Multilateration Systems Implementations

International Civil Aviation Organization

North American, Central American and Caribbean Office

Surveillance Seminar for the NAM/CAR/SAM Regions

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Agenda

- Evolutionary Deployments
  - North America
  - International
- Surface Surveillance Applications (A-SMGCS)
  - North America
    - FAA
  - World wide
    - Operational
    - Planned
- Wide Area Surveillance
  - North America
    - Operational
  - Worldwide
    - Operational
    - Planned

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Evolutionary Deployments

- North America
  - FAA Technical Center
  - Atlanta Hartsfield
  - Dallas Fort Worth (ATIDS)
  - Gulf of Mexico (HITS)
  - Toronto - Lester Pearson Airport
- International
  - London Heathrow
  - Frankfurt

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N. America Trials

- FAA Technical Center (Atlantic City, NJ) 1992-95
  - FAA and MIT Lincoln Labs sponsored tests to determine feasibility of transponder multilateration on airport surface.
- Atlanta – Hartsfield International Airport 1995-97
  - FAA, MIT and NASA sponsored
  - Limited coverage of airport
  - Further performance analysis of surface MLAT
  - Included first WAM trials (PRM)
- Dallas Fort Worth Airport (ATIDS) 1998-2000
  - FAA contract for major evaluation of surface MLAT
  - FAA used to develop/verify system requirements
  - 6 sensors coverage of East side of DFW
  - Resulted in inclusion of MLAT for ASDE-X
- Toronto – Lester B. Pearson Int'l (2000-01)
  - NavCanada evaluation of surface MLAT

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N. America trials

- Gulf of Mexico (HITS) 2001 – 2005
  - NASA sponsored R&D program
  - WAM for low level helicopter operations to oil platforms
  - Sensors installed on platforms and shore based
  - Coverage area > 15,000 sq miles @ 1500 ft
  - MLAT Performance compared to ATCBI-6 SSR

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International

- London Heathrow 1996-97
  - Commissioned by NATS (National Air Traffic Services)
  - Limited deployment (5 sensors) focused on performance in gate/stands area (multipath & accuracy.
  - Successful and resulted in first ATC operational MLAT system worldwide.
- Frankfurt 1997-98
  - Sponsored by Fraport
  - Limited deployment for technical evaluation
  - Successful and resulted in 2nd operational system

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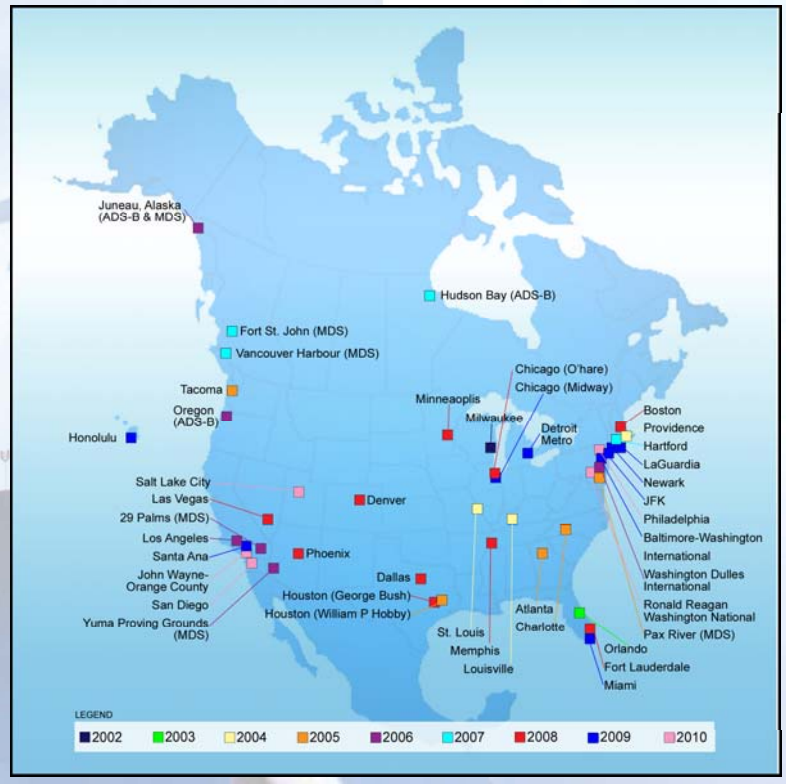
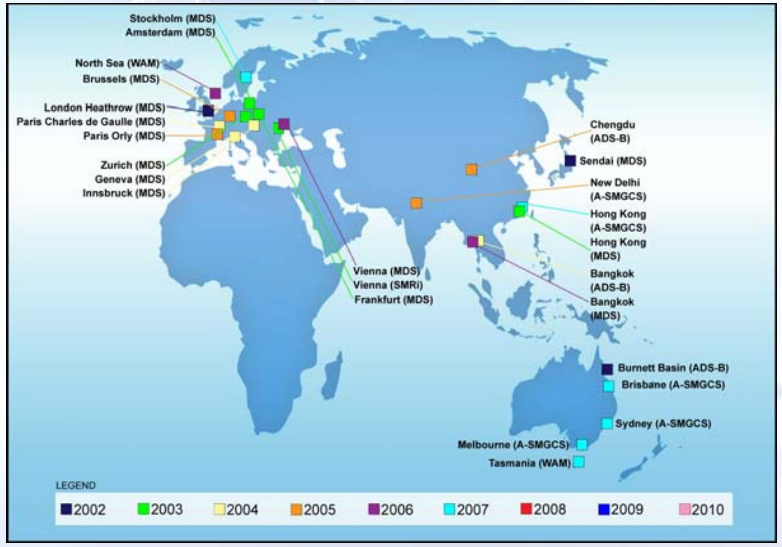
Sensis MLAT Worldwide Locations





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Examples of Multilateration Based Surveillance Systems

Advanced Surface Movement Guidance & Control Applications

Wide Area Surveillance (WAM)

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MLAT for ASMGCS

- ASDE-X (U.S. FAA)
  - Atlanta Hartsfield
  - Milwaukee
- International
  - London Heathrow (Operational)
  - Vienna (Operational)
  - Sydney (Planned)

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Summary of Requirements

- Coverage
  - Movement area on the surface and extending to a height of 100 meters above the surface and the airspace used by arriving & departing traffic to a distance of 5 nm
- Accuracy
  - 7.5 meter, 95% confidence, runway, taxiway and apron centerlines; 12 meter, 99% confidence
  - Stands to within 20 meter averaged over 5 seconds
  - Airborne targets – 20 meter, 95% @ 2.5 nm; 40 meter, 95% @ 5 nm from threshold.
- Probability of MLAT detection (active Mode S)
  - 99.9% within any 2 second period on runway & taxiway
  - 99.9% within any 5 second period in the stands
- False Targets (False detections) PFD
  - $<10^{-4}$ defined as any spurious output or any position report >50 meter from true position
- Update rate
  - 1 per second minimum average for any target in the coverage area, based on squitter rate of Mode S transponders.

Source: Eurocae ED-117

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FAA /International Comparison

- Coverage area
  - FAA systems do NOT require gate coverage
  - Most international require gate coverage
  - More sensors required
- Transponders
  - FAA requires tracking of older Mode A/C
  - Most international are Mode S only, European Mode S mandate.
  - Compatible with ADS-B (Mode S ES)
- Interrogation
  - FAA requires interrogation of older transponders
  - European prefer to minimize interrogations however addressed Mode S used for Mode A and Mode C.

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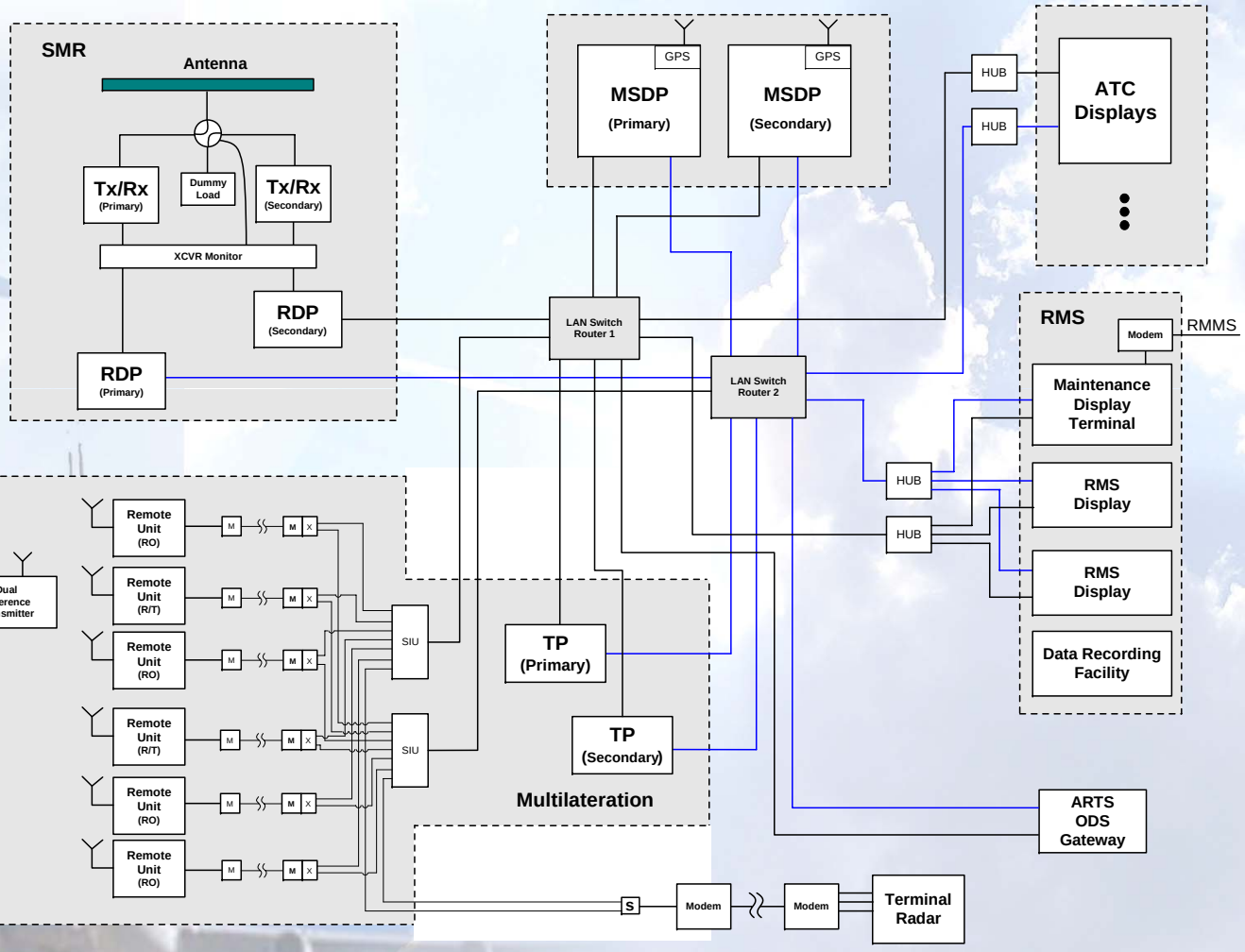
Typical ASDE-X System Architecture



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Atlanta Hartsfield

- ASDE-X System at Atlanta International Airport
- Commissioned June 7, 2006
  - Surface Movement Radar (2)
  - Multilateration System (MDS)
  - Multi-sensor Data Processor (sensor fusion)
  - Safety Logic (Conflict detection and alerts)
  - Remote Monitoring & Control System (RMS)
  - Display Processors
  - Controller Displays (8)
- Surface Movement Radars
  - 2ea X – band solid state; 1 on ATCT (352' AGL); 1 remote tower 90'
- Multilateration system
  - 16 remote units
    - 8 receiver only
    - 6 receiver + interrogator
    - 2 reference transmitter

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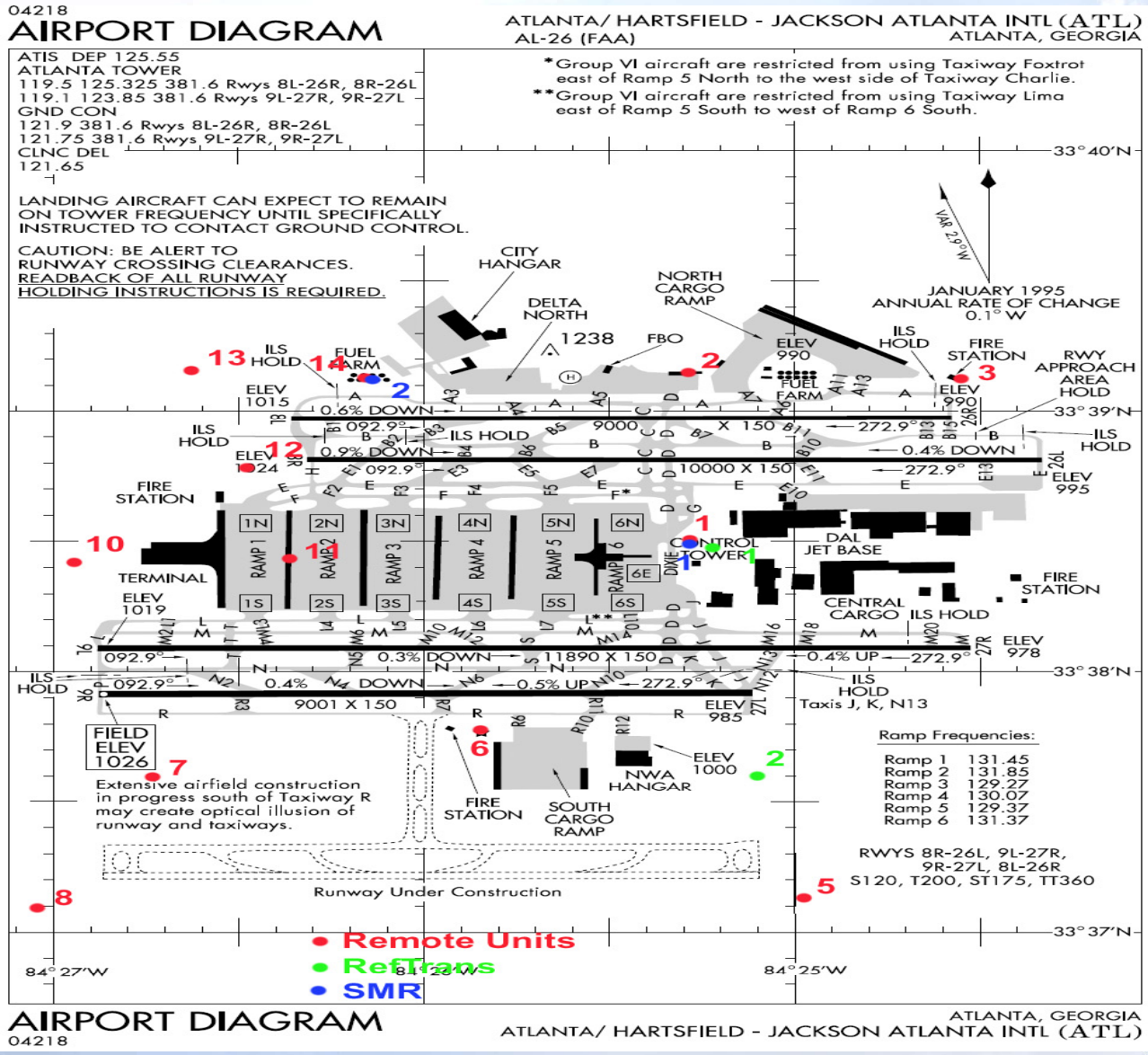
ATL Sensor Locations



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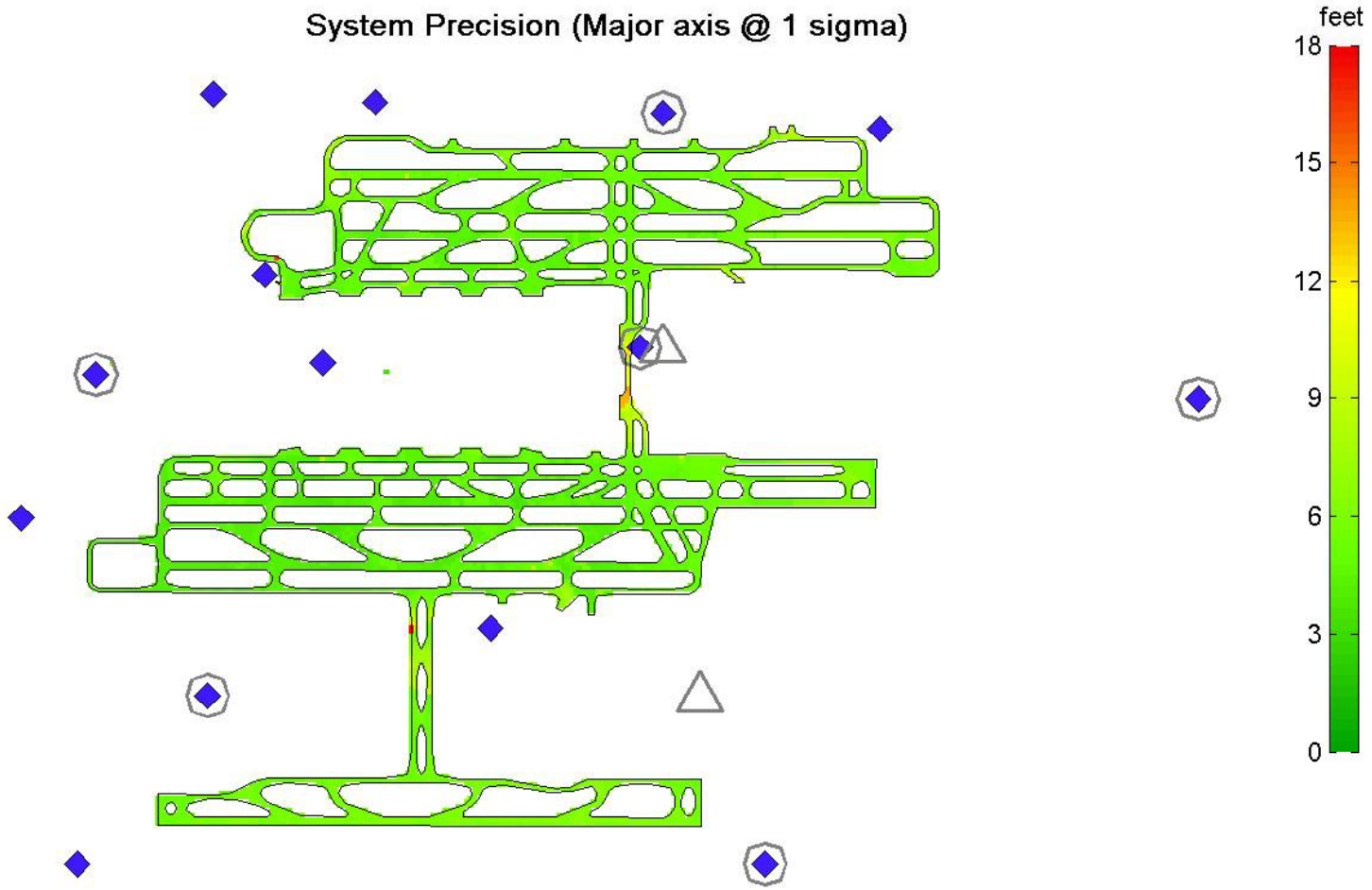
ATL Multilateration Accuracy



Multilateration Precision in feet

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MKE – General Mitchell International

- ASDE-X System at Milwaukee
- Commissioned October, 2003
  - Surface Movement Radar (1)
  - Multilateration System (MDS)
  - Multi-sensor Data Processor (sensor fusion)
  - Safety Logic (Conflict detection and alerts)
  - Remote Monitoring & Control System (RMS)
  - Display Processors
  - Controller Displays (8)
- Surface Movement Radars
  - 1ea X – band solid state
- Multilateration system
  - 10 remote units
    - 4 receiver only
    - 4 receiver + interrogator
    - 2 reference transmitter

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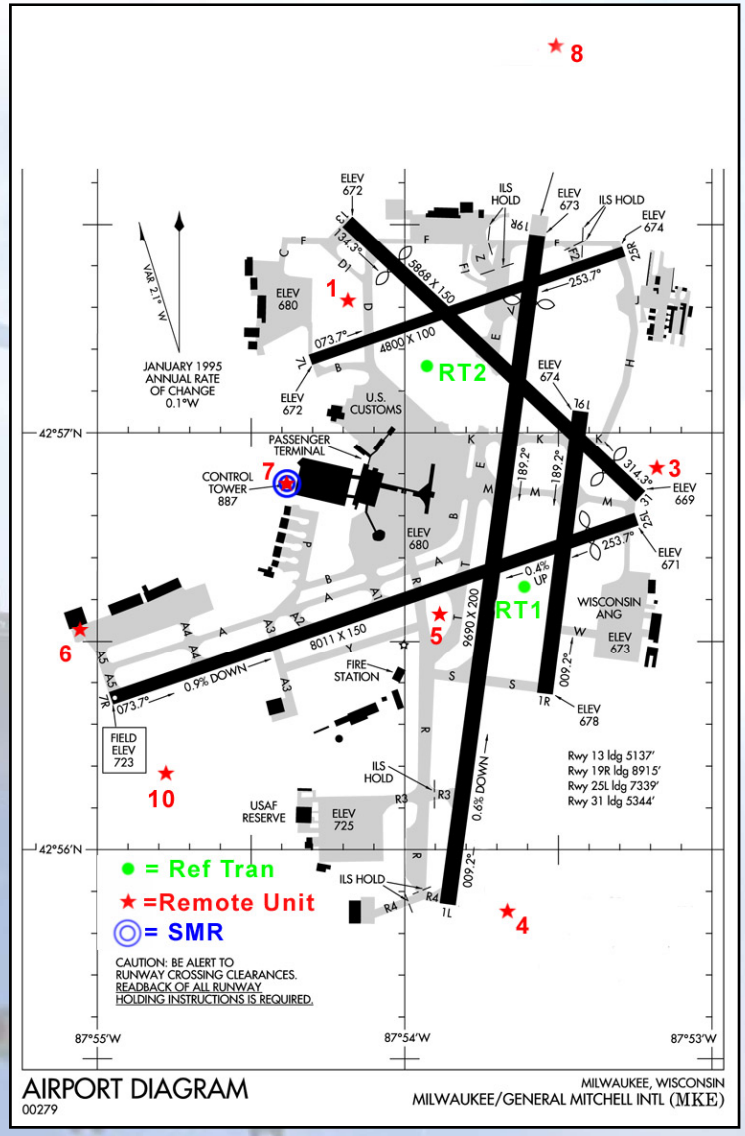
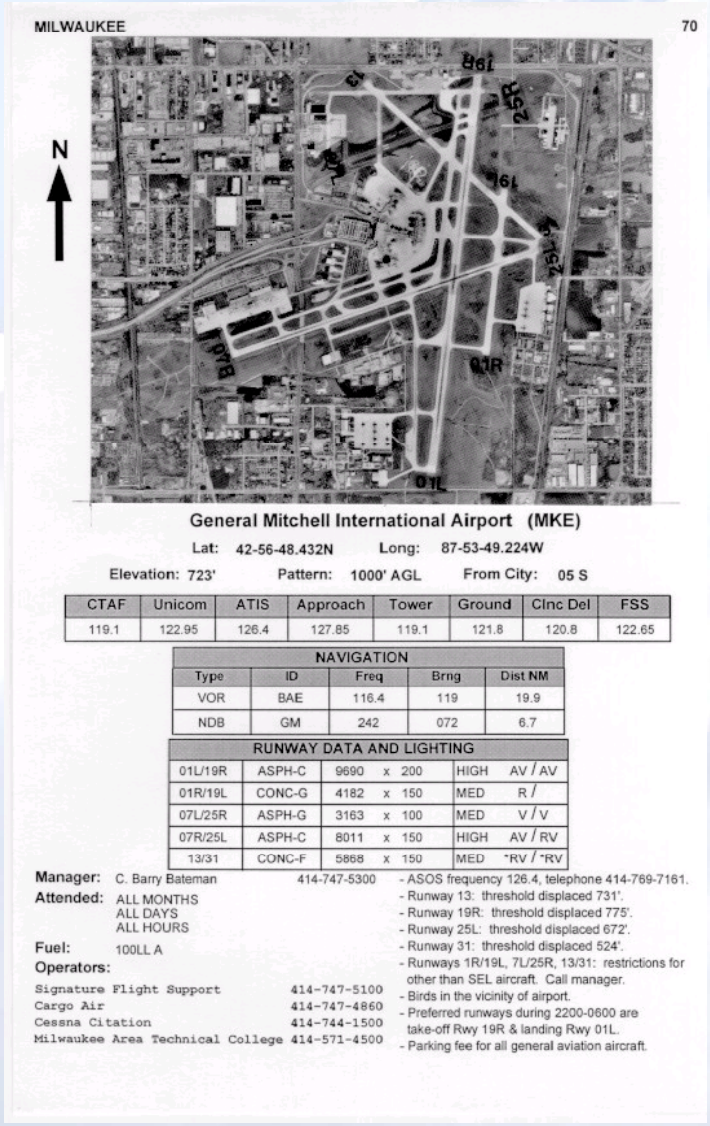
MKE Sensor Locations





MILWAUKEE 70

N

19R 25R 19L 07R 01L

General Mitchell International Airport (MKE)

Lat: 42-56-48.432N Long: 87-53-49.224W

Elevation: 723' Pattern: 1000' AGL From City: 05 S

CTAF	Unicom	ATIS	Approach	Tower	Ground	Clnc Del	FSS
119.1	122.95	126.4	127.85	119.1	121.8	120.8	122.65

NAVIGATION

Type	ID	Freq	Brng	Dist NM
VOR	BAE	116.4	119	19.9
NDB	GM	242	072	6.7

RUNWAY DATA AND LIGHTING

01L/19R	ASPH-C	9690 x 200	HIGH	AV / AV
01R/19L	CONC-G	4182 x 150	MED	R /
07L/25R	ASPH-G	3163 x 100	MED	V / V
07R/25L	ASPH-C	8011 x 150	HIGH	AV / RV
13/31	CONC-F	5868 x 150	MED	*RV / *RV

Manager: C. Barry Bateman 414-747-5300

Attended: ALL MONTHS
ALL DAYS
ALL HOURS

Fuel: 100LL A

Operators:

Signature Flight Support 414-747-5100
Cargo Air 414-747-4860
Cessna Citation 414-744-1500
Milwaukee Area Technical College 414-571-4500

- ASOS frequency 126.4, telephone 414-769-7161.
- Runway 13: threshold displaced 731'.
- Runway 19R: threshold displaced 775'.
- Runway 25L: threshold displaced 672'.
- Runway 31: threshold displaced 524'.
- Runways 1R/19L, 7L/25R, 13/31: restrictions for other than SEL aircraft. Call manager.
- Birds in the vicinity of airport.
- Preferred runways during 2200-0600 are take-off Rwy 19R & landing Rwy 01L.
- Parking fee for all general aviation aircraft.

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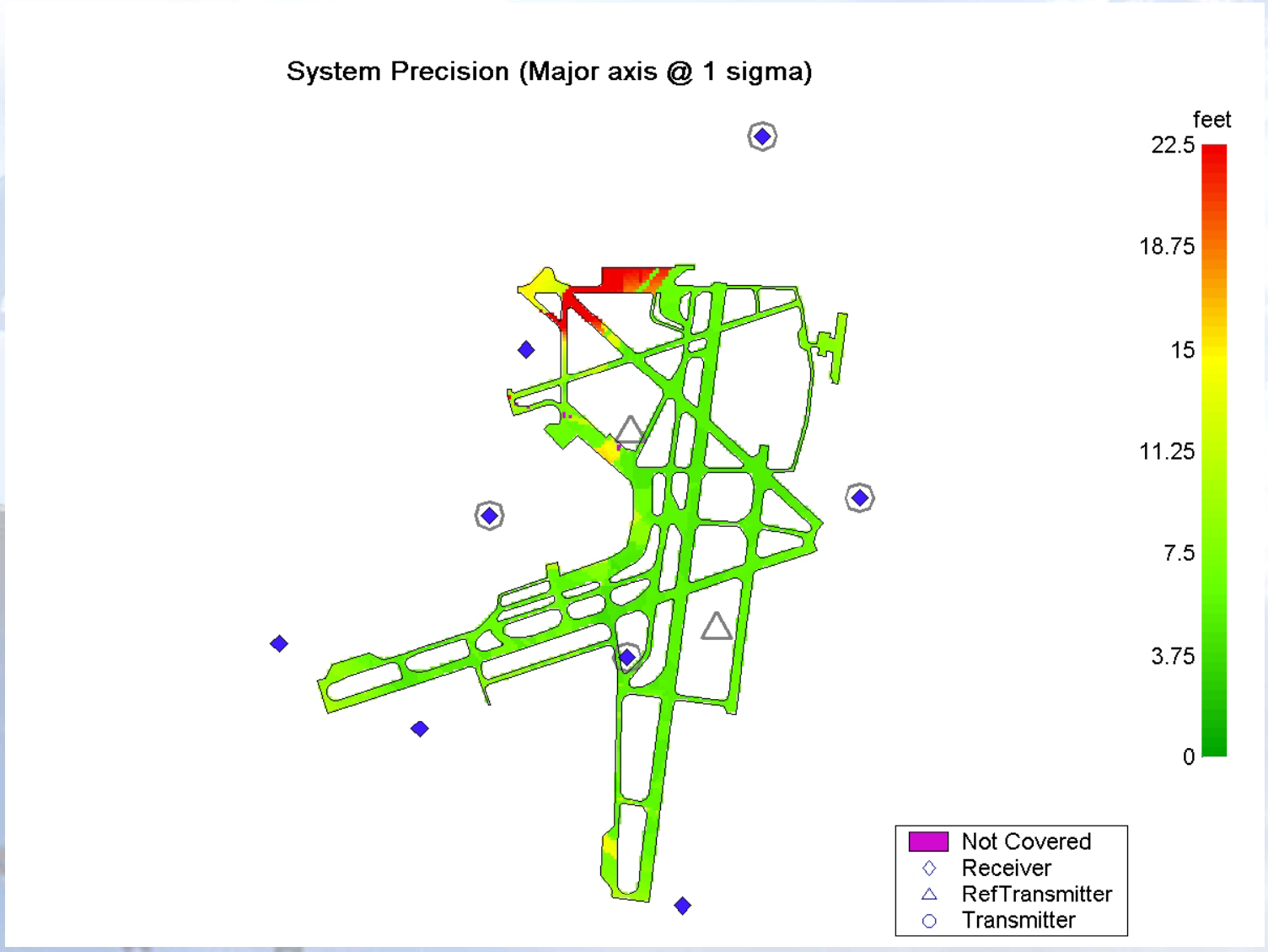
MKE MLAT Coverage



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London Heathrow

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LHR Profile - world's busiest airports

LHR is 3rd busiest airport in the world – in terms of total passengers

	Airport	Total passengers
1.	Atlanta, Hartsfield (ATL)	85,907,423
2.	Chicago, O'Hare (ORD)	75,510,003
3.	**London, Heathrow (LHR)**	**67,915,389**
4.	Tokyo, Haneda (HND)	63,282,219
5.	Los Angeles (LAX)	61,485,269
6.	Dallas/Ft. Worth (DFW)	59,064,360

In terms of cargo it is the 17th (MEM is the largest)

Current installation:

- 20 RU MDS system – 10 RO + 7 RT
- 3 Reference Transmitters
- Test system

Future T5 expansion

- 6 additional RU

Future T4 enhancement

- 2 additional RU

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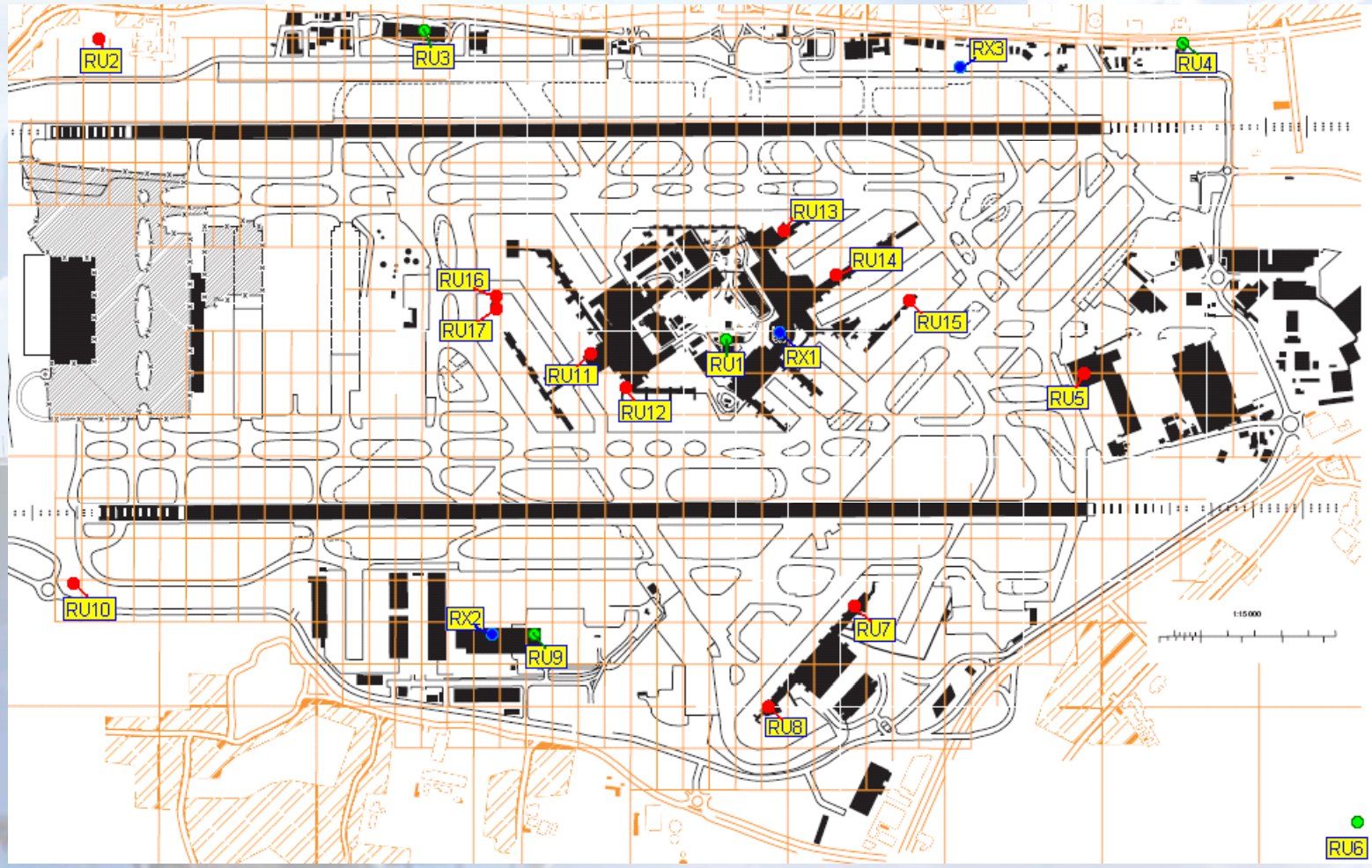
Current LHR Sensor Locations



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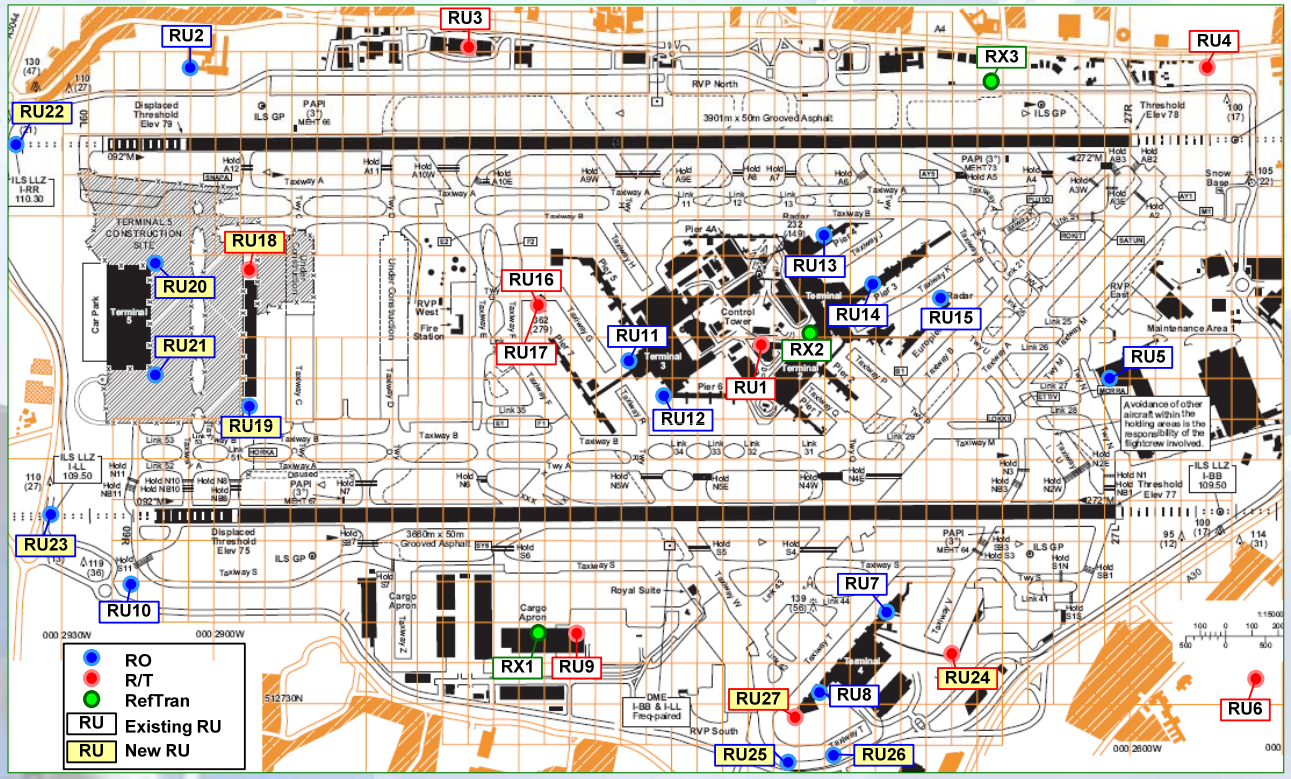
LHR expansion T4 & T5



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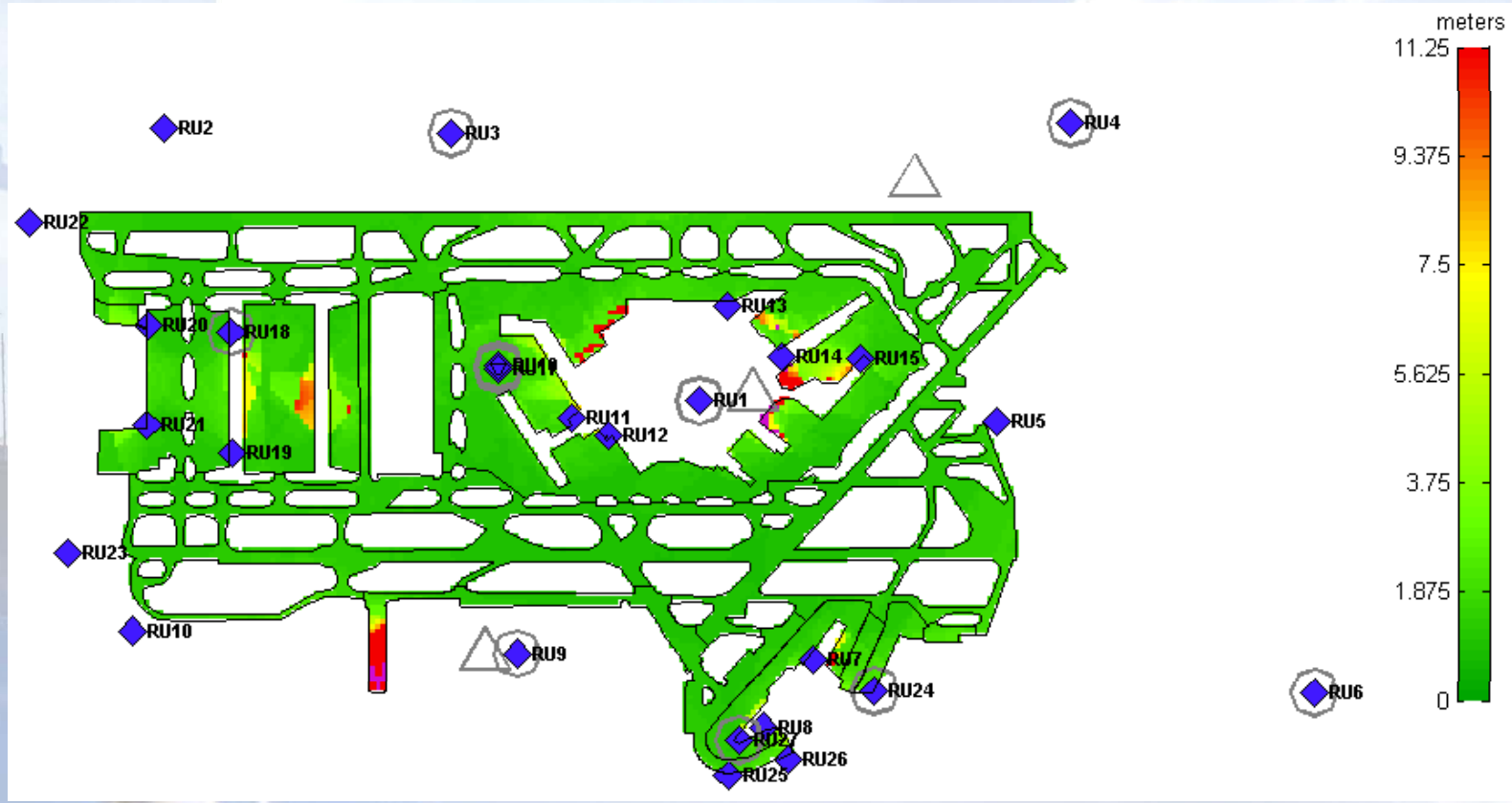
LHR MLAT Coverage



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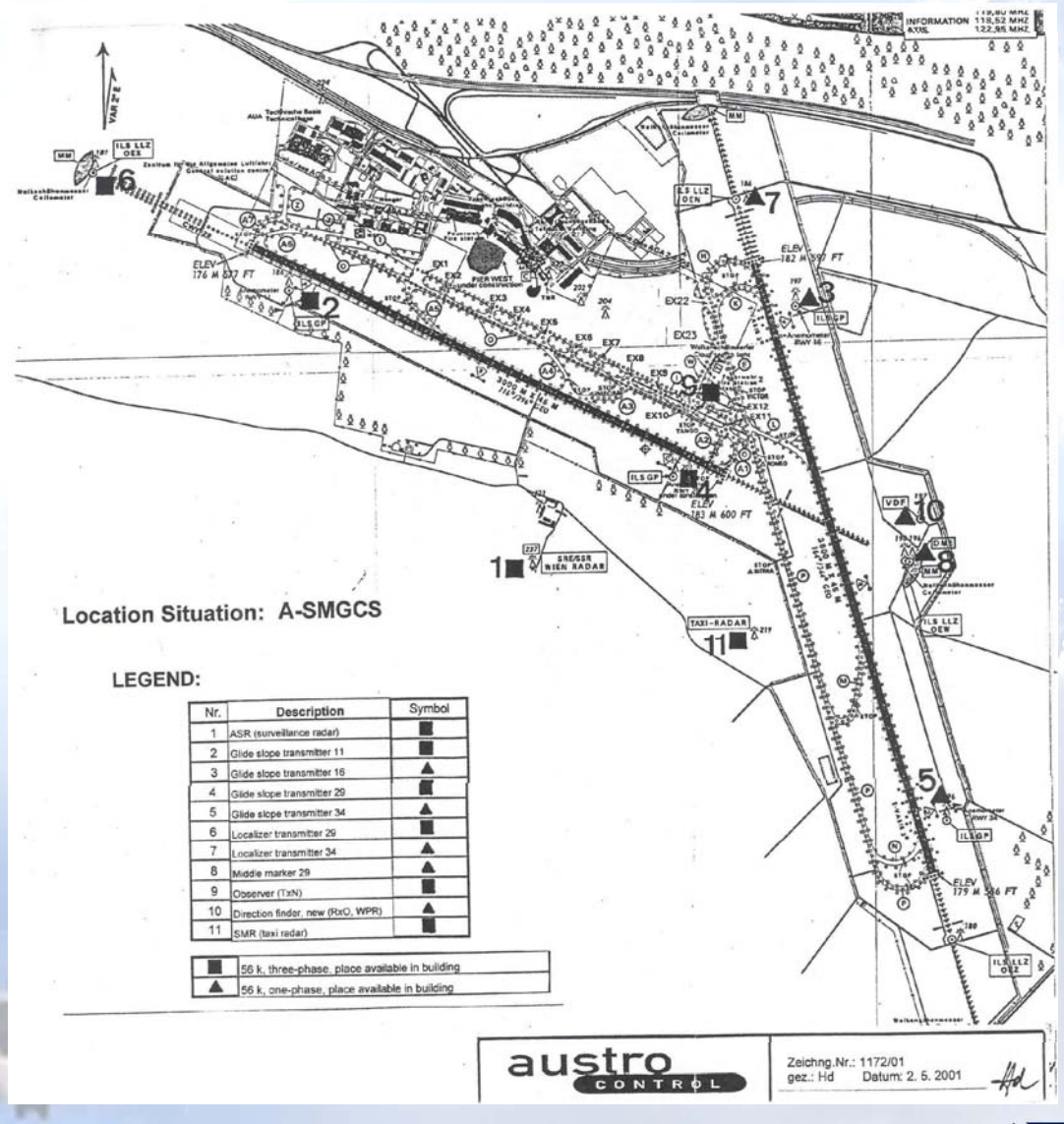
Vienna MLAT Sensor Locations



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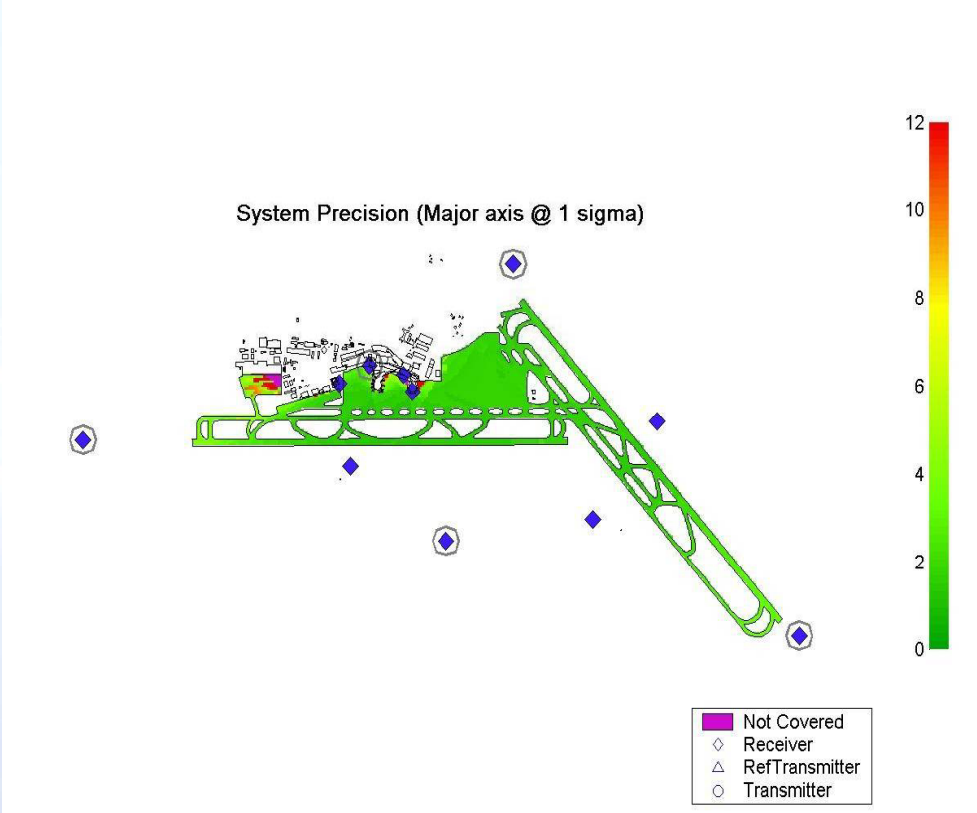
Vienna

- VIE MLAT System
  - 11 Remote Units
    - 5 RT
    - 6 RO
    - 1 Reference Tx
  - Coverage
    - Runways
    - Taxiways
    - Gates



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Sensis A-SMGCS for Australian Airports

- Customer
  - Airservices Australia
- Airports
  - Sydney
  - Brisbane
  - Melbourne
- Status
  - Contract Award 6/2006
  - Site Prep 03/2007
- A-SMGCS Architecture
  - Surface Movement Radar
  - Multilateration
  - Automatic Dependent Surveillance Broadcast (ADS-B)
  - Multi-sensor data processing
  - Conflict Alert
  - Tower Displays
  - Remote Monitoring System
  - Data Distribution
  - Aerobahn
  - VeeLo
  - Product Support Facility

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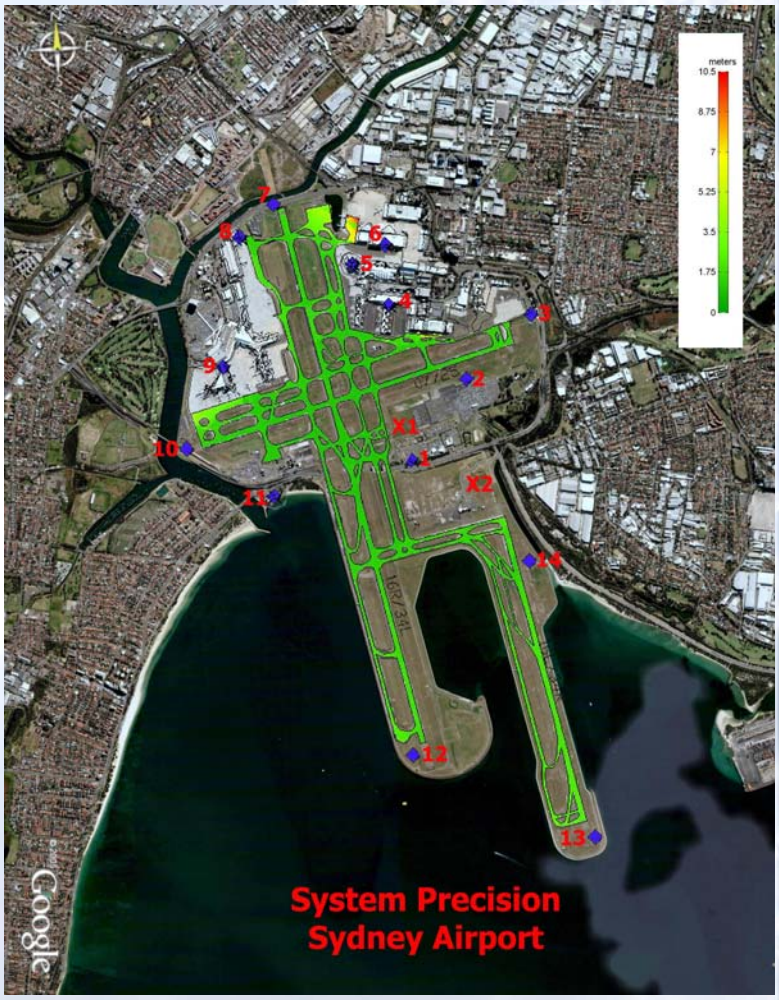
Sydney MLAT Coverage

- Sydney MLAT System
  - 16 Remote Units
    - 4 RT
    - 10 RO
    - 2 Reference TX
  - Full coverage
    - Runways
    - Taxiways
    - Apron
    - Gates



Runways & Taxiways

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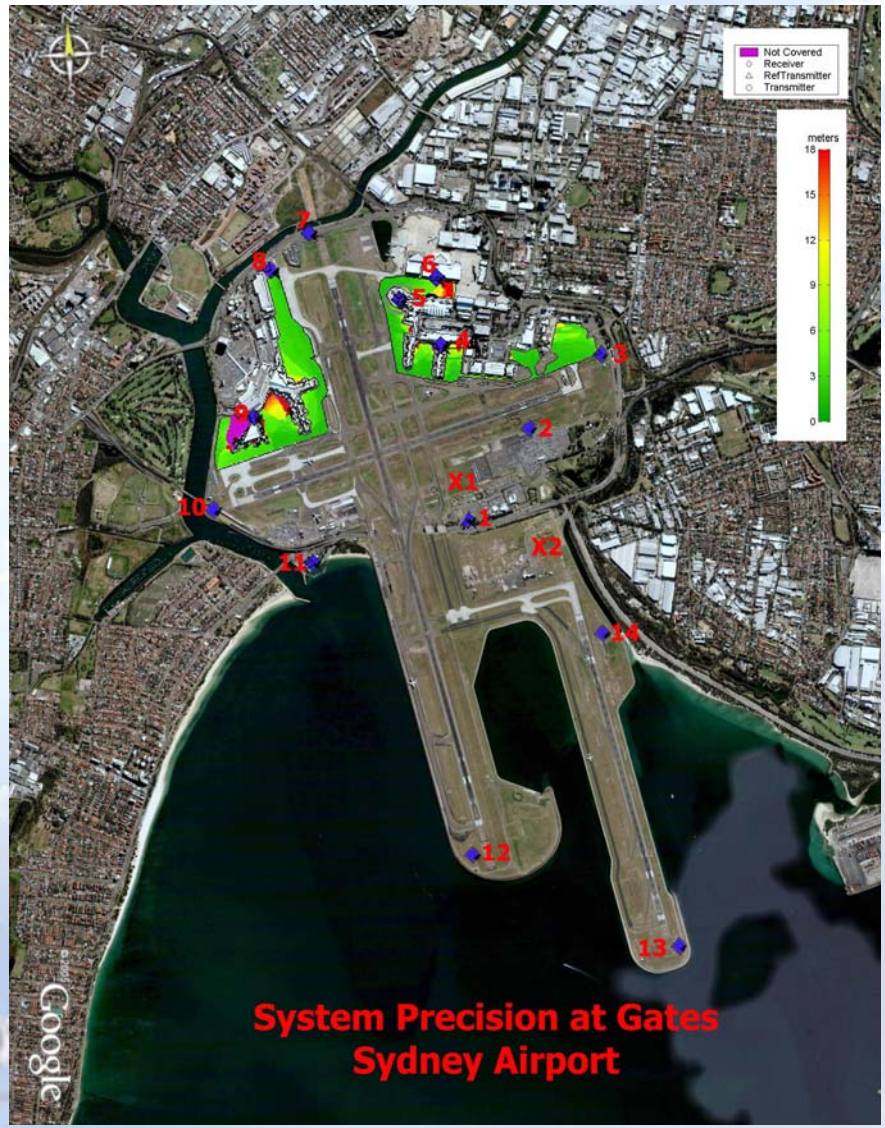
Sydney Gate Coverage



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MLAT for Wide Area Surveillance

- North America
  - 29 Palms California (military)
- Europe
  - Innsbruck
  - UK North Sea
- Asia Pacific
  - Tasmania

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29 Palms Wide Area MDS System

- Basic requirements
  - Coverage from 100 to 40,000 feet AGL
  - Accuracy within 100 m 1 sigma
  - Capacity 400 simultaneous targets
  - Mode S and Mode A/C
  - 1 second update rate w 90% probability
  - Track initiate within 5 seconds
- System components
  - 32 Remote Units
    - 14 RO
    - 18 RT
  - GPS Time synchronization
  - Solar power
  - MW data links

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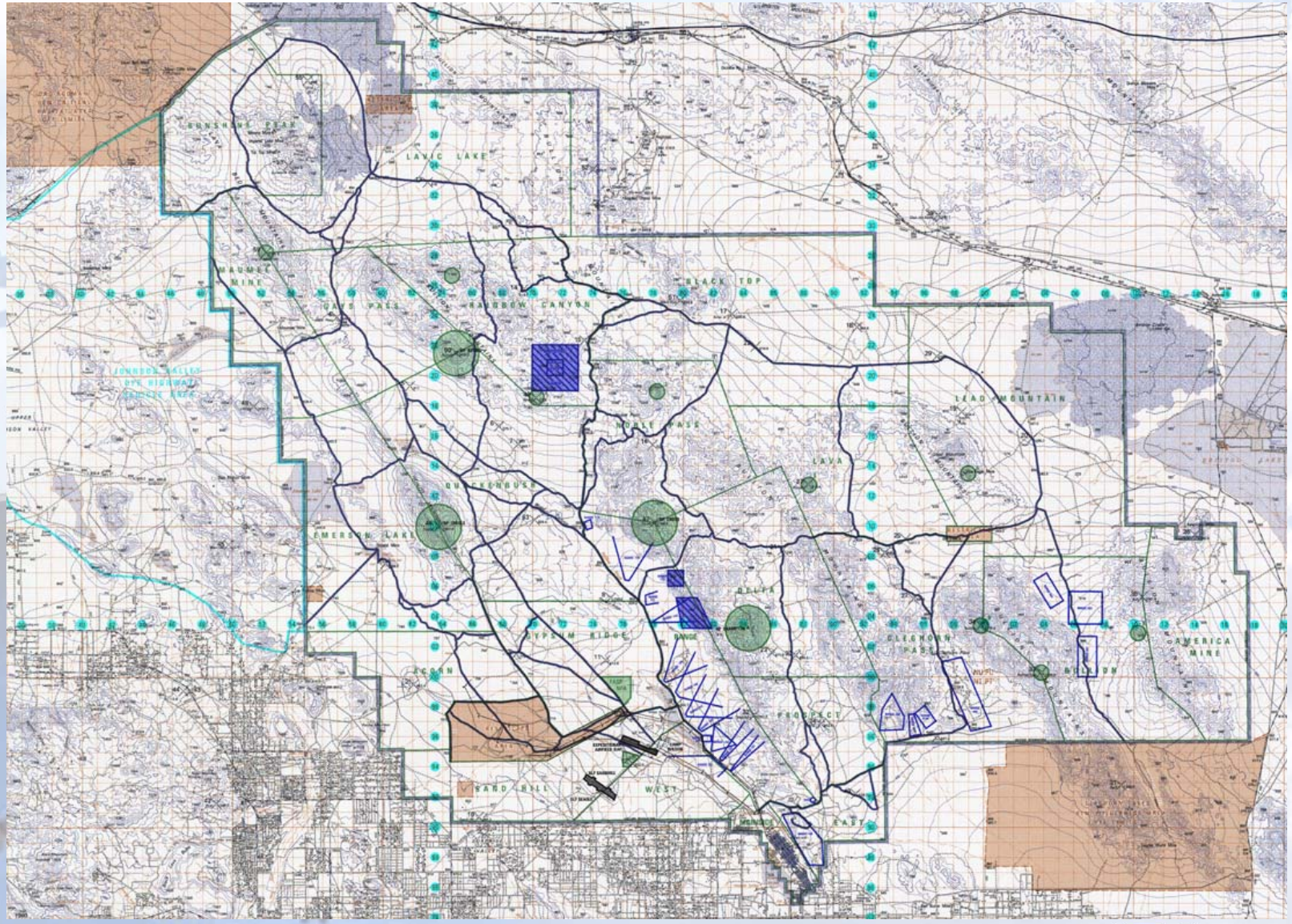
29 Palms Wide Area MDS System



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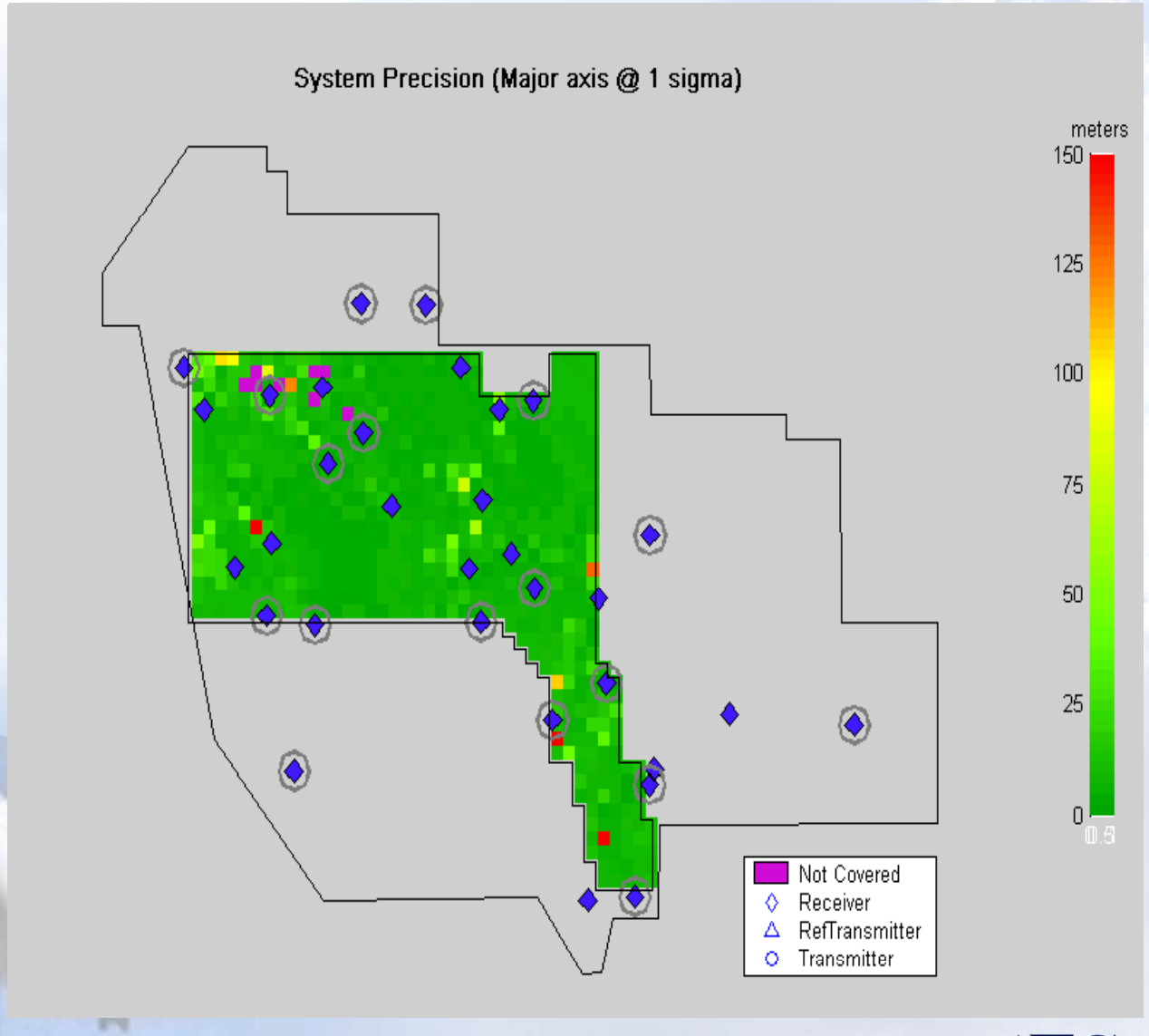
Receiver Precision for 100 ft AGL



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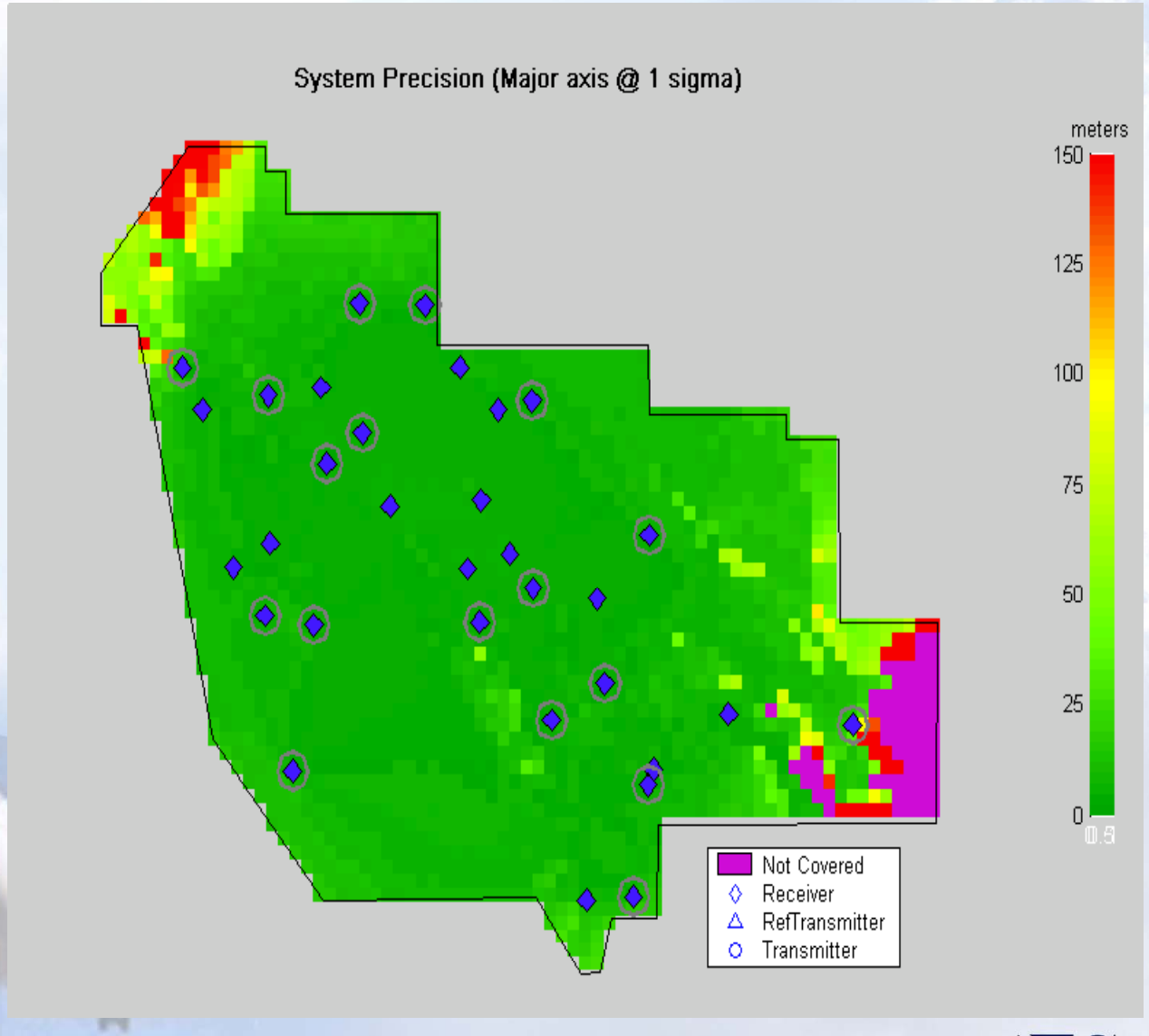
Receiver Precision for 500 ft AGL



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System demonstration

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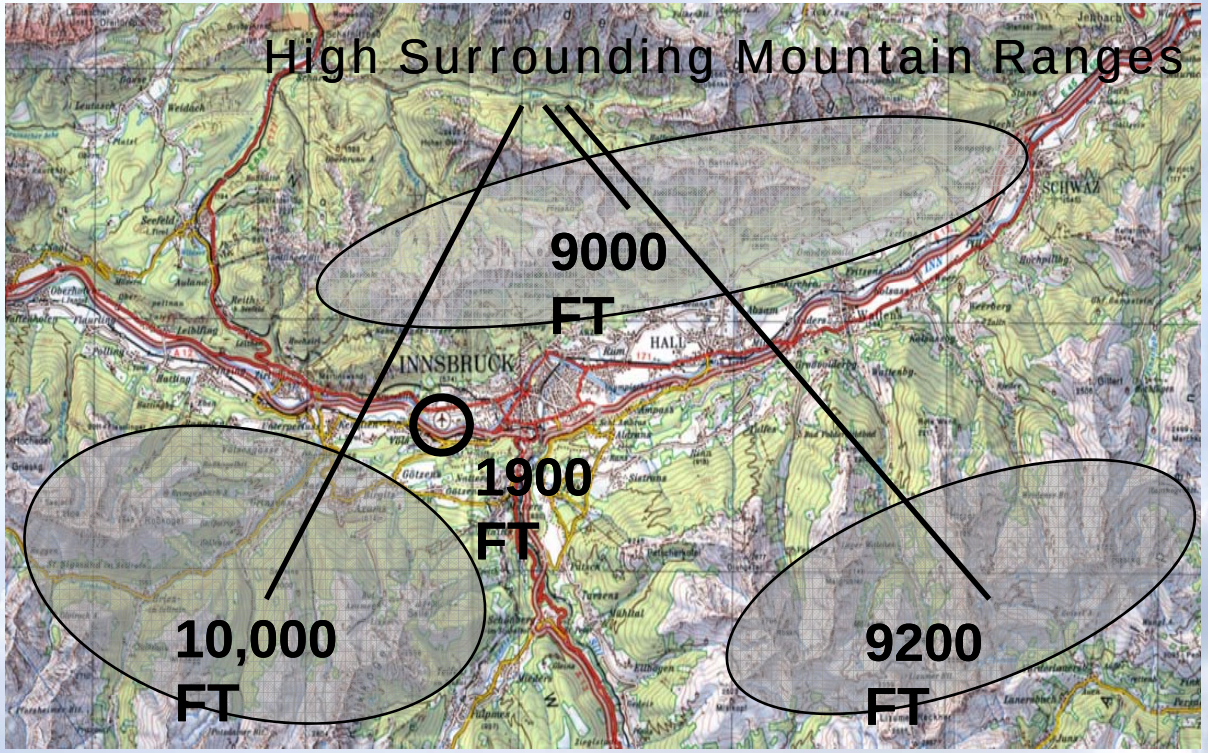
The Innsbruck, Austria Challenge

- Mountainous terrain surrounding narrow valley
- Traffic mix with 200 daily operations
  - VFR, IFR and glider
  - Charter peaks at 360+ daily
- Off-centerline LLZ/DME approach
- No radar for approaches… one-in/one-out procedures



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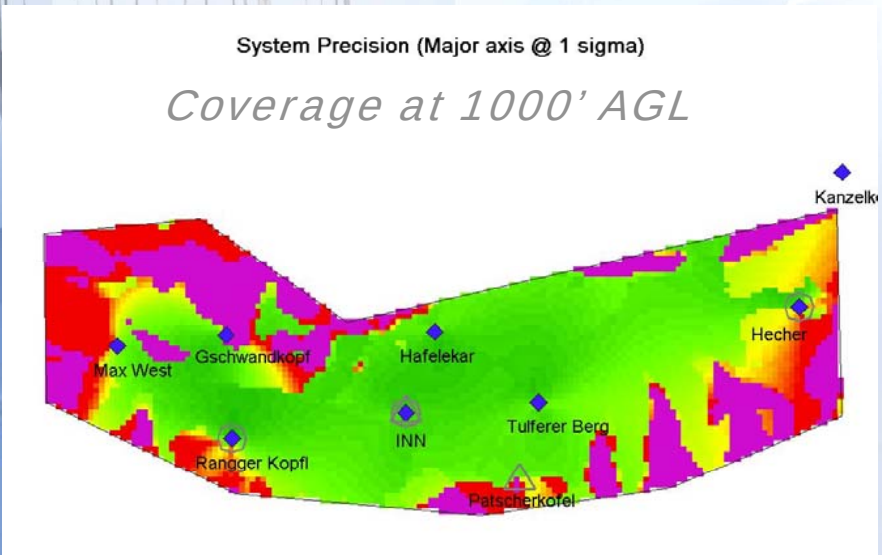
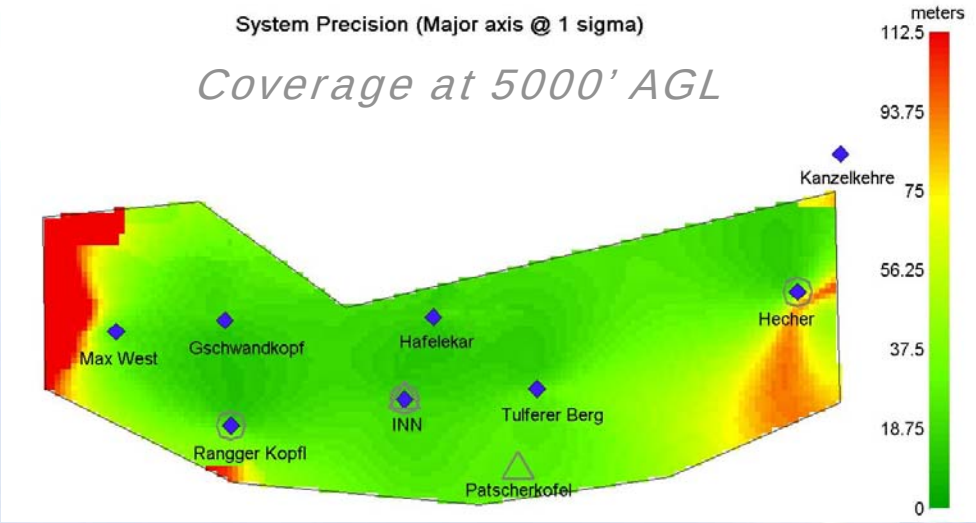
Austro Control Surveillance Considerations

- Radar implementation deemed technically, logistically and politically difficult
  - Coverage limited by mountainous terrain
  - Highly expensive initial acquisition and lifecycle cost
  - Additional environmental considerations
- Chosen solution… Wide–Area Multilateration with ADS-B





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Innsbruck: MDS Measured Results

Error Thresh	Pos < Threshold		Track < Threshold	
10m	232	14.46%	261	16.27%
20m	794	49.50%	868	54.11%
50m	1535	95.70%	1592	99.25%
70m	1554	96.88%	1599	99.69%
100m	1575	98.19%	1601	99.81%
1000m	1604	100.00%	1604	100.00%
Number of Positions: 1604				

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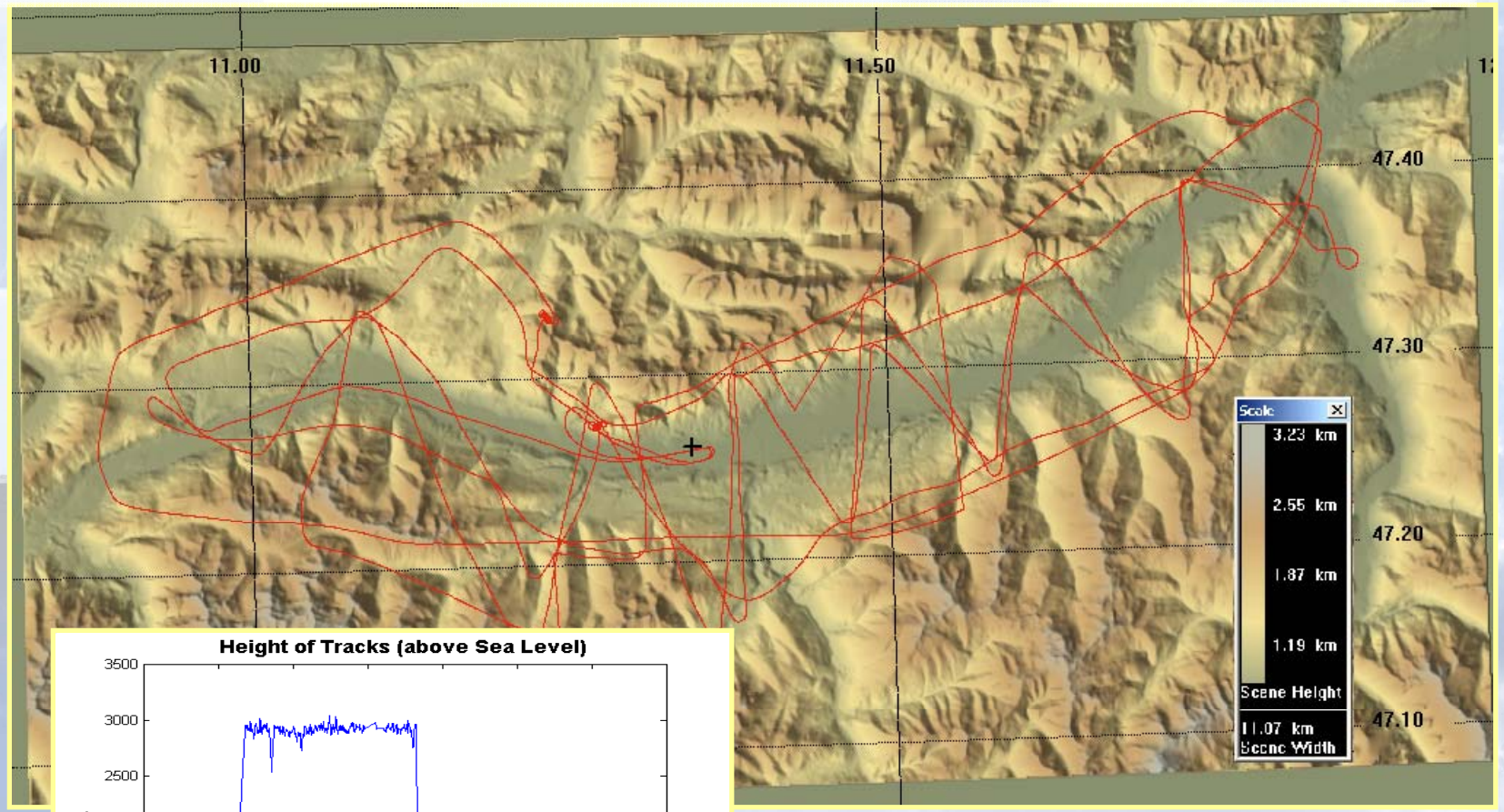
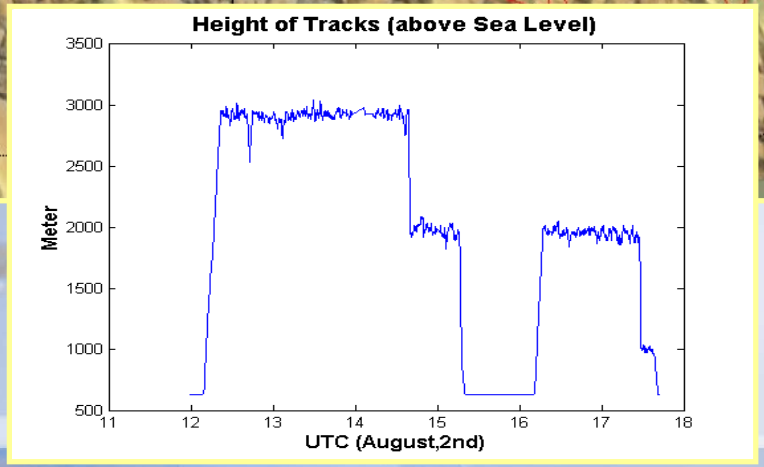
Innsbruck: MDS Performance

Test-flight on August, 2nd 2004





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System demonstration

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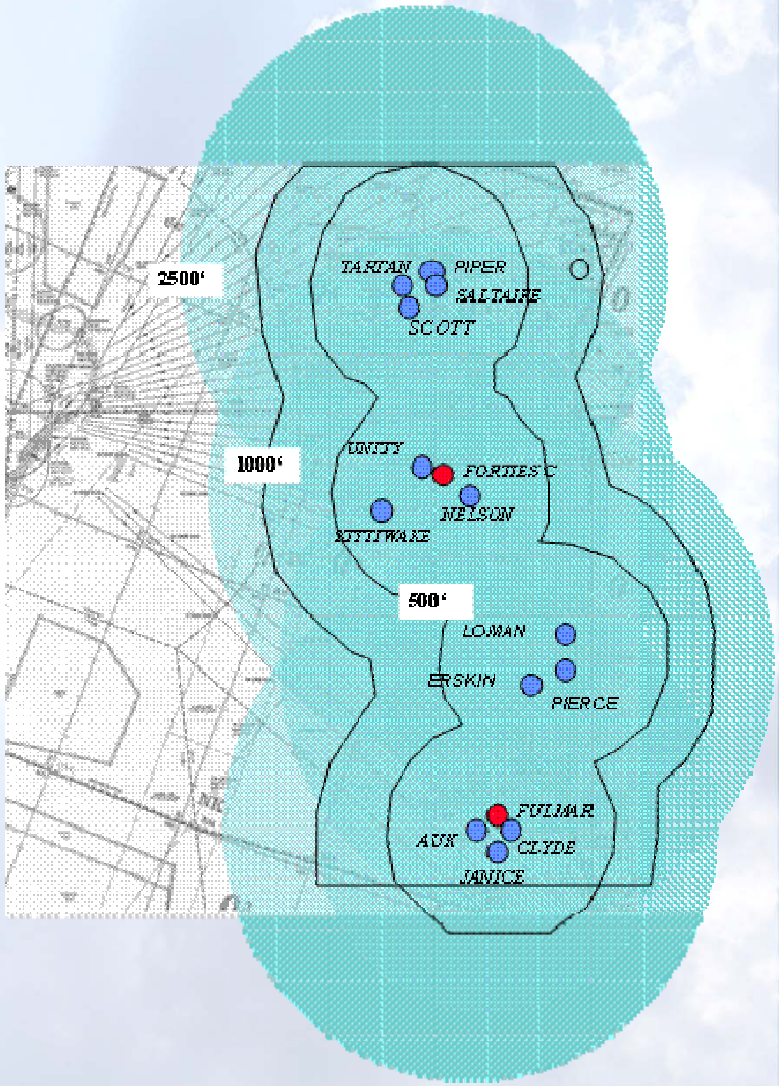
UK North Sea

- System Requirements
  - coverage volume extends from 200 to 2,500 feet above mean sea level.
  - horizontal position error of the system less than 150 m Root Mean Square (RMS).
  - Target load - simultaneously track at least 200 transponder equipped aircraft inside the coverage volume.
  - Track initiation - initiate a track on a target within 10 seconds of entering the coverage volume at least 90% of the time and within 15 seconds of entering the coverage volume at least 95% of the time.
  - Update rate – 5 seconds



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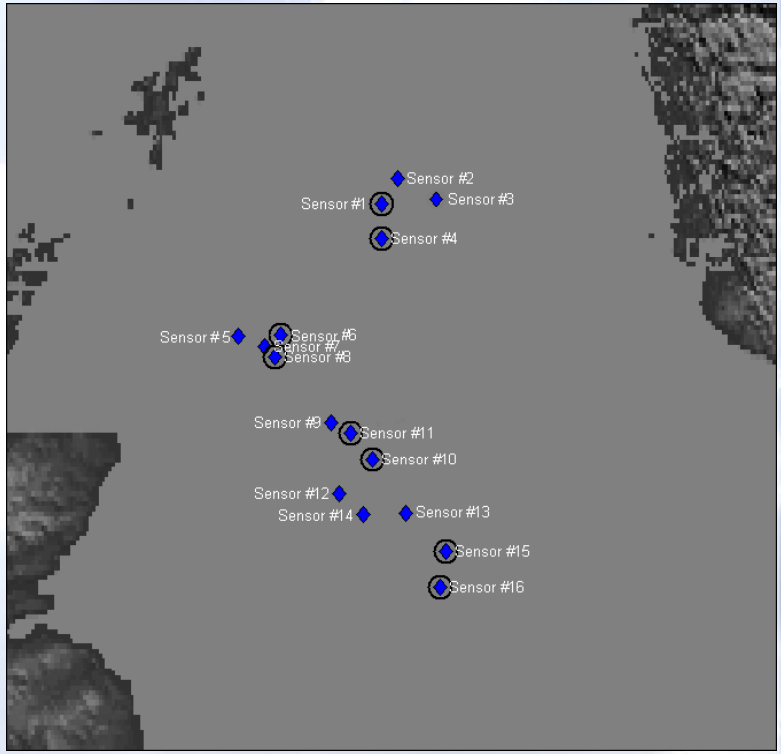
UK North Sea

- System Features
  - 16 Remote Units
  - Installed on oil platforms, some not stationary.
  - GPS time synchronization
  - Central processing located at Aberdeen Center
  - Data from Remote units sent over existing comm links.
  - Used to monitor helicopter traffic from Aberdeen to platforms and transiting platforms.
  - Area beyond shore based radar coverage
  - 60,000 square miles @ FL100
  - 25,000 helicopter operations per year



Sensor Locations

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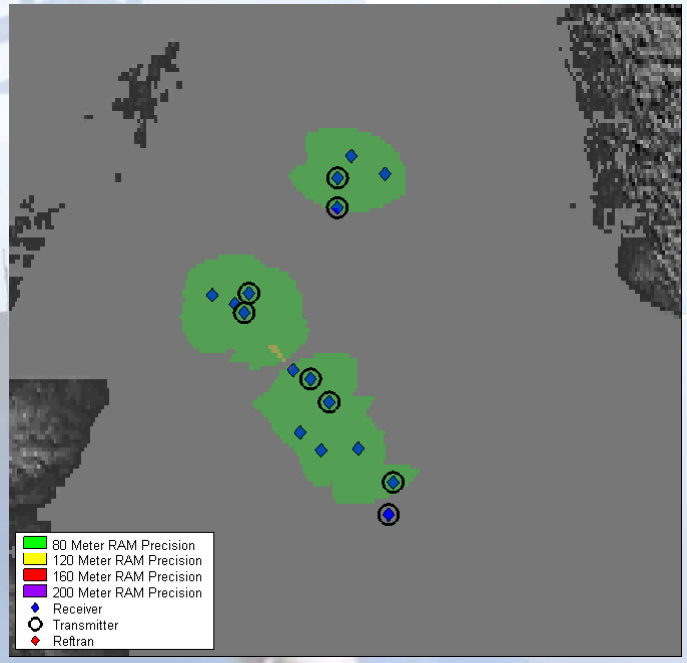
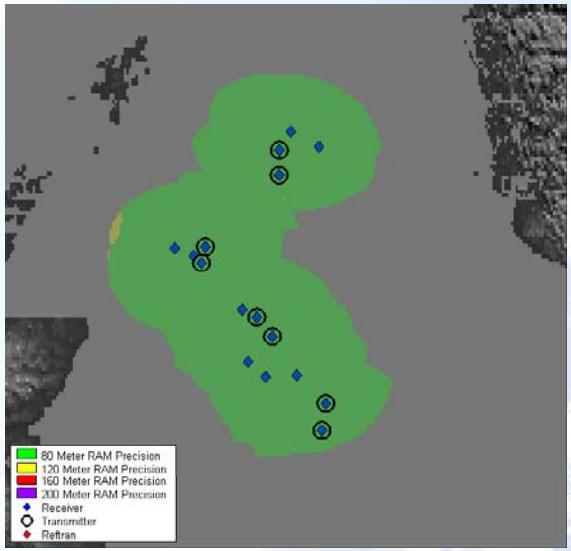
UK North Sea Coverage/Precision

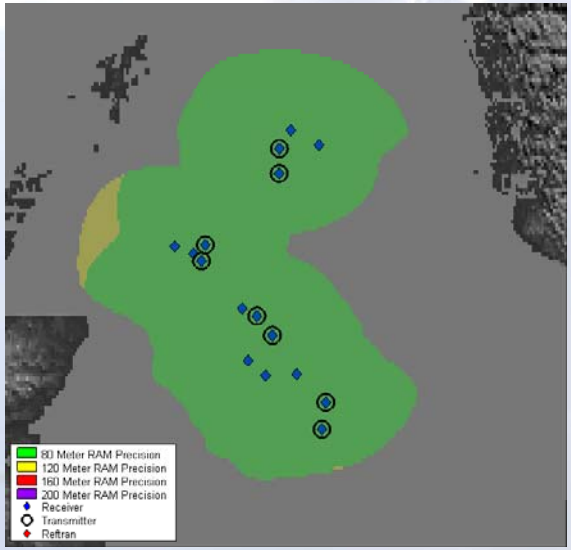
200 Ft AMSL



1500 Ft AMSL



2500 Ft AMSL



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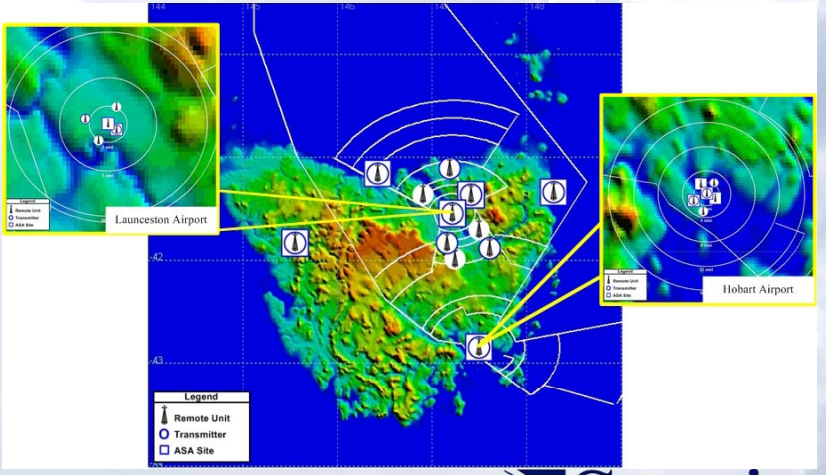
TAS WAM Program Overview

- ATC Radar Services from Sensis MDS
  - 150 X 350 NM Coverage Area
  - 150 M accuracy or better
  - Altitudes from GL to 18,000 ft
  - 4 Second Update Rate
  - Mlat and ADS-B Coverage
- Delivery Includes:
  - 19 Remote Units (RT/RO)
  - SSR Site Monitors
  - Remote Monitoring System (Hobart/MEL TAAATS)
  - SSF
  - Training & Program Support
- Status:
  - Completed DDR
  - FAT April 2007
  - Site Installation Begins May 2007
  - Operational February 2008

Remote Units, Processors and Communication Rack

Remote Control and Monitoring System



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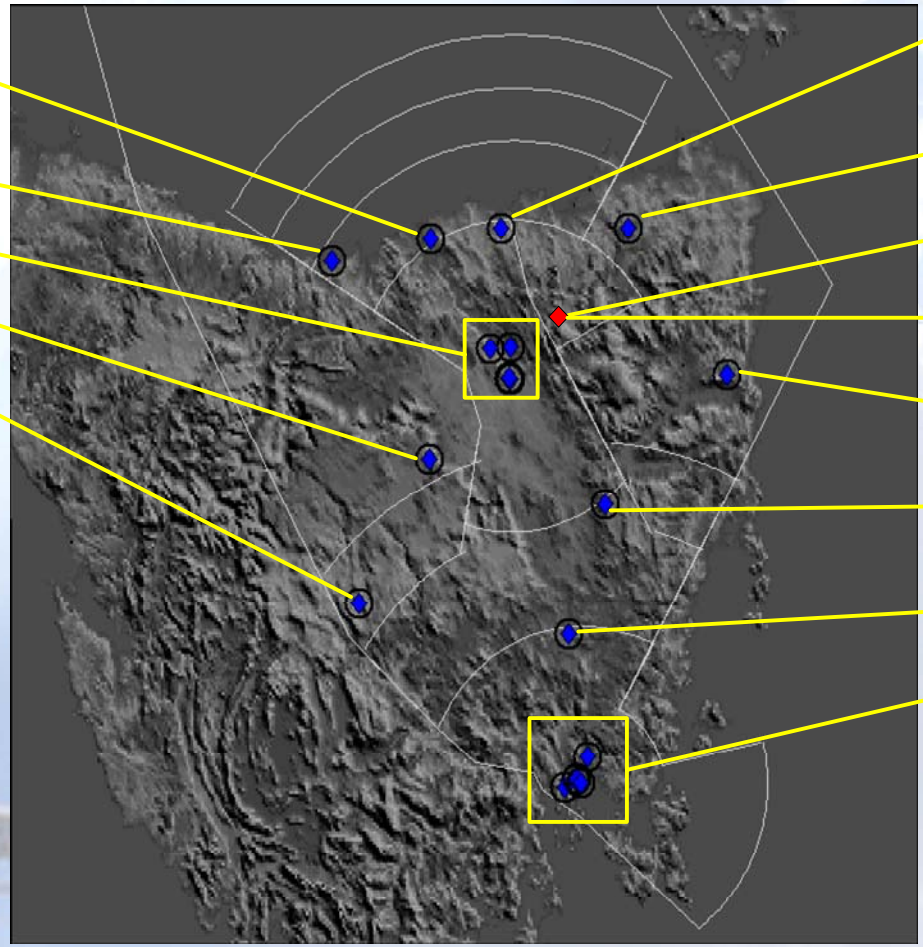
Tasmania Sensor Locations



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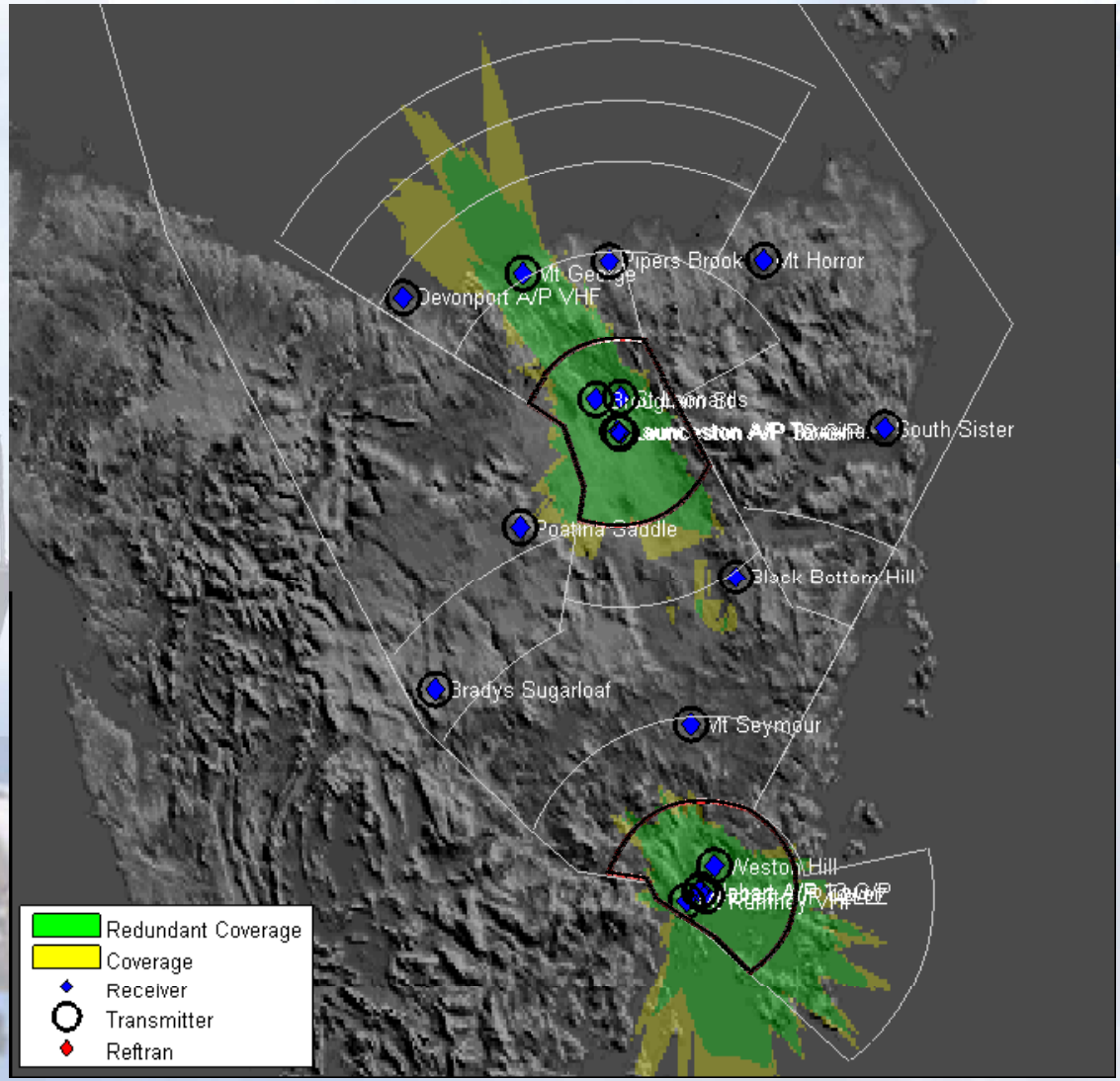
Tasmania Coverage 1500 AGL



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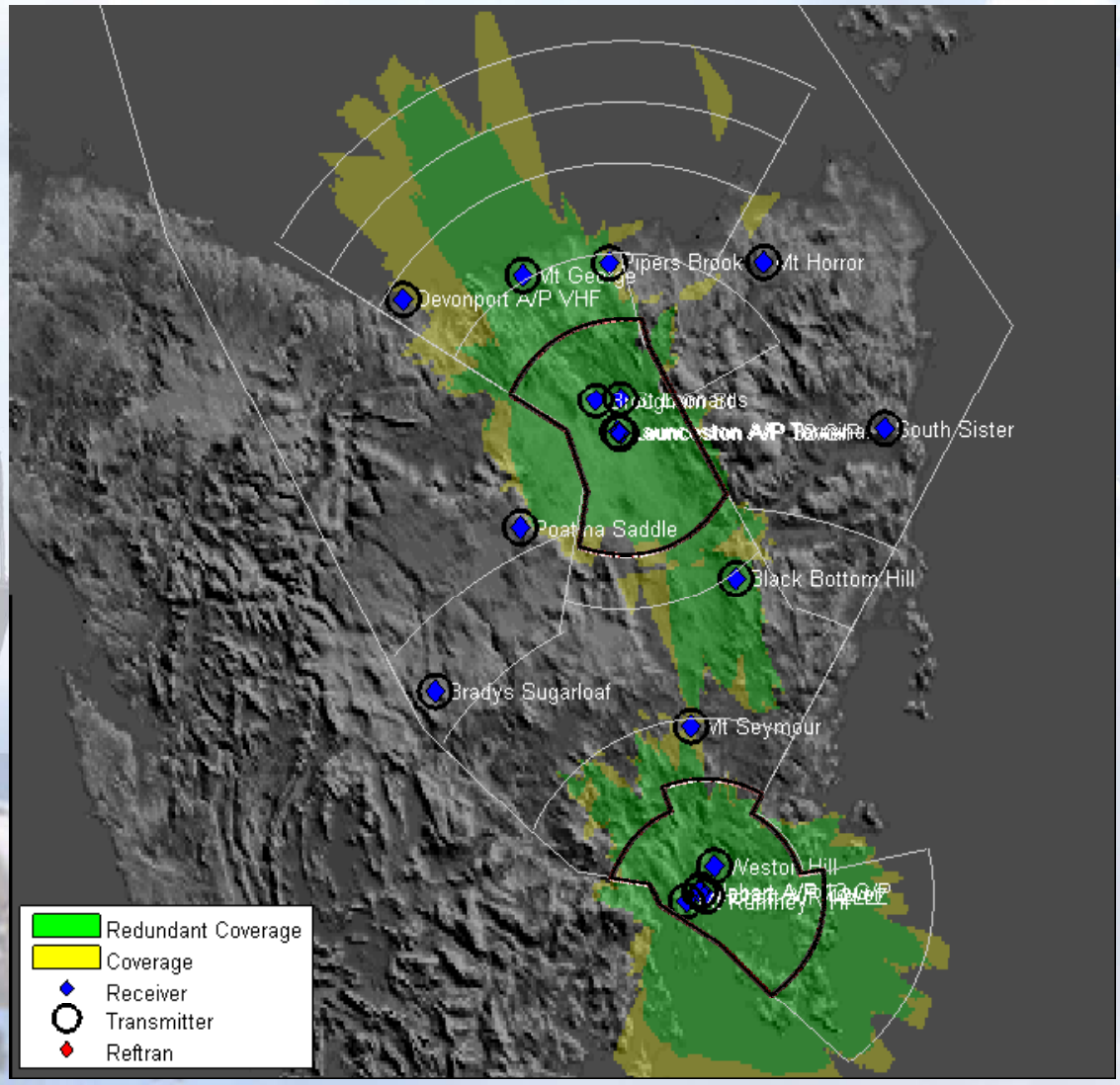
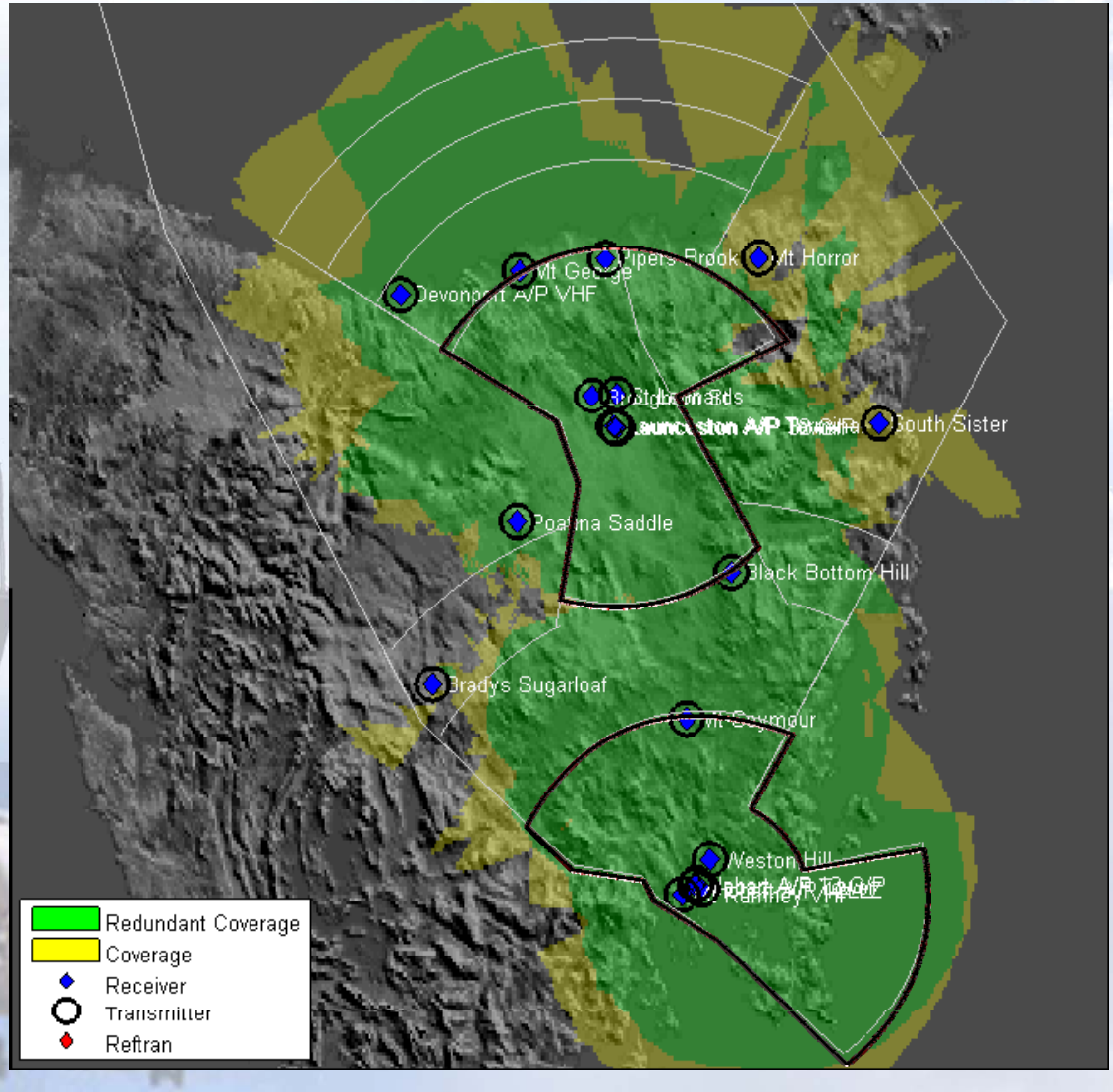
Detect the Difference

Tasmania Coverage 2500 ft AGL



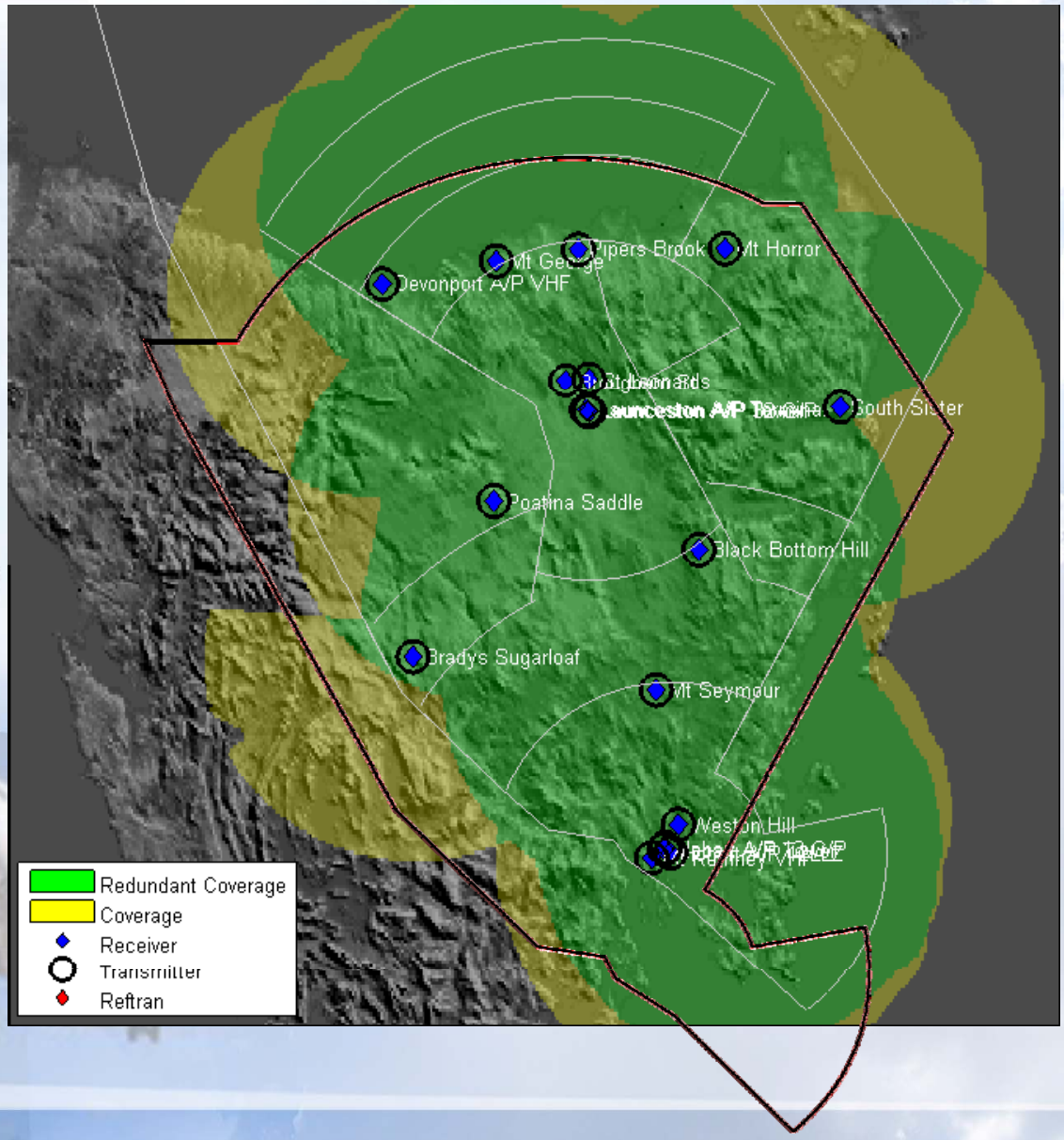
Sensis
Detect the Difference

Tasmania Coverage 5500 ft AGL



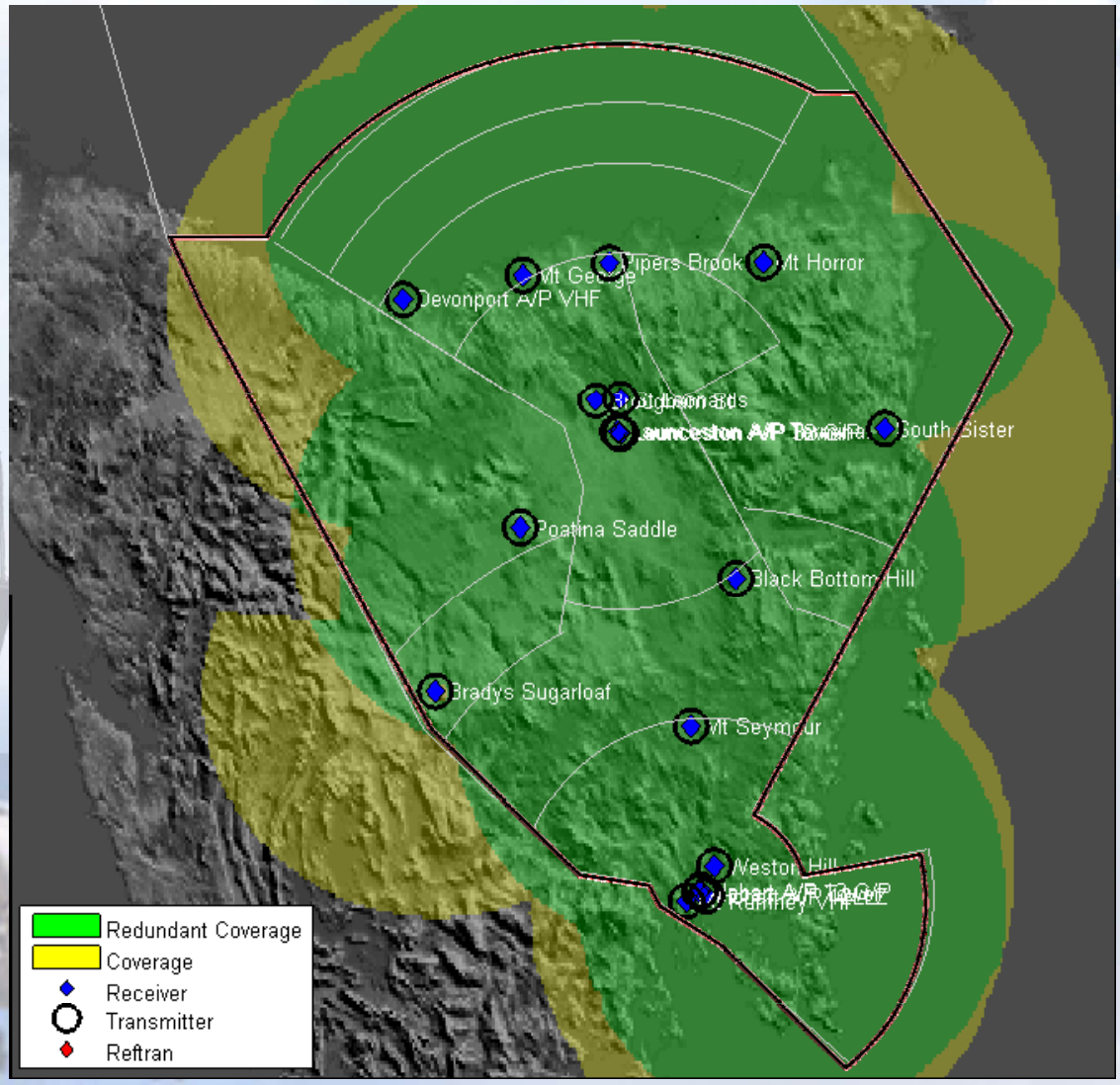
Sensis
Detect the Difference

Tasmania Coverage FL 115



Sensis
Detect the Difference

Tasmania Coverage FL 180



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Reference Materials

- ICAO 9830-AN/452 Manual of ASMGCS
- Eurocae MASPS for ASMGCS (ED 87A)
- Eurocae MOPS for MLAT as part of ASMGCS (ED 117)
- RTCA DO 181A MOPS for ATCRBS/Mode S
- ICAO 9688-AN/952 Manual on Mode S Specific Services
- ICAO SARPS Annex 14 Aerodromes
- ICAO 9157 Aerodrome Design Manual
- Propagation of Mode S beacon Signals on the Airport Surface; M.L. Wood, The Lincoln Laboratory Journal: Volume 2, Number 3, 1989
- Operational and Spectrum Tests for ATIDS at DFW Airport; ATC-272, M.L. Wood, MIT/LL, Sept. 20, 1999
- Airport Target Identification System (ATIDS) Evaluation Test Report; RIRP-DFW-0xx-A, TRIOS Associates, Inc., Oct. 5, 2000
- Clarification Mode S Transponder in an Airport ASMGCS Environment; Eurocontrol MODES/SYS/002, Edition 1.1, 3 May 2005
- Mode S Transponder Operating Procedures – Proposal for Amendment to ICAO PAN-OPS, Doc 8186, EANPG/48 WP/30, Nov. 13 2006

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