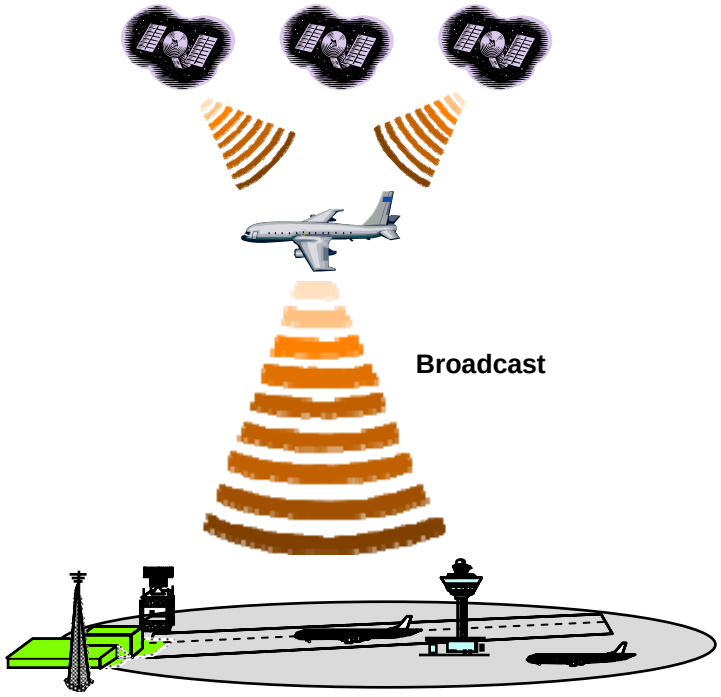


- **Low cost receivers**
  - Affordable coverage & redundancy
  - Up to 250 nm range
- **High accuracy independent of distance**
- **High Update rate**
- **Provides Identity of the aircraft**
- **Supports Cockpit Display of Traffic Information**
- **Cooperative**

ADS-B

RANNOCH CORPORATION

- **1090 MHz ADS-B**
  - Commercial aircraft
  - Leading technology for Europe and Australia
- **UAT ADS-B**
  - General Aviation
  - Largest implementation in Alaska

ADS-B Equipage Levels

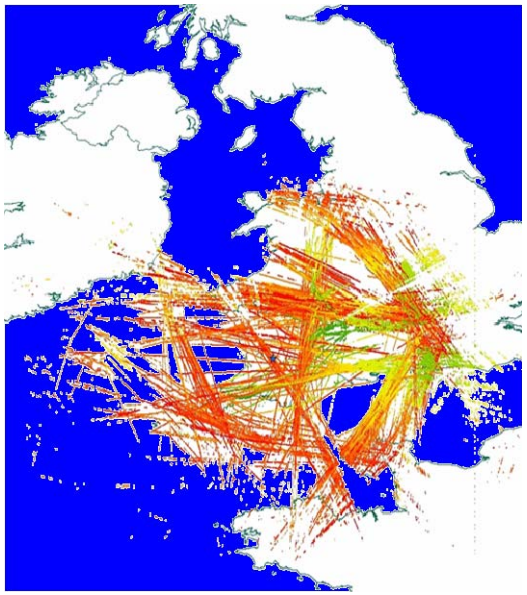
RANNOCH CORPORATION

- 5% of US-based Mode S aircraft with ADS-B
- Rannoch trials with UK NATS late 2004
  - 30% of Mode-S aircraft with ADS-B

December 2004 (2603 Mode-S Aircraft)

	Aircraft	% ADS-B	% Mode-S
Aircraft ID & Type	**682**	**89.9%**	**26.2%**
Airborne Position	**357**	**47.0%**	**13.7%**
Airborne Velocity	**613**	**80.8%**	**23.5%**
Any ADS-B	759	100%	29.2%

1. Source: Mitre @ RTCA Spring Forum – May 2005



Multilateration Overview

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- **Uses Time Difference Of Arrival (TDOA) to triangulate or multilaterate aircraft position**
  - Determines position from Mode S and Mode A/C transponder transmissions
- **Supports update rates of once per second**
- **More accurate than primary and secondary radar**
  - Accuracy less than 5 meters (RMS)
- **Sensors are networked to support the most demanding coverage requirements**
- **Supports 1090 MHz ADS-B**

Multilateration Configuration

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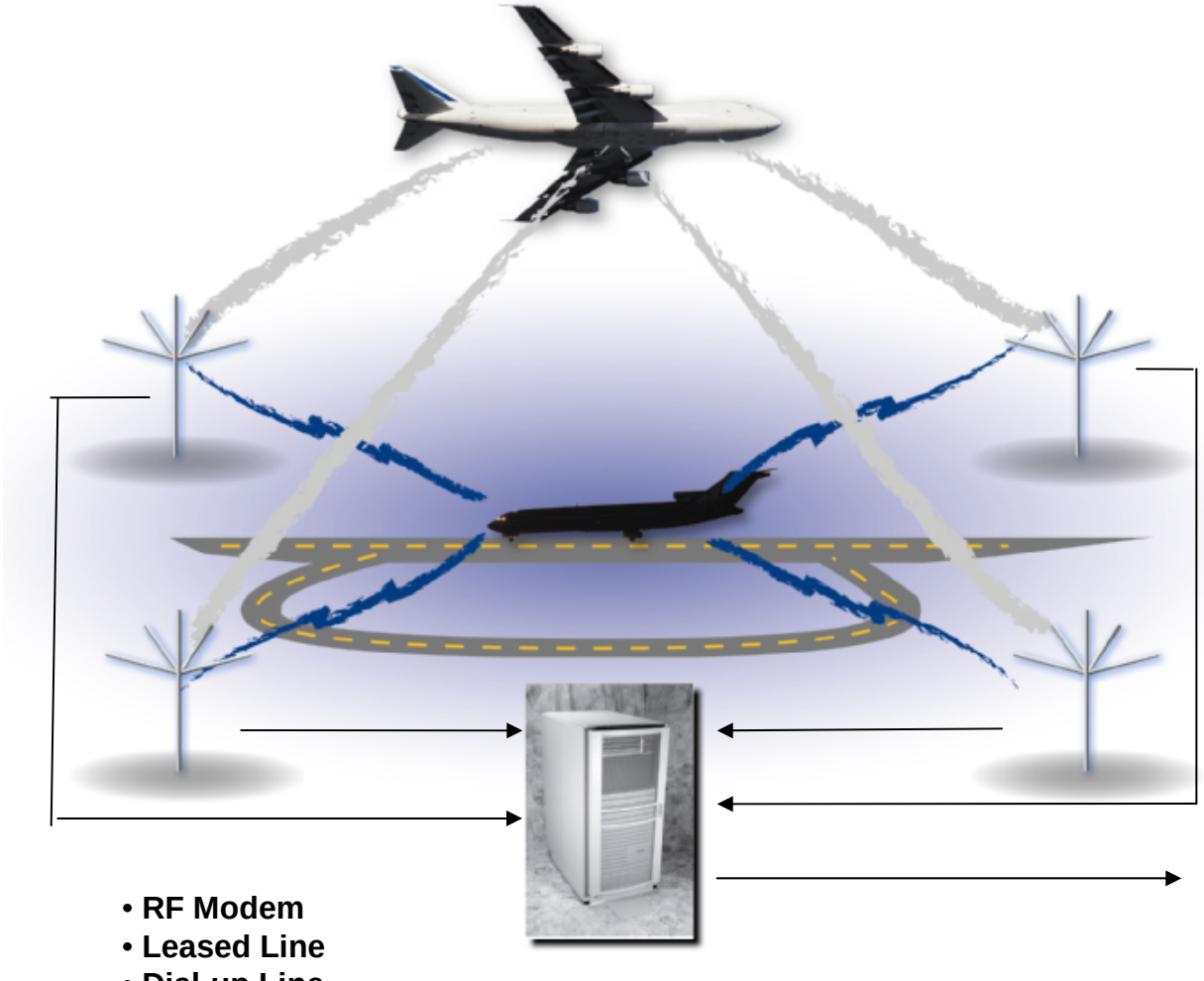

- Passive or Active
- Independent of ATC
- Real time, 1 sec. Update
- Detailed aircraft info

- RF Modem
- Leased Line
- Dial-up Line
- Ethernet

Taiwan Example

RANNOCH CORPORATION

- **Active WAM-ADS-B**
  - 8 receivers, 2 interrogators
  - 160 Nm
- **ATC of KinMen- Pengu route**
  - 2 ATC display consoles
- **En-route, approach, ground**
  - Approach (fog)
  - Surface
- **Rapid deployment**
  - 6 months to operational

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Taiwan ADS-B/Mulitaleration

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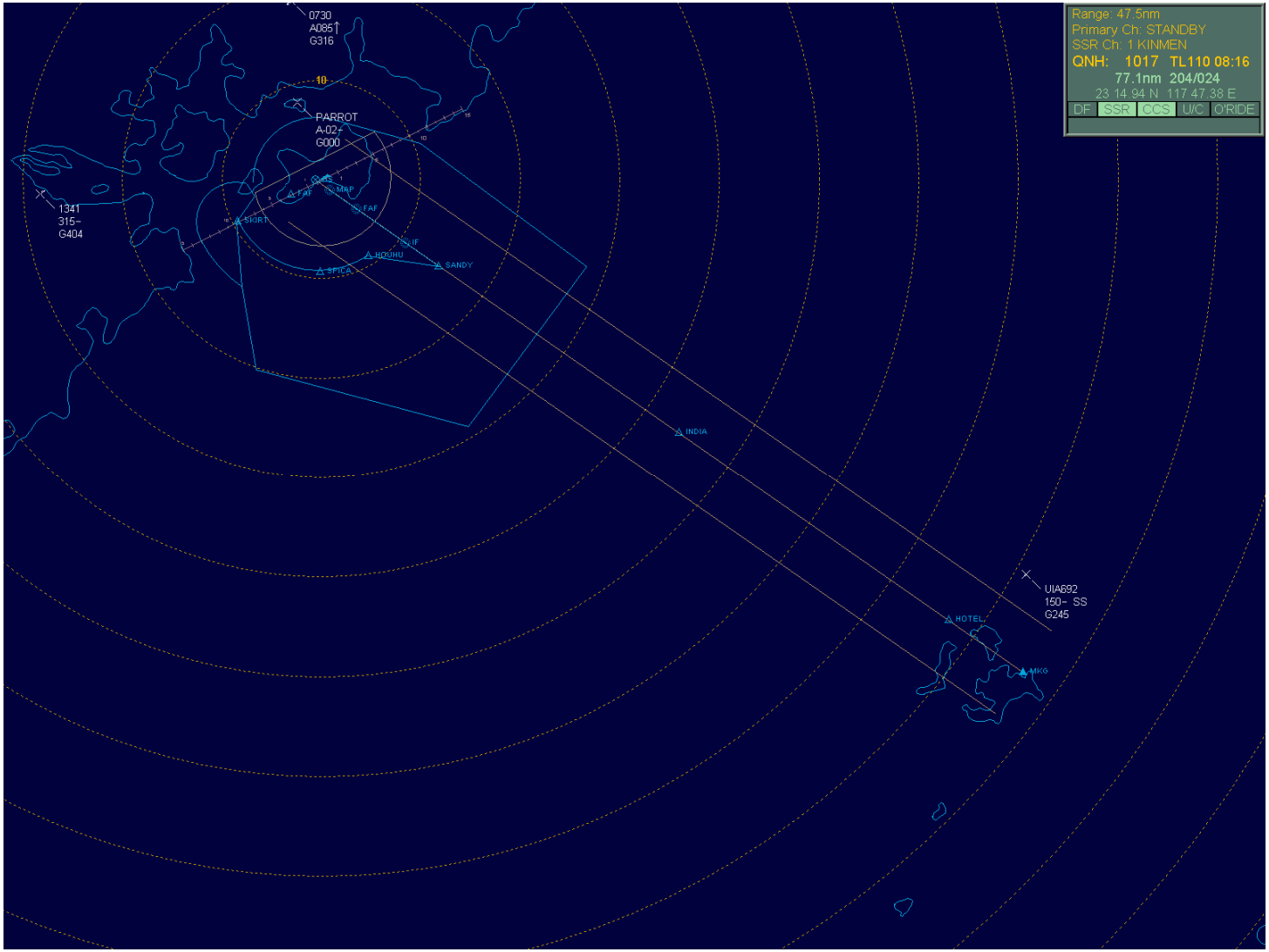

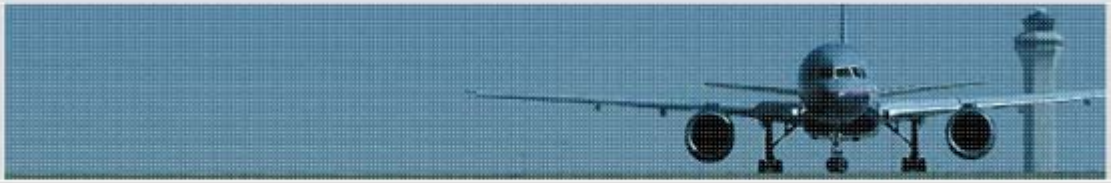

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ADS-B Backup Example

MLAT Accuracy Requirements

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- Based on ATCBI-6 specification (FAA-E-2923)
- Specified accuracy
  - Range Accuracy [para. 3.1.3.1]
    - Range Bias: ± 30 ft
    - Range Jitter Standard Deviation (SD): 25 ft
  - Azimuth Accuracy [para. 3.1.3.2]
    - Bias: ± 0.033 deg
    - Jitter SD: 0.066 deg
- Angular accuracy translation to linear
  - Linear (rms) = Bias + 2 (Jitter SD)

Range (NM)	Accuracy (rms-meters)	Region
60	320	Terminal Area
125	667	
250	1333	Enroute ATCBI-6 limit

Example Regional Coverage Assessment

RANNOCH CORPORATION

- **AirScene Wide Area MLAT installations (terminal coverage):**
  - Cincinnati
  - Indianapolis
  - Louisville
  - Columbus
- **Example Regional Coverage achieved by combining the four systems in a network**
- **Very high availability achieved due to multiple redundancy in sensors**
  - Each MLAT has 5 sensors
  - Total sensor count for regional network is 20
- **Achieves approximately 125,000 square miles coverage for enroute (≥18,000 ft)**

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MLAT Enroute Coverage

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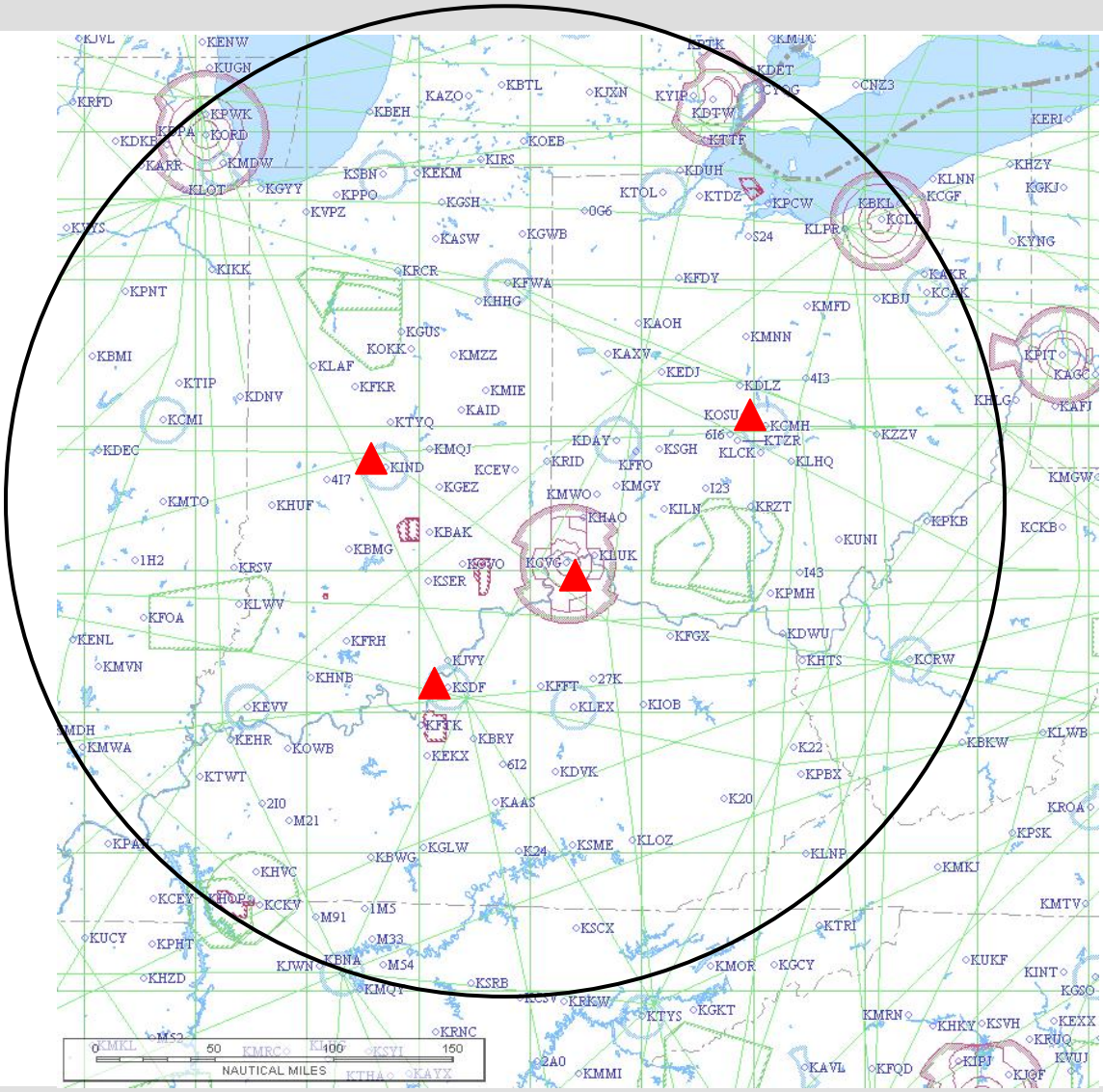

MLAT enroute coverage (≥18,000 ft)

Approximately 125,000 sq mi

Chart indicates Jet Routes

▲ AirScene MLAT sites

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MLAT Coverage: 18,000 ft

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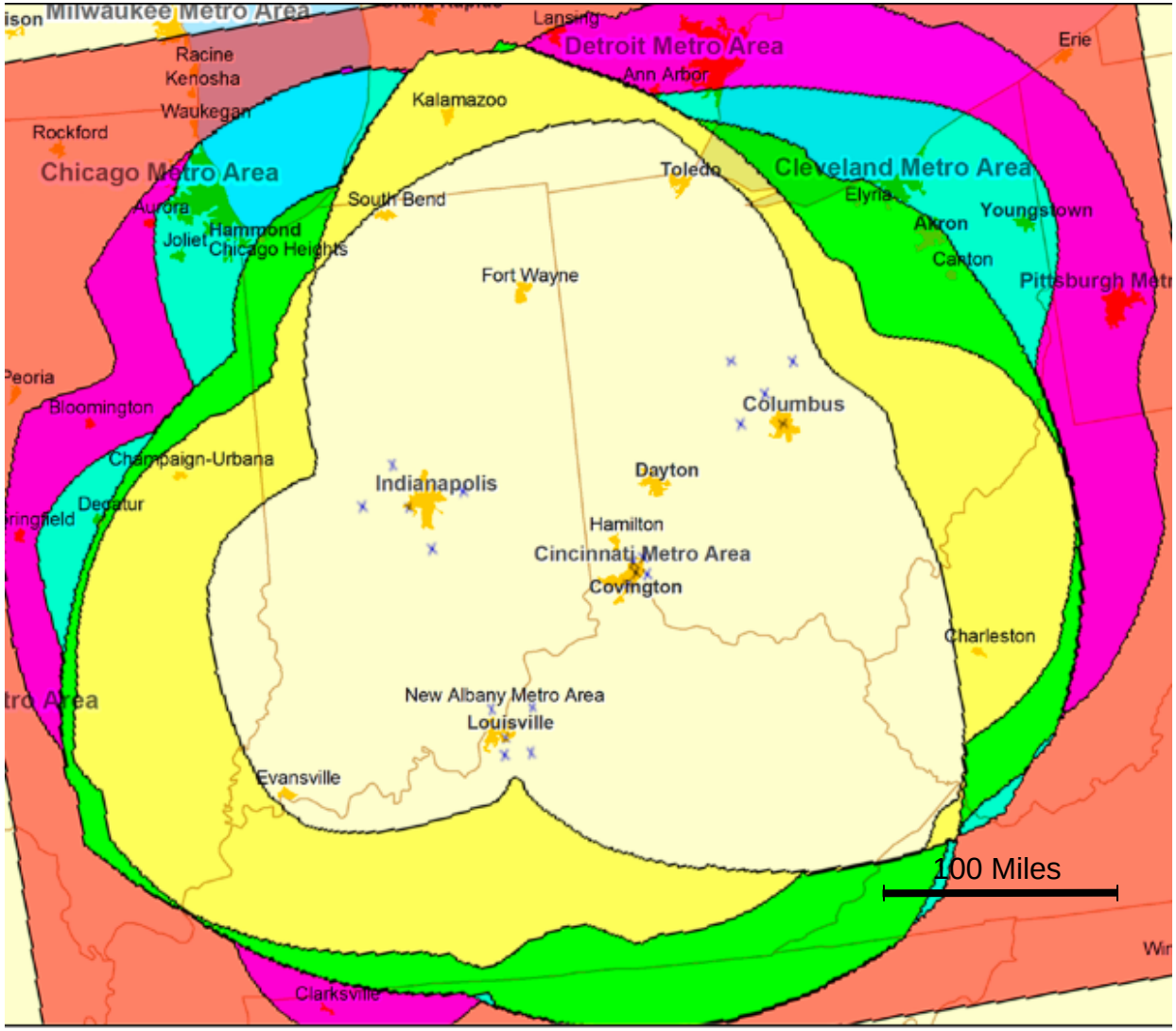

- Accuracy < 25 meters (RMS)
- 25 < Accuracy < 100
- 100 < Accuracy < 320
- 320 < Accuracy < 666
- 666 < Accuracy < 1333
- Accuracy > 1333

MLAT Coverage: 10,000 ft

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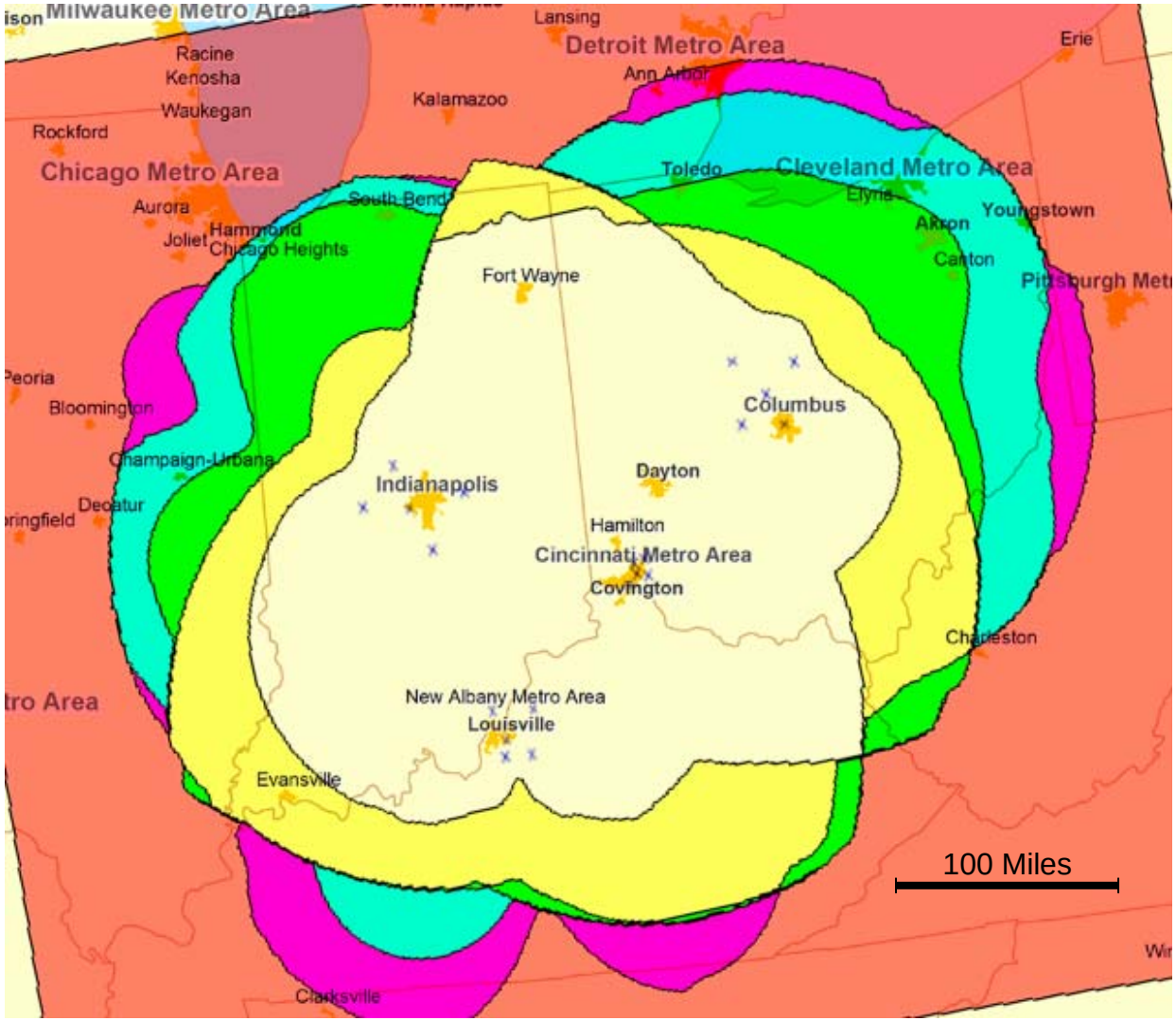

- Accuracy < 25 meters (RMS)
- 25 < Accuracy < 100
- 100 < Accuracy < 320
- 320 < Accuracy < 666
- 666 < Accuracy < 1333
- Accuracy > 1333

MLAT Coverage: 4,000 ft

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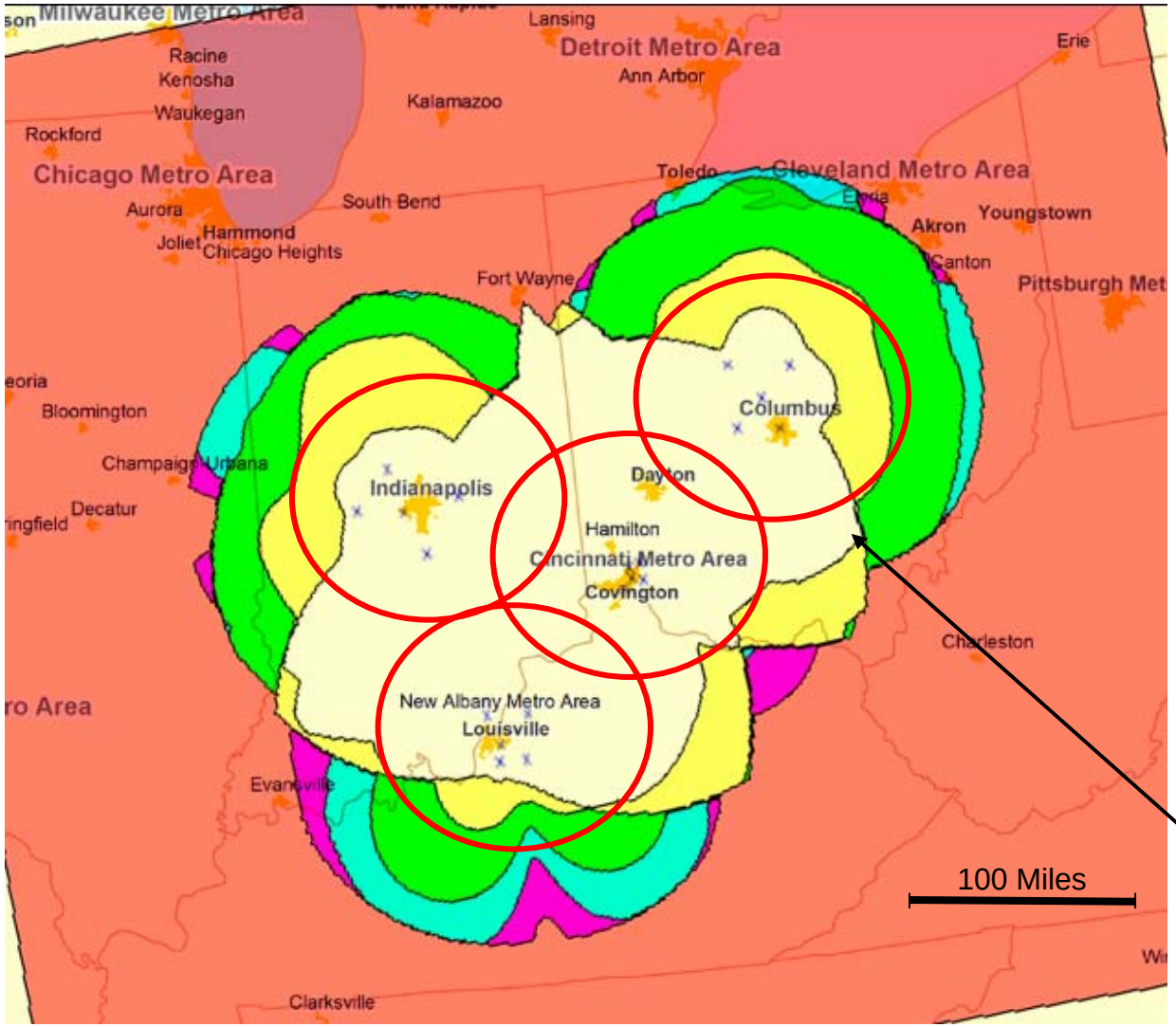

Terminal accuracy required = 320 m

- Accuracy < 25 meters (RMS)
- 25 < Accuracy < 100
- 100 < Accuracy < 320
- 320 < Accuracy < 666
- 666 < Accuracy < 1333
- Accuracy > 1333

Terminal coverage required = 60 NM

MLAT Cov, 3 Airports: 18,000 ft

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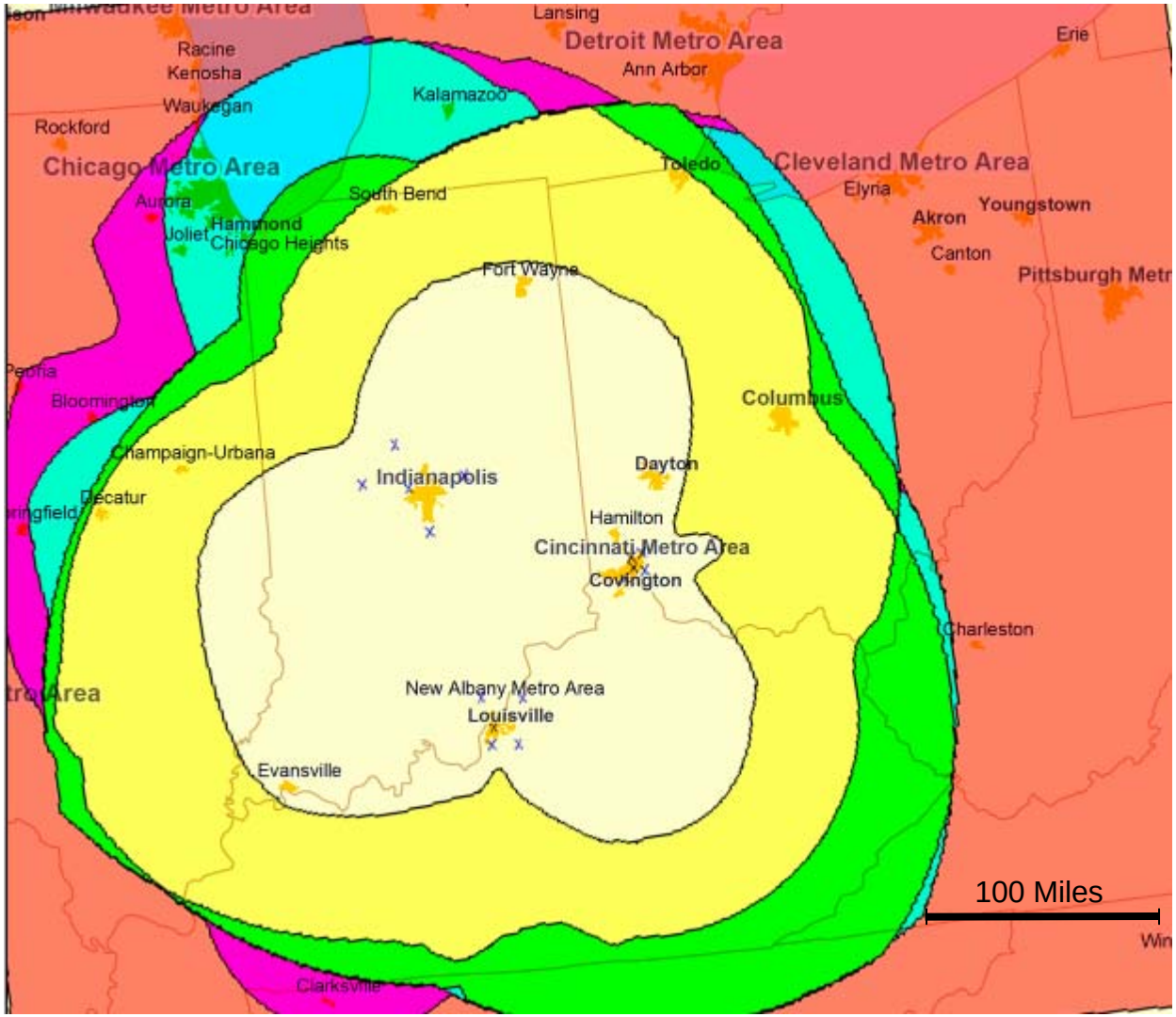

- Accuracy < 25 meters (RMS)
- 25 < Accuracy < 100
- 100 < Accuracy < 320
- 320 < Accuracy < 666
- 666 < Accuracy < 1333
- Accuracy > 1333

MLAT Cov. Failed State: 18,000 ft

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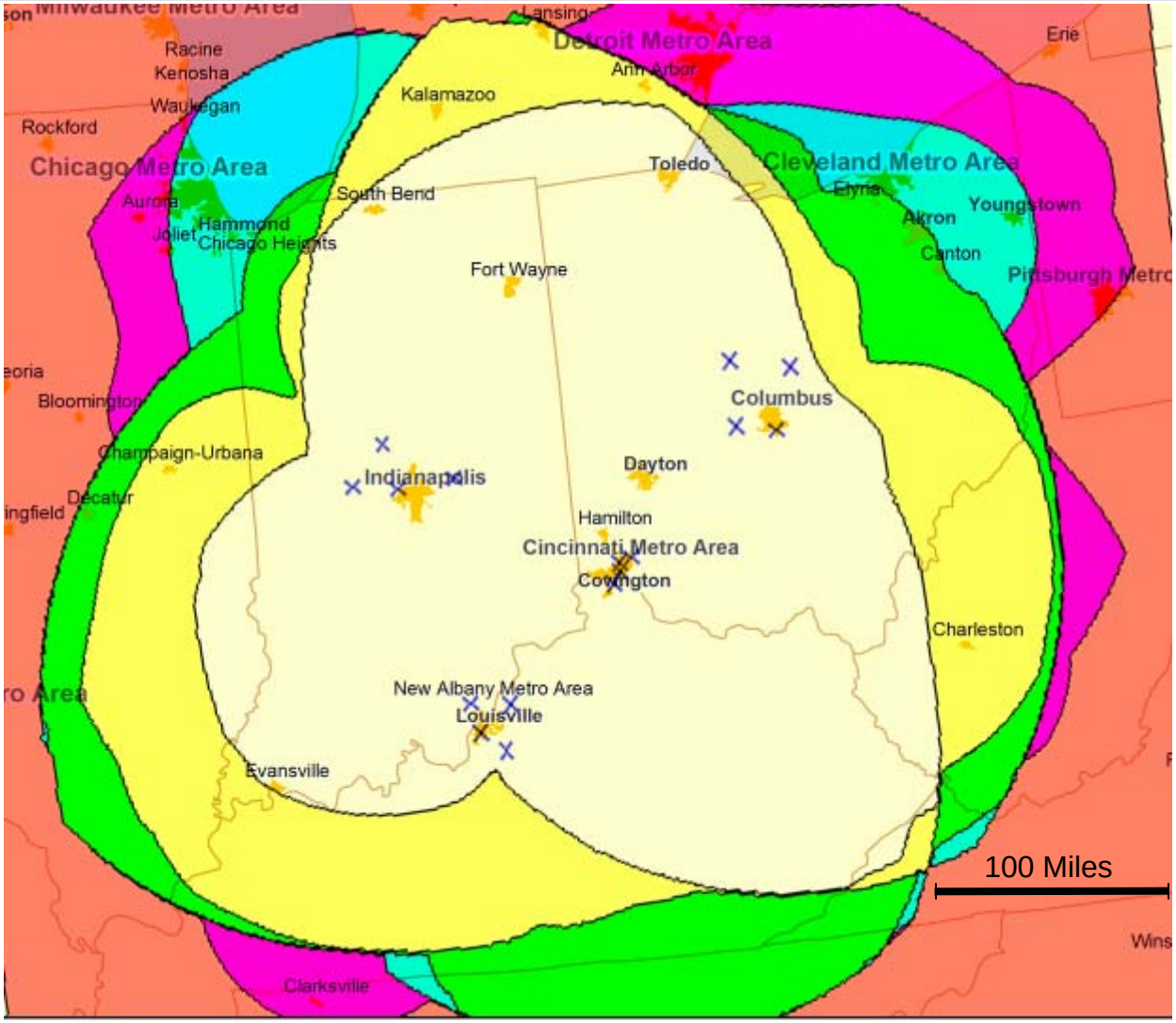

One sensor failed at each airport

No impact on availability

- Accuracy < 25 meters (RMS)
- 25 < Accuracy < 100
- 100 < Accuracy < 320
- 320 < Accuracy < 666
- 666 < Accuracy < 1333
- Accuracy > 1333

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ADS-B Coverage: 18,000 ft

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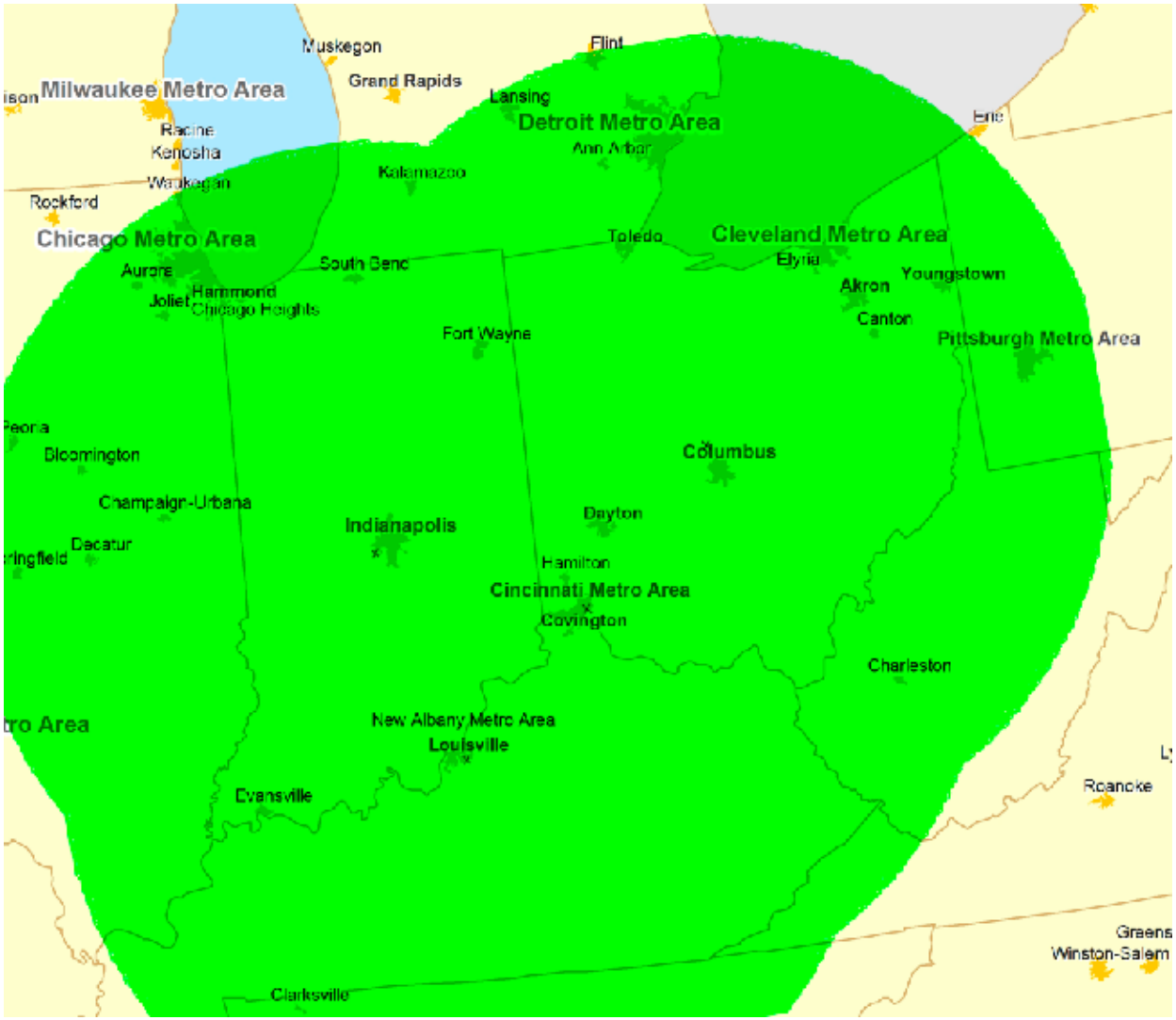

Single ADS-B receiver at each MLAT airport

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ADS-B Coverage: 10,000 ft

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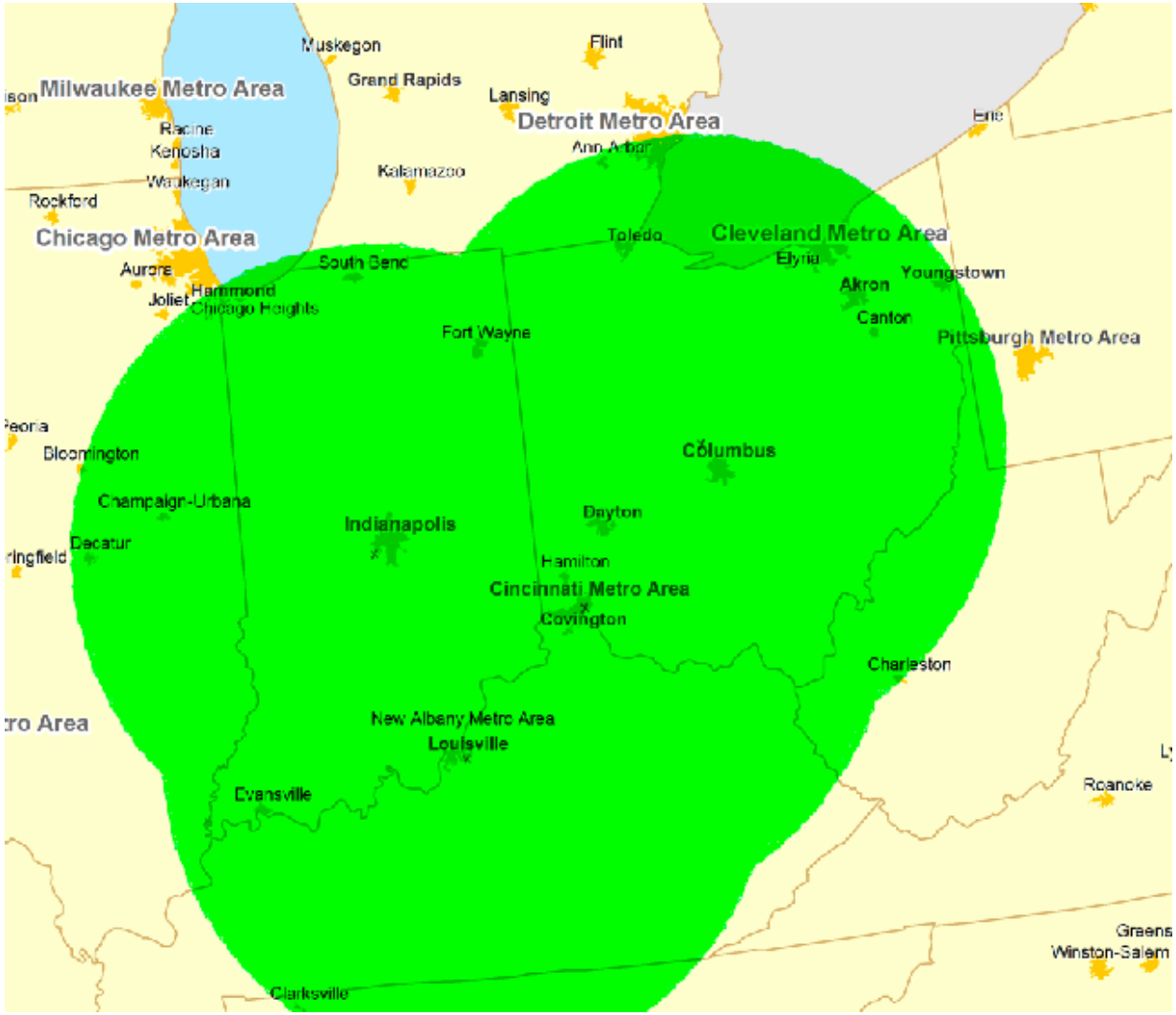

Single ADS-B receiver at each MLAT airport

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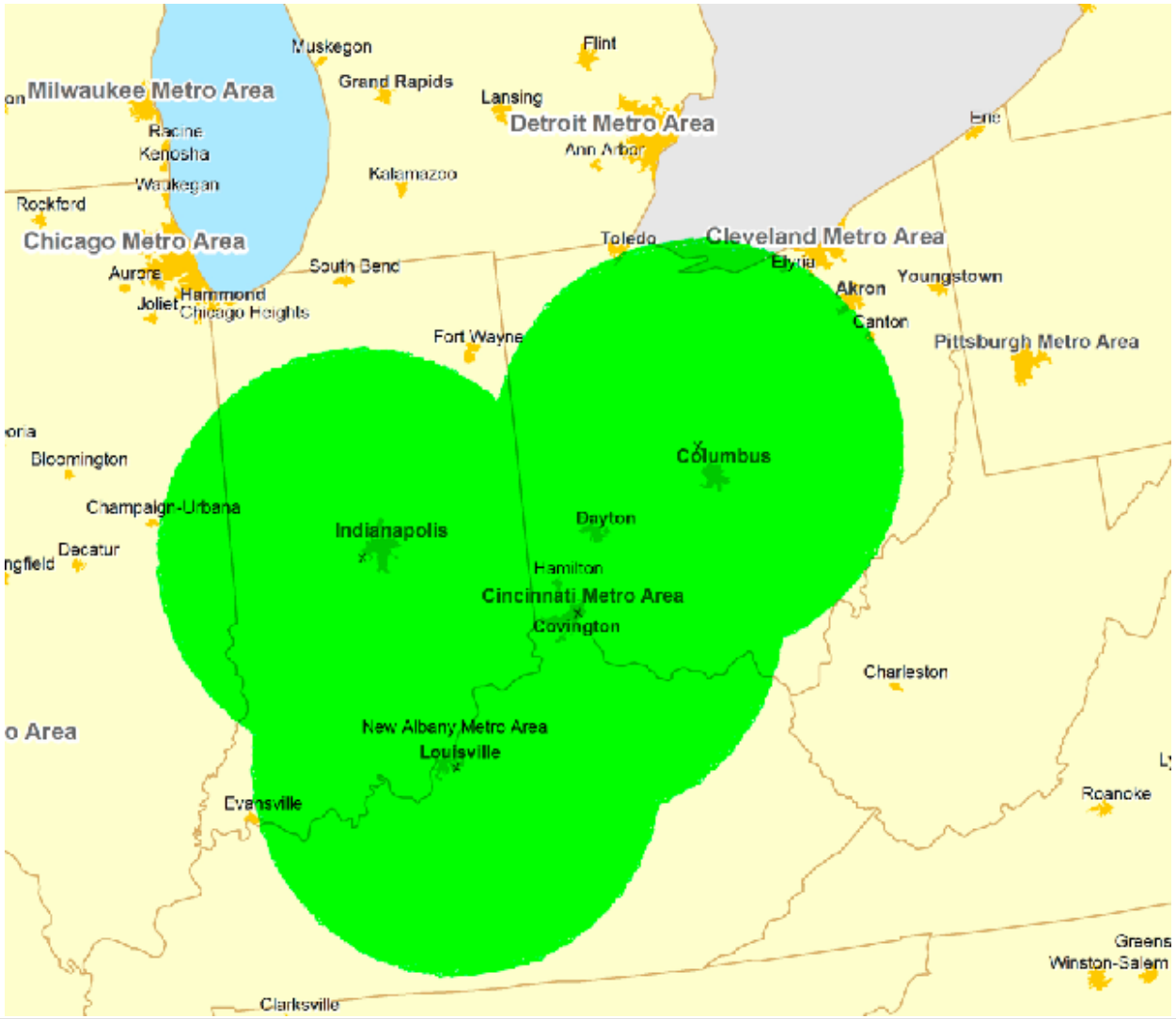
ADS-B Coverage: 4,000 ft

RANNOCH CORPORATION



Single ADS-B Receiver at each MLAT airport

Conclusions

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- **High participation levels of ADS-B equipage will take several years**
- **Multilateration/ADS-B are currently being implemented as an alternative to Secondary Surveillance Radar**
  - **Link these systems are capable of providing high availability enroute surveillance**
- **ADS-B ground receivers can be used to support multilateration**
  - **Multilateration can serve as a backup to ADS-B**
  - **Multilateration can be used to independently verify ADS-B**
- **Significant multilateration/ADS-B infrastructure is already in place in the US and Europe**