Aeronautical Mobile Airport Communications System (AeroMACS) Development Status

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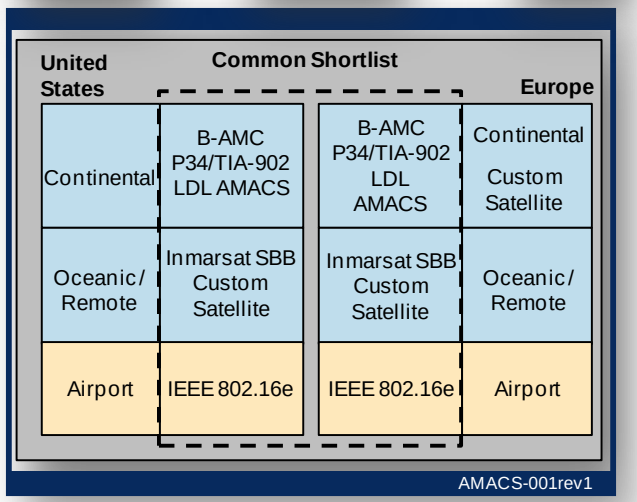
ITT

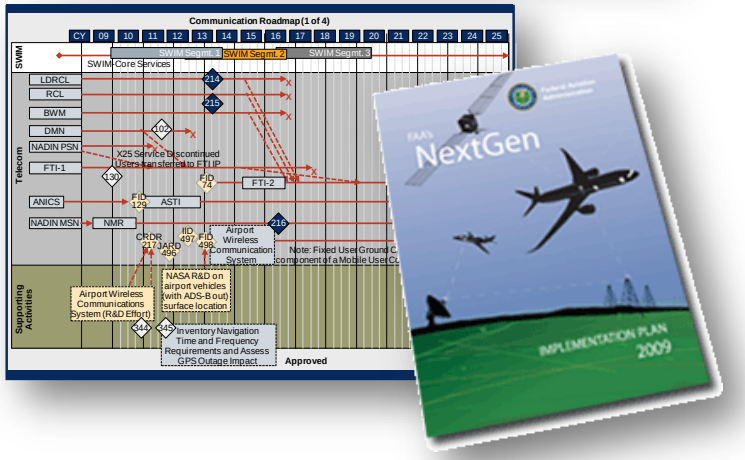
Overview

- Modernization of airport surface operations requires enhanced, high bandwidth communications capabilities to handle expected services
- A portion of the C-Band AN(R)S band, 5091 to 5150 MHz, was co-allocated as AM(R)S for airport surface mobile communications
- Standards are under development in the U.S. RTCA for the Aeronautical Mobile Airport Communications System (AeroMACS)
- Concepts of Use (ConUse), System Requirements, and a recommended System Profile for the proposed C-Band AeroMACS are being developed by the ITT Corporation under contract with NASA Glenn Research Center via sponsorship and guidance of the FAA
- Presented here is a summary of both the status of ITT's C-band research contract and NASA Glenn's related research
- An official NASA Contractor Report (NASA/CR-2010-216324) for ITT's research will be posted to the NASA Glenn Technical Reports Server http://gltrs.grc.nasa.gov/ during Q2 CY2010

Background

- Future Communications Study (AP-17), ICAO Aeronautical Communications Panel, Recommendation #1:
  - Develop a new system based on the IEEE 802.16e standard operating in the C-band and supporting the airport surface environment.
- FAA's NextGen Implementation Plan to improve collaborative Air Traffic Management includes "New ATM Requirements: Future Communications"
  - Concepts of use, preliminary requirements, and architecture for C-band airport surface wireless communication system
  - Test bed infrastructure to enable validation of aviation profile





RTCA SC-223

- RTCA Program Management Council approved SC-223 in July 2009 for Airport Surface Wireless Communications standard development
  - Aeronautical mobile airport communications system (AeroMACS) profile based on IEEE 802.16-2009 standard
  - Co-Chairs: Honeywell/Aloke Roy and ITT/Ward Hall; Government Official; FAA/Brent Phillips; AeroMACS Profile Working Group Lead: Harris/Art Ahrens
  - Plenary meetings held on 3-4 November 2009, 26-27 January 2010, 17-18 April 2010; Planned for 15-16 June 2010 and 17-18 August 2010
  - Coordinating with EUROCAE WG-82
  - Initial AeroMACS profile to be defined by October 2010

Approach for Technical Parameter Profile

- System profiles define AeroMACS operation in the unique airport surface environment
- Profile based on IEEE 802.16e broadband mobility standard
- Leverages commercial mobile Worldwide Interoperability for Microwave Access (WiMAX) for profiles, hardware, software, and network architecture
- Test and analysis will assess whether application needs are met
- RTCA SC-223 is developing FAA profile recommendations; EUROCAE WG-82 is developing common profile for EUROCONTROL in parallel

Profile Area	Key Parameter Selections
RF/Radio parameters • Frequency band • Channel BWs • Channel center frequencies	 5091 to 5150 MHz 5, 10 MHz Center frequencies at 5 MHz increments
Power class • Max DL TX power • Max UL TX power	 Unchanged from IEEE 802.16e
Duplex Mode • TDD/FDD	 TDD
Physical Layer • M-ary QAM range • Coding options • MIMO	 Performance profiles – Min. performance defined in 802.16e and sensitivity values scaled for frequency
MAC Layer • ARQ • Security protocols • Mobile protocols • QoS options	 Unchanged from IEEE 802.16e

Typical Communication Service Requirements

Communication Service	Example Airport Application	Performance Parameters	Typical values	Supported by 802.16e
Point-to-Point Data Link – (Low, Medium Speed, < 200 kbps)	Backup for sensor cable link (weather sensor)	Data rate	100 kb/s	Yes
		Packet Error Rate (PER)	1.0×10^{-3}	
		Delay	1sec	
		Jitter	100 msec	
Point-to-Point Data Link – (High Speed)	Backbone linking BS, link to relay gateway node in remote area	Data rate	1 Mb/s	Yes
		PER	1.0×10^{-3}	
		Delay	100 ms	
		Jitter	100 nsec	
Point-to-Multipoint, Broadcast	Scheduled broadcast of weather info, NOTAM	Data rate	200 kb/s	Yes
		PER	1.0×10^{-3}	
		Delay	1 s	
		Jitter	< 1 ms	
Command & Control Point-to-Point data Link	Remote operation of ADS-B ground station	Data rate	200 kb/s	Yes
		PER	1.0×10^{-6}	
		Delay	100ms	
		Jitter	< 1 ms	
Command & Control Network	Operation of surface devices at remote airport (e.g. Virtual tower)	Data rate	200 kb/s	Yes
		PER	1.0^{-4}	
		Delay	200 ms	
		Jitter	< 10 ms	

Typical Communication Service Requirements

Communication Service	Example Airport Application	Performance Parameters	Typical values	Supported by 802.16e
Digital Voice Network	Provide N circuits for ATC or AOC operations	Data rate	10 kb/s x N	Yes
		PER	1.0×10^{-3}	
		Delay	100 ms	
		Jitter	<100 ms	
Point-to-Point Video Link	Airport surveillance, Robotic vehicles	Data rate	600 kb/s	Yes
		PER	1.0×10^{-3}	
		Delay	200 ms	
		Jitter	< 10 ms	
Mobile – Basic	Handoff control for voice, data sessions-low speed	Data rate	200 kb/s	Yes
		PER	1.0×10^{-3}	
		Delay	200 ms	
		Jitter	< 10 ms	
Multi-media	Collaborative Decision Making	Data rate	1 Mb/s	Yes
		PER	1.0×10^{-3}	
		Delay	100 ms	
		Jitter	< 10 ms	
Mobile – Enhanced	Handoff control for video, higher data rate applications – high speed (160 knots)	Data rate	1 Mb/s	Need not yet established
		PER	1.0×10^{-3}	
		Delay	200 ms	
		Jitter	< 10 ms	
Relay/Gateway	Extend network coverage on the Airport surface, ad-hoc CDM	Data rate	1 Mb/s	Relay supported in future amendment
		PER	1.0×10^{-3}	
		Delay	200 ms	
		Jitter	< 10 ms	

Expected Range of Service Requirements

Parameter	Minimum Expected Requirement	Maximum Expected Requirement
Data Rate	10 kb/s	1 Mb/s
Packet Error Rate (UDP)	1.0×10^{-4}	1.0×10^{-3}
Delay	100 ms	1 s
Time Jitter	100 ns	10 ms

AeroMACS Additions to NASA-CLE CNS Test Bed

- CNS Test Bed at NASA Glenn and adjacent Cleveland Hopkins International Airport (CLE) already includes Sensis' precision multilateration (MLAT) surveillance and unlicensed WiFi network
- ITT's AeroMACS prototype implements features required to support mobile wideband communications for safety and regularity of flight services in an operational airport environment
- Full network installed, including user verification and security with Authentication, Authorization, and Accounting (AAA) server function
- AeroMACS hardware and network installation completed in October 2009 with two multi-sector base stations providing wide area coverage and redundancy (one on Glenn property, one on CLE) and eight subscriber stations (two on Glenn, six on CLE)

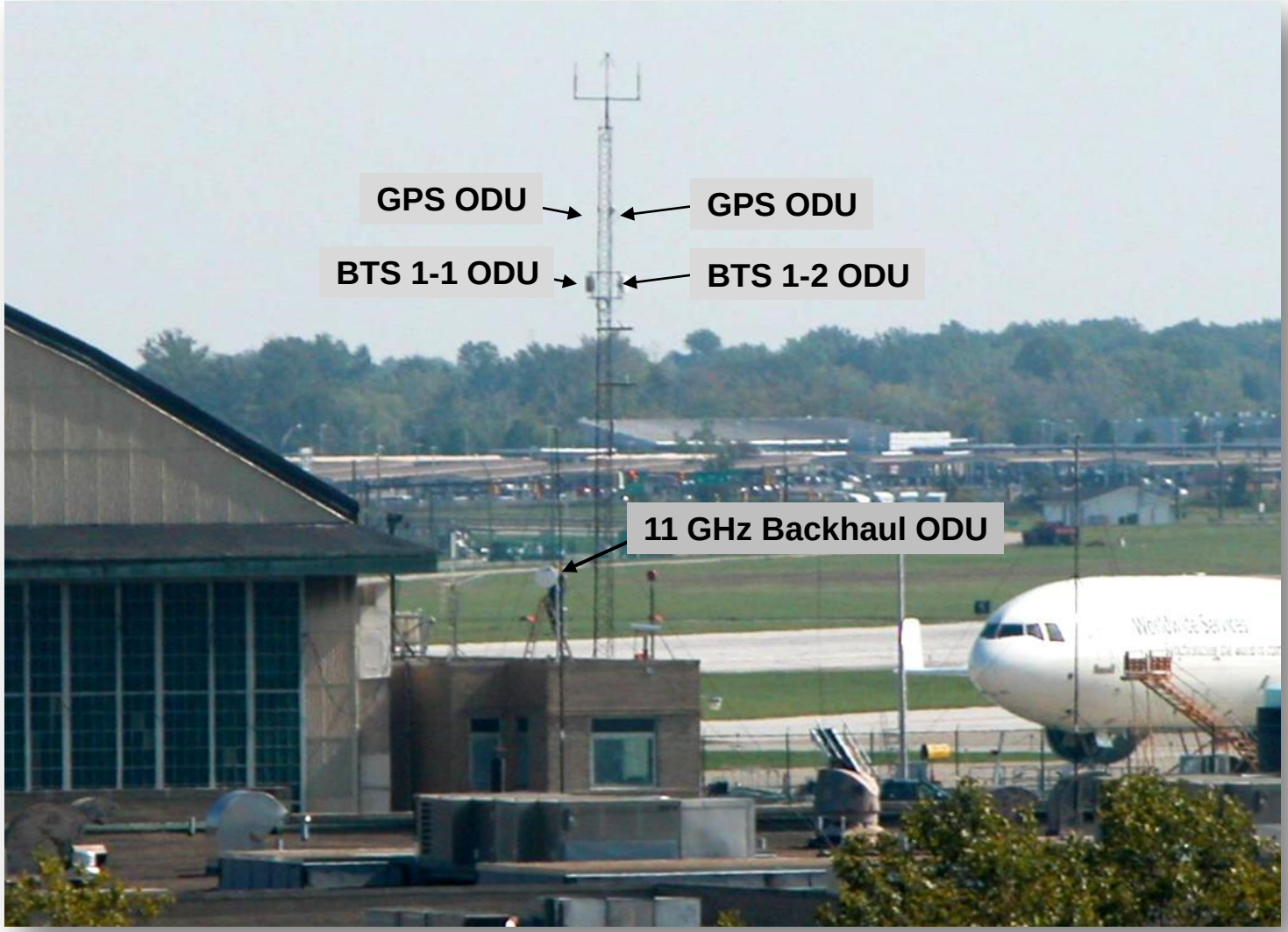
NASA-Cleveland Test Bed AeroMACS Network Layout

Core Server

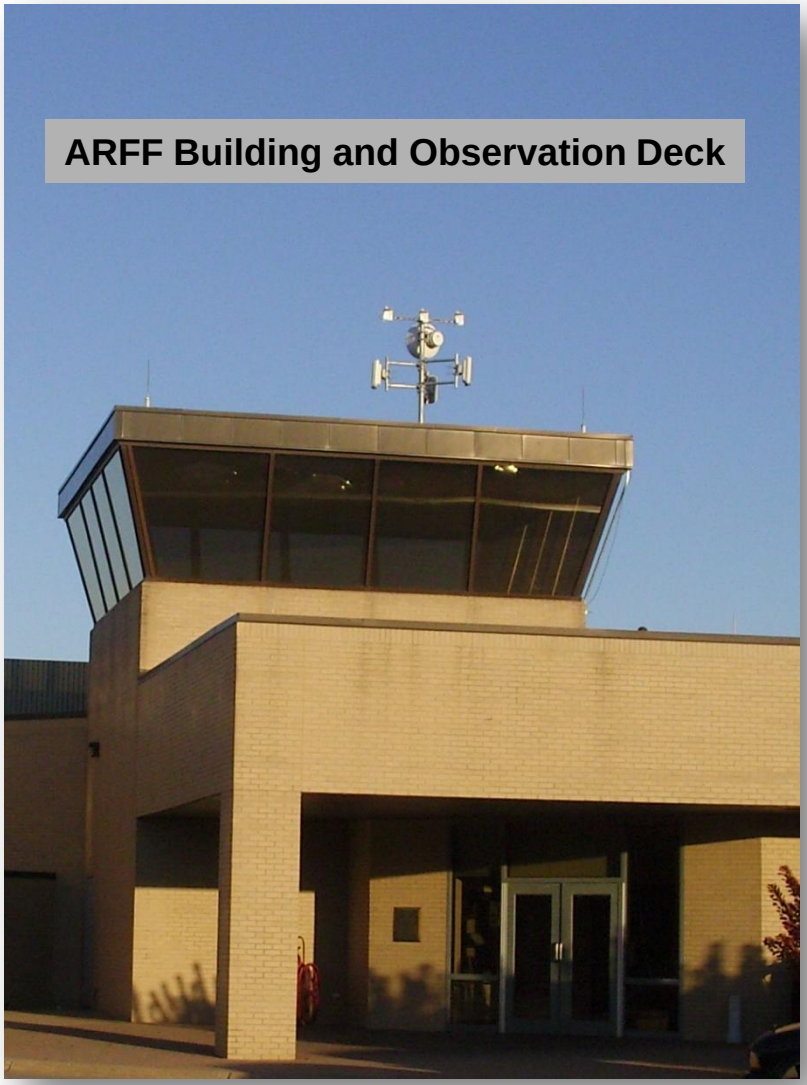
Subscriber Stations

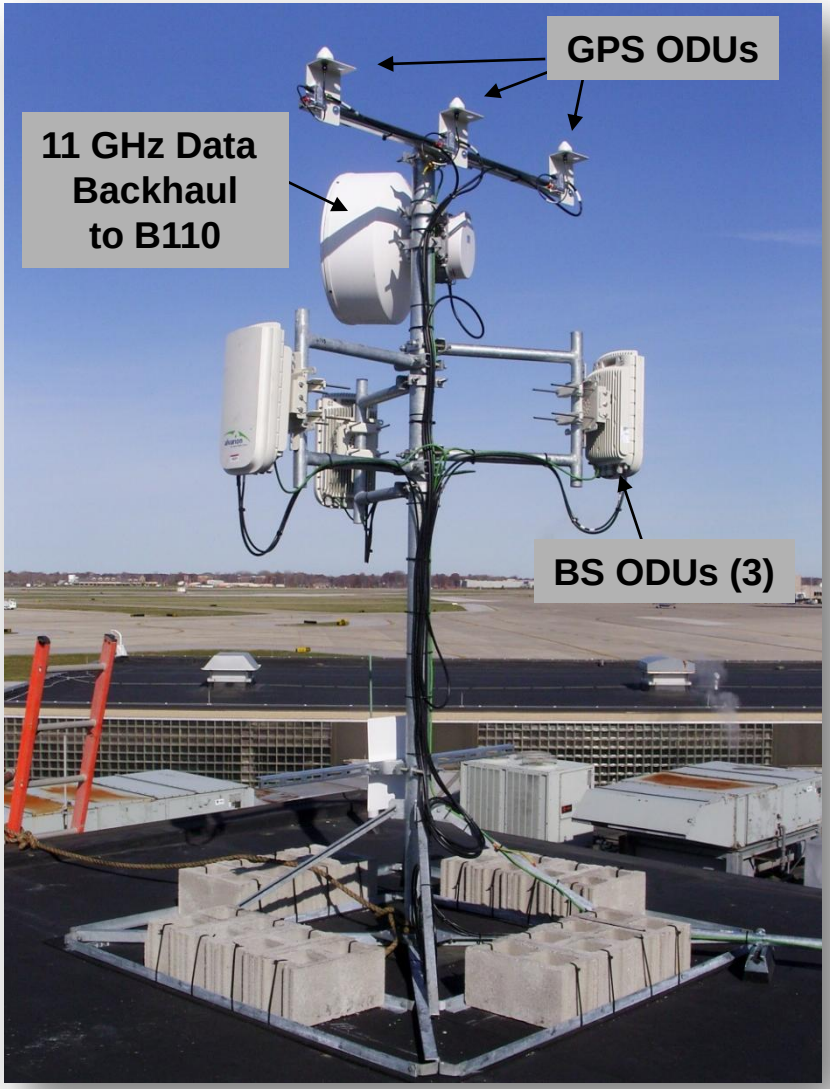
Base Stations

Two-Sector Base Station Located at NASA Glenn Hangar Building 4



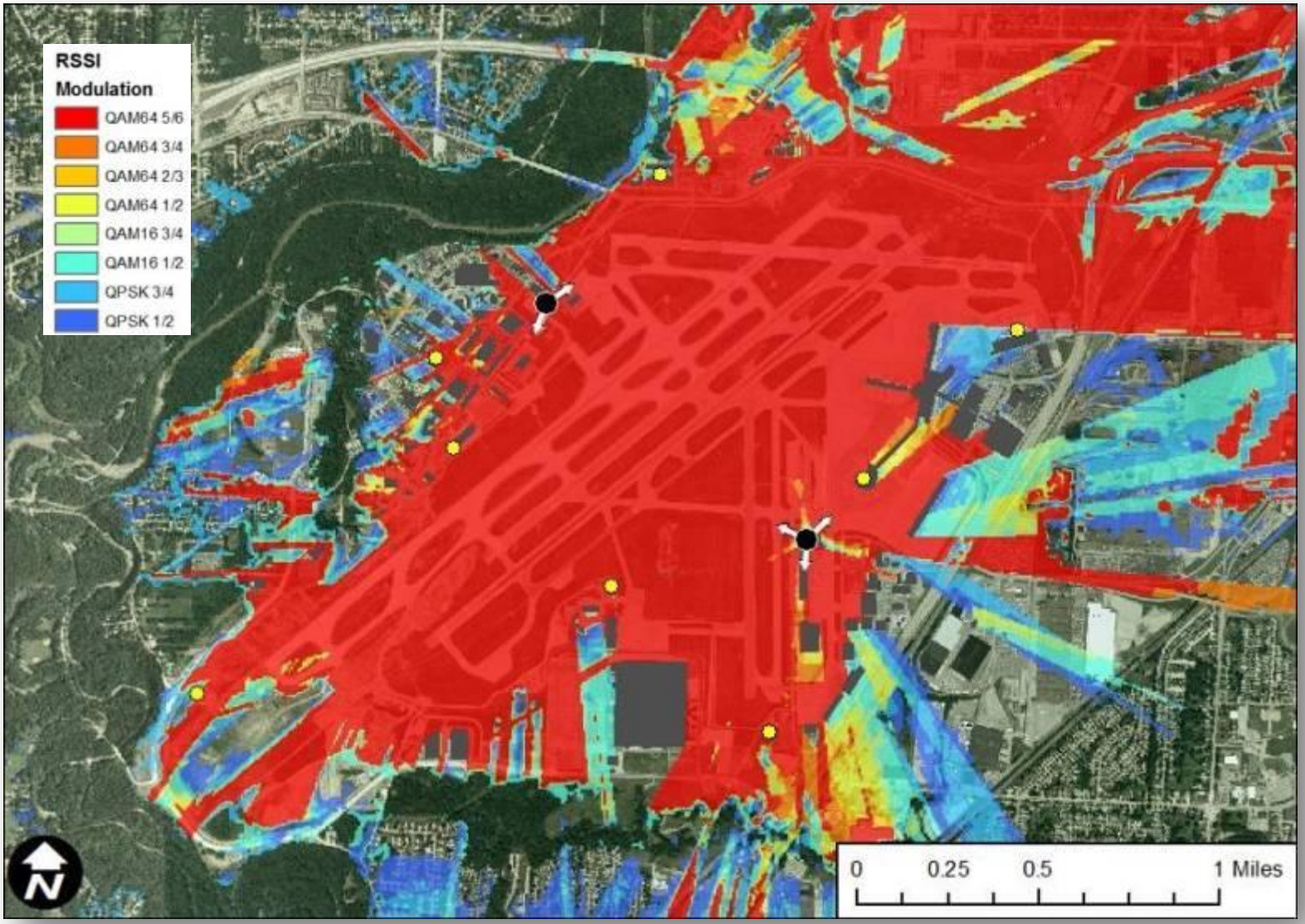
Three-Sector Base Station Located at CLE Airport Rescue and Firefighting (ARFF) Building





Subscriber Station Installation Example on Sensis MLAT Equipment at NASA Glenn Building 500

Predicted AeroMACS Link Performance



Initial Data Throughput Measurements Between Buildings 500 and 4

- Initial data throughput measurement results available for links between NASA Building 500 and two Base Station sectors at NASA Building 4
  - > 6.5 Mbps in Downlink direction (BS to SS)
  - > 4 Mbps in Uplink direction (SS to BS)
    - Conditions
      - 5 MHz Channel bandwidth
      - TDD ratio 60% (DL), 40% (UL)
      - TCP data traffic

BTS Sector	Measured Throughput DL, Mbps	Expected DL Throughput, Mbps	Measured Throughput UL, Mbps	Expected Throughput UL, Mbps
BTS1_1	6.82	6.5	5.40	4.0
BTS1_2	6.54	6.5	4.19	4.0

AeroMACS Parameter Evaluation Test Plans

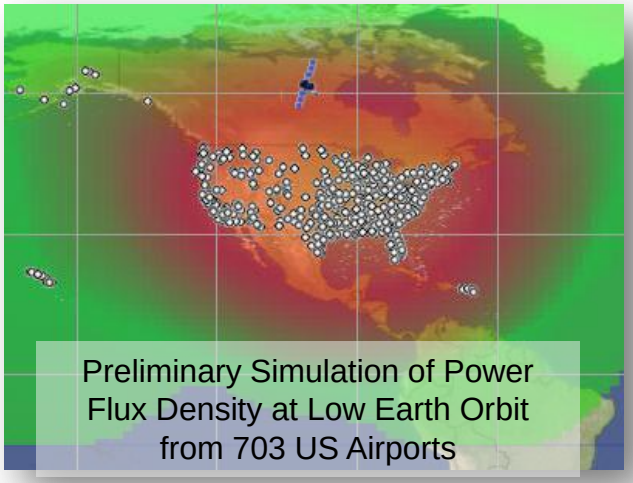
- Measure data throughput and packet integrity for the following conditions:
  - 5 and 10 MHz channel bandwidths
  - Stationary and mobile subscriber stations at speeds of at least 40 knots
  - Line-Of-Sight (LOS) and Non-LOS (N-LOS) propagation links
  - Presence of adjacent channel activity
- Mobility tests with hand-off transition between base station coverage sectors and between base stations
- Determine transmit power required to maintain a minimum level of link performance:
  - Single subscriber station antenna
  - MIMO antenna diversity
- Characterize link performance when transferring sensor data from MLAT sensors in test bed
  - Mixture of data traffic streams
  - Traffic priority setting with Quality of Service (QoS) settings

AeroMACS Development Considerations

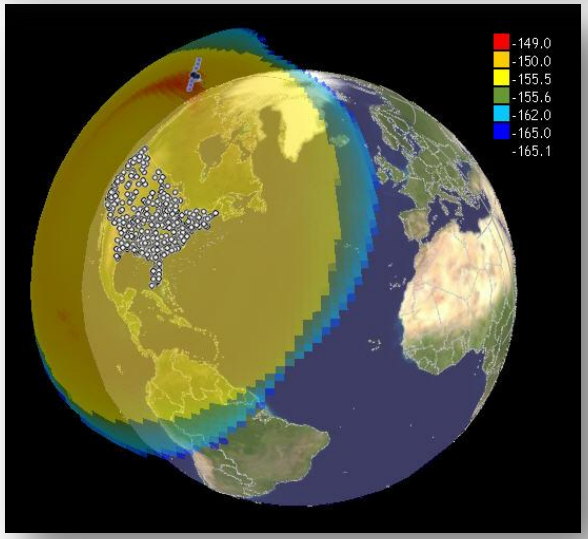
- Frequency Spectrum Use
  - Compliance with International Telecommunications Union Radiocommunications (ITU-R) Co-Allocation for Aeronautical Mobile Route Service [AM(R)S] in 5091-5150 MHz band
  - Assessment of AeroMACS interference within (Mobile Satellite Service feeder links, Aeronautical Mobile Telemetry, MLS) and adjacent bands
  - Channelization of allocated spectrum within commercial WiMAX Forum standard options
- Wireless Security Implications
  - Assess compliance with NIST Recommended Security Controls for Federal Information Systems and identify potential gaps
- Potential Services and Providers
  - Identify potential categories of AeroMACS services for airport users and options for implementation to enable multiple service providers

Spectrum Interference Initial Assessment

- Establish limits on aggregated AeroMACS transmissions to not exceed interference threshold for MSS feeder links
- Model based on Visualyse Professional 7 software from Transfinite Systems Limited
  - Includes: antennas, stations, carriers, links, and interference paths to determined signal, interference, and noise levels.
  - Preliminary model included all 703 US towered airports
  - Refined model benchmarks MITRE case for omni antennas at 497 major US towered airports
- Plan to increase complexity and realism of interference models:
  - Multi-sector antennas; multiple base and subscriber stations per airport; co-channel and adjacent band; proximity; frequency reuse; multipath signal propagation



Preliminary Simulation of Power Flux Density at Low Earth Orbit from 703 US Airports



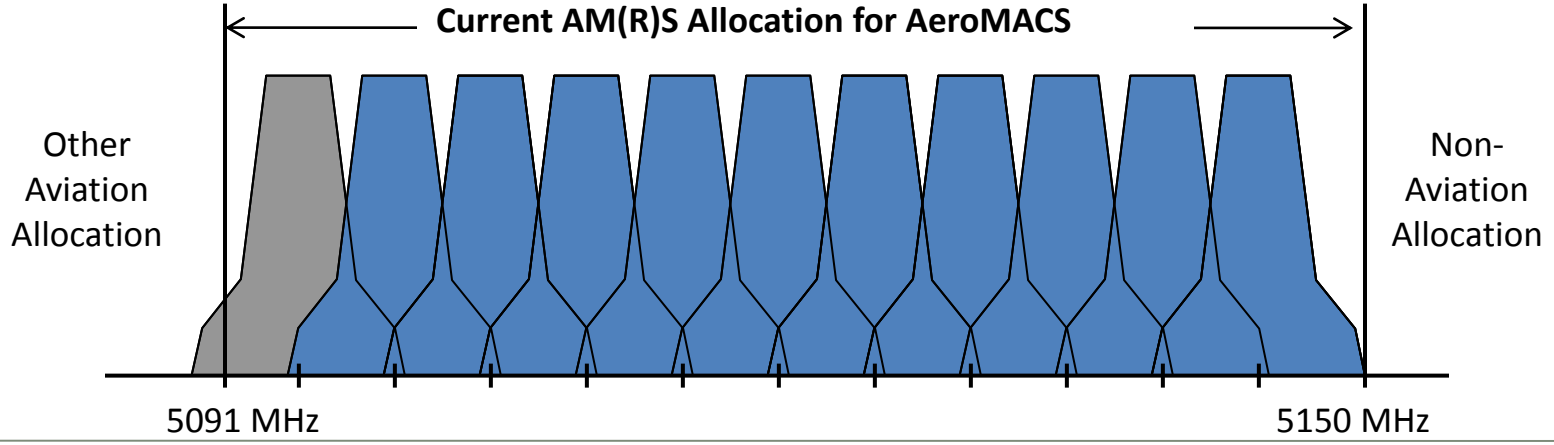
Power Flux Density at Low Earth Orbit from 497 US Airports

Channelization Considerations

- Selection of standard channel BW depends on several factors:
  - Current 59 MHz and potential 30 MHz allocation
  - Guard bands to limit out-of-band transmitted power
  - Anticipated number of BS and SS for practical airport installation
  - Amount of frequency spectrum reuse at the largest airports
  - Bandwidth requirements of potential applications
  - Availability of equipment with WiMAX Forum channel masks
  - Number of independent AeroMACS infrastructure operators

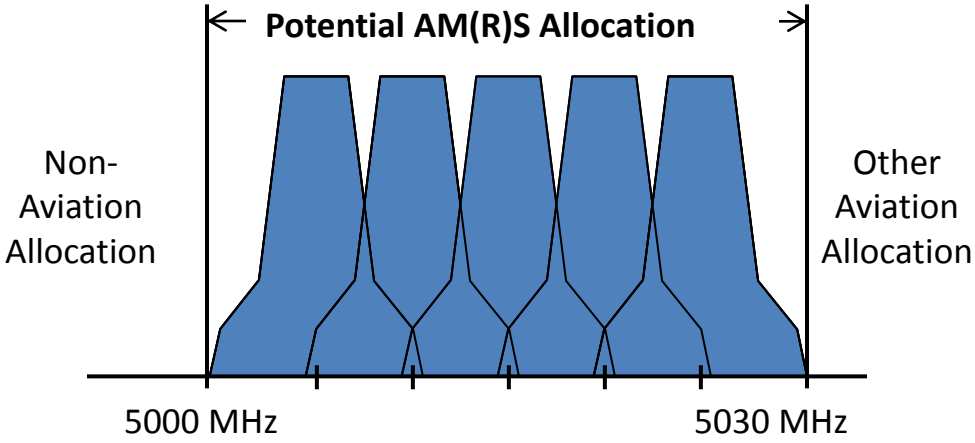
Initial Channelization Methodology/Channel Plan

- Select common channel bandwidths of 5 MHz
- Equally spaced 5 MHz center frequency grid from 5005-5145 MHz
- Proposed channel plan consisting of 10 usable channels within the current AM(R)S allocation (5091-5150 MHz)
- Out-of-band (OOB) interference into adjacent aeronautical band (5030-5091 MHz) may be coordinated via ICAO for 11th channel
- 55 MHz of the total 59 MHz allocation may be usable with stringent channel mask



Initial Channelization Methodology/Channel Plan

- Methodology supports potential future AM(R)S allocation in 5000-5030 MHz
- Potential for channel plan consisting of 5 usable 5 MHz channels
- All 30 MHz of the potential allocation might be usable
- Need to investigate mechanisms to meet out-of-band interference requirement (-44 dBc; -27 dB/MHz at the band edges)
  - Guard bands, band edge filter, or more stringent channel mask



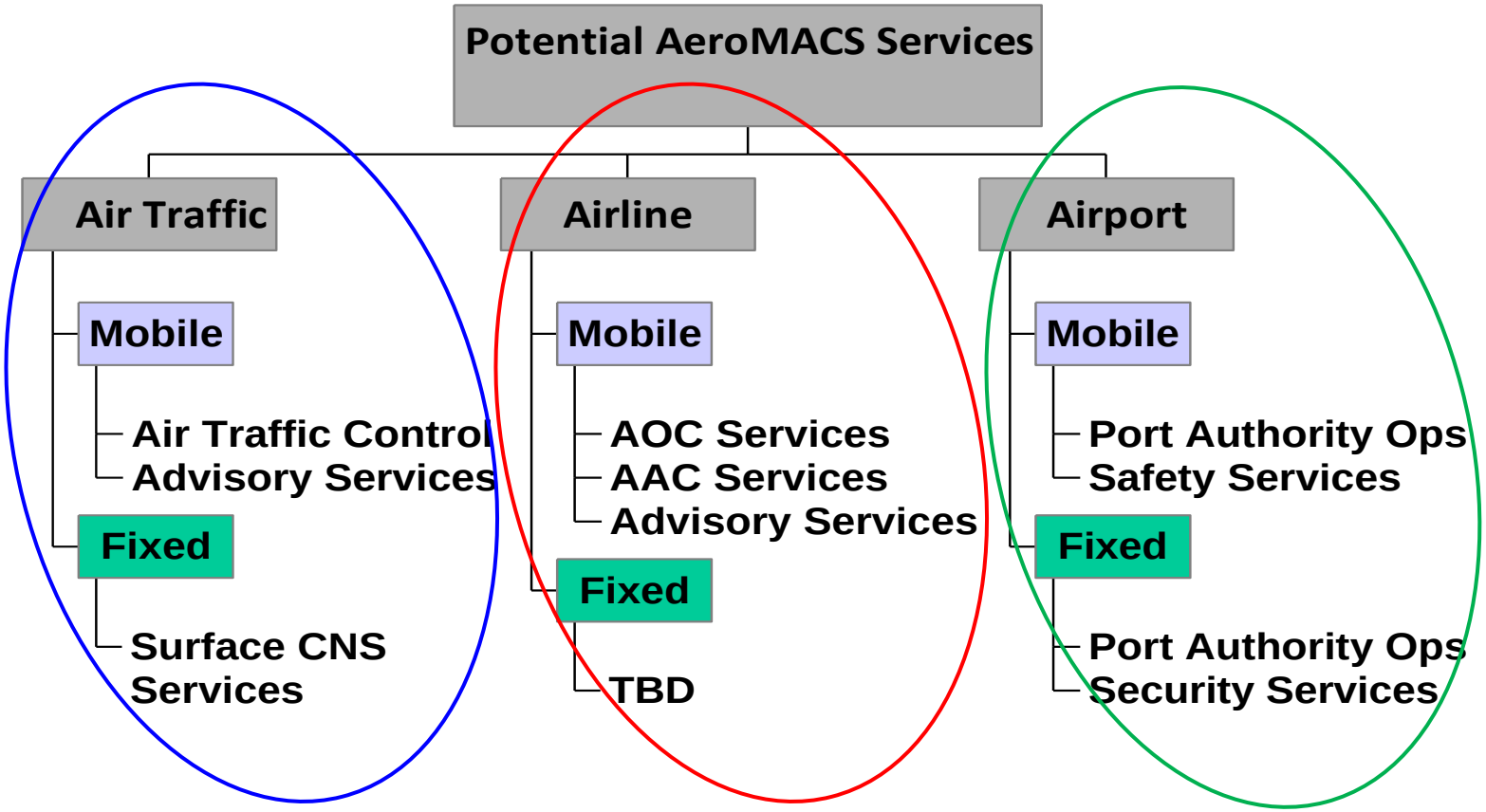
Wireless Security Initial Assessment

- WiMAX security functions meet the NIST SP800-53 controls for access, audit and accountability, and identification and authentication.
  - WiMAX PHY and MAC layer mechanisms assist in addressing NIST Control SC-5, Denial of Service (DOS) Protection.
- WiMAX standard meets all NIST Systems and Communication Protection Controls with regards to user data
- WiMAX mechanisms that minimize impact of DOS and signal attenuation or interference from contending RF sources include:
  - OFDM/OFDMA reduces interference by breaking signal into subcarriers
  - Adaptive Antenna Systems (AAS) focus transmission and reduce unintentional interference
  - Dynamic Frequency Selection (DFS) can change frequency if interference is detected

Potential WiMAX Security Vulnerabilities

- Some MAC messages generated by a BS do not use encryption to ensure messages received by a SS are authentic and unaltered. Intentionally forged MAC information could cause service disruption.
- Potential vulnerabilities include:
  - **DOS by forging "Mobile Neighbor Advertisement" messages:** Malicious generation of BS lists can omit or falsify important information causing loss of SS connection during handoffs
  - **DOS by spoofing "Downlink Burst Profile Change Request" messages:** A forged BS message can cause a SS to change to the wrong modulation method resulting in temporary loss of communication
  - **Battery Drain by spoofing "Mobile Traffic Indicated" messages:** Repeated forging of these messages may defeat power conservation mechanisms of battery-powered SSs by responding to forged traffic IDs
- NASA Glenn plans to verify the impact of these vulnerabilities via the Test Bed

Potential AeroMACS Service Categories in U.S.



- FAA, FTI, Others?
- ARINC, SITA, Airlines, Others?
- Port Authority, Commercial?

AeroMACS Service Examples and Provision Options

Air Traffic Services	
Service Examples	• Air traffic control commands beyond Data Comm Segment 3 • Surface communications, navigation, and surveillance (CNS) fixed assets
Provision Options	• Government-owned (licensed)/Government-operated (GO/GO) • Government-owned (licensed)/Commercially-operated (GO/CO) • Non-competed service extension via FAA Telecommunications Infrastructure (FTI) • Open commercial competition by FAA
Airline Services	
Service Examples	• Airline Operational Control (AOC) • Airline Administrative Communications (AAC) • Advisory information • System Wide Information Management (SWIM) • Aeronautical Information Management (AIM) • Meteorological (MET) data services
Provision Options	• Commercially-owned (licensed)/Commercially-operated (CO/CO) • Non-competed service extension via exiting AOC service providers • Airline service provision internally • Open commercial competition by airlines
Airport Operator/Port Authority Services	
Service Examples	• Security video • Routine and emergency operations • De-icing/snow removal
Provision Options	• Local Government-owned (licensed)/Commercially-operated (GO/CO) • Commercially-owned (licensed)/Commercially-operated (CO/CO) • Open commercial competition by Operator/Port Authority

Airport Surface Experiments and Demos

THEVAN

Sensor Systems MLS 5 GHZ Antenna

Sensis Mode S Vehicle Locator 24-bit ICAO address

Viking S3-B

- FY10 Experiments
  - Network performance, mobile sector handoffs, blockage/ outage recovery, signal propagation
  - QoS data prioritization, data throughput, channelization
  - Security with authentication and encryption
- Potential Demos
  - Communication of MLAT surveillance data via AeroMACS
  - Loading graphical weather products into cockpit
  - Precision monitoring of 4D surface trajectories

Conclusion

- Initial Concepts of Use, requirements, and service examples are established for an AeroMACS system
- An initial set of specification-level system profile parameters are recommended with detailed analysis continuing
- The NASA-CLE CNS Test Bed is modified with a functional prototype AeroMACS network and will be used to:
  - establish performance capability
  - validate AeroMACS profile parameter recommendations
  - verify spectrum compliance and security vulnerabilities
  - evaluate selected service applications

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