



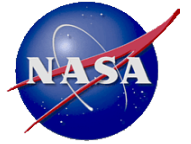
# **Aeronautical Mobile Airport Communications System (AeroMACS) Technical Development Briefing**

**NASA Glenn Research Center  
Rafael Apaza**

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10/17/2016

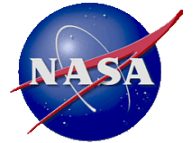
**Eighteenth Workshop Meeting on the ICAO  
South America Implementation Meeting**



# Presentation Outline

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- Background
- AeroMACS Technology and Applications
- NASA CNS Test Bed
- Development and Trials
- Future Work
- Standardization and WiMAX Forum
- Concluding Remarks



# Why Airport Surface Wireless Communications?

## Today

### Wired Infrastructure

- Aging (40 yrs.)
- Costly deployment
- Rigid
- Costly maintenance
- Buried infrastructure
- Vulnerable
- Limited availability
- Point-to-point
- Noise susceptibility



## Tomorrow

### Wireless Infrastructure

- Scalable
- Agile
- Flexible
- Affordable
- Implements new protocols
- Supports fixed and mobile nodes
- Networked



# AeroMACS Background

**AeroMACS** – a wireless airport surface communications technology based on IEEE 802.16e standard designed to **deliver critical networked communications services to mobile and fixed systems**

- Airport Wireless Communications (AeroMACS) concept developed by NASA Glenn under Space Based Technologies (SBT) Project 2002-2006.
- After SBT ended, NASA-FAA partnership continued AeroMACS development (SAA 3-978)
- In **2007**, ITU's WRC07, the extended 5091-5150 MHz MLS for Airport Surface communications (wheels down).
- NASA GRC in partnership with FAA developed AeroMACS prototype system utilizing NASA GRC CNS Test Bed facility
- AeroMACS is part of NextGen and SESAR technology portfolio for airport surface operational improvements
- FAA has initiated the first round of AeroMACS deployments for fixed nodes – 9 airports





# AeroMACS Technology Description

**AeroMACS is a Digital Broadband Wireless Access system**

- Member of “**Mobile WiMAX**” (IEEE802.16e)
  - Operates in AM(R)S band (5091-5150 MHz, Bandwidth = 5 MHz)
  - TDD/OFDMA
  - Adaptive Modulation and Coding: QPSK, 16QAM & 64QAM
  - Adaptive MIMO Switching - MIMO-A/STC & MIMO-B/SM (Optional)
  - Quality of Service (QoS)
- Enables IP-based “**High Speed Wireless Access**”
- Downlink/Uplink ratio adjustable: 26:21, 29:18, 32:15 & 35:12
- Provides “**Security**” using SS/MS Certificate, Security Keys and Encryptions
- Supports “**Mobility**” (up to 50 knots = 92.6 km/h)



# AeroMACS Applications: Fixed and Mobile



	<b>Air Traffic</b>	<b>Air Carriers</b>	<b>Airports</b>
<b>Mobile Apps</b>	<ul style="list-style-type: none"> <li>✓ AT Comm.</li> <li>✓ AAtS</li> <li>✓ Gate Clearance</li> <li>✓ NOTAMS</li> <li>✓ Surface 4 DT</li> <li>✓ ATIS</li> </ul>	<ul style="list-style-type: none"> <li>✓ Surface Mgmt.</li> <li>✓ Fueling</li> <li>✓ Weather</li> <li>✓ De-icing</li> <li>✓ EFB</li> <li>✓ Flight Info.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Fire &amp; Rescue</li> <li>✓ Wild Life Mgmt.</li> <li>✓ Mobile Security</li> <li>✓ RWY Status</li> <li>✓ Coordination</li> </ul>
<b>Fixed Apps</b>	<ul style="list-style-type: none"> <li>✓ Surveillance</li> <li>✓ Weather</li> <li>✓ Navigation Aids</li> <li>✓ Visual Aids</li> </ul>	<ul style="list-style-type: none"> <li>✓ Ramp Mgmt.</li> <li>✓ Flight Ops.</li> <li>✓ Ramp Services</li> <li>✓ Baggage</li> </ul>	<ul style="list-style-type: none"> <li>✓ Security Gates</li> <li>✓ Construction</li> <li>✓ NOTAM-D</li> <li>✓ Lighting</li> </ul>



# NASA GRC CNS Test Bed Configuration

**2006 - NASA GRC in partnership with industry and government established the CNS Test Bed in North East Ohio**

- Originally test bed consisted of three airports (BLK, CLE and LPR) and the NASA Glenn Research Center (GRC)
- Today's configuration consists of NASA GRC and Cleveland Hopkins Airport
- Objectives:
  - Prototype
  - Evaluate
  - Measure
  - Reduce risk
- Applied Research
  - Advanced Integrated Surveillance
  - Airport Surface Wireless Communications
  - Secure Information Sharing
  - Staffed Virtual Tower
  - Precise 4-D Trajectory Negotiation

### Test Frequencies

5005 MHz	5105 MHz
5015 MHz	5110 MHz
5025 MHz	5115 MHz
5095 MHz	5120 MHz
5100 MHz	5125 MHz

### Test Bed Locations

**CLE**

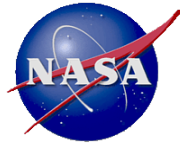
- CMF
- ASH
- Glycol Tank
- Snow Barn
- ARFF
- Terminal C

**GRC**

- Bldg. 4
- Bldg. 110

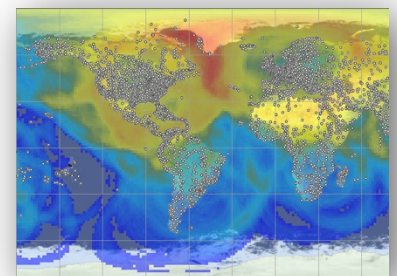
**FAA**

- ALSF



# AeroMACS NASA Trials and Investigation

- Aircraft Mobile Application Testing – AeroMACS testing on Boeing 737-700 corporate aircraft
  - Weather to the cockpit using EFB, System Performance
  - Antenna performance
  - Throughput Validation
  - Partners: Boeing, United Airlines, WSI, ITT, FAA, NASA, CLE Airport Authority
- Surveillance Video Test – First trial using terminal radar video
- RTCA, ICAO, WiMAX standards and technical profile development support
  - US RTCA standards DO-345 and
  - International Civil Aviation Organization SARPS completed
- Standard Compliance Trial – First compliance system test and demonstration with Hitachi Corp.
- World Wide satellite interference analysis

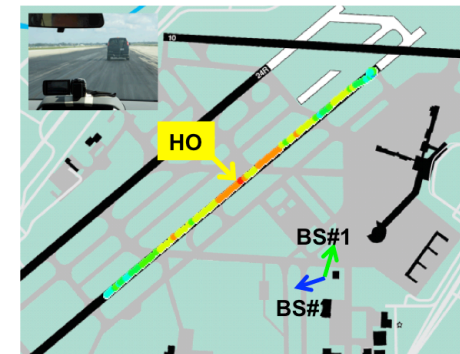
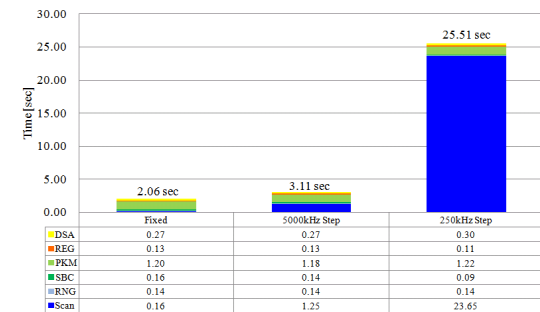
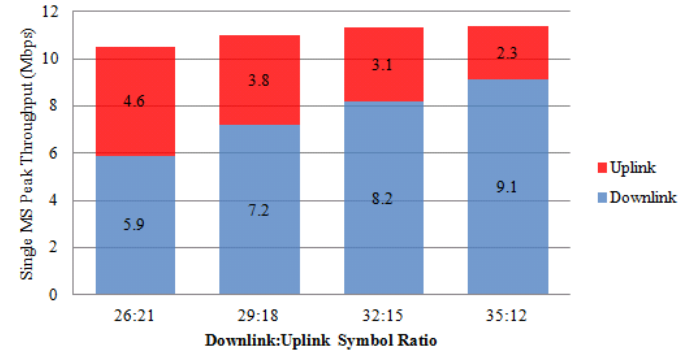




# NASA Prototype Compliance Testing

## Hitachi Prototype Testing

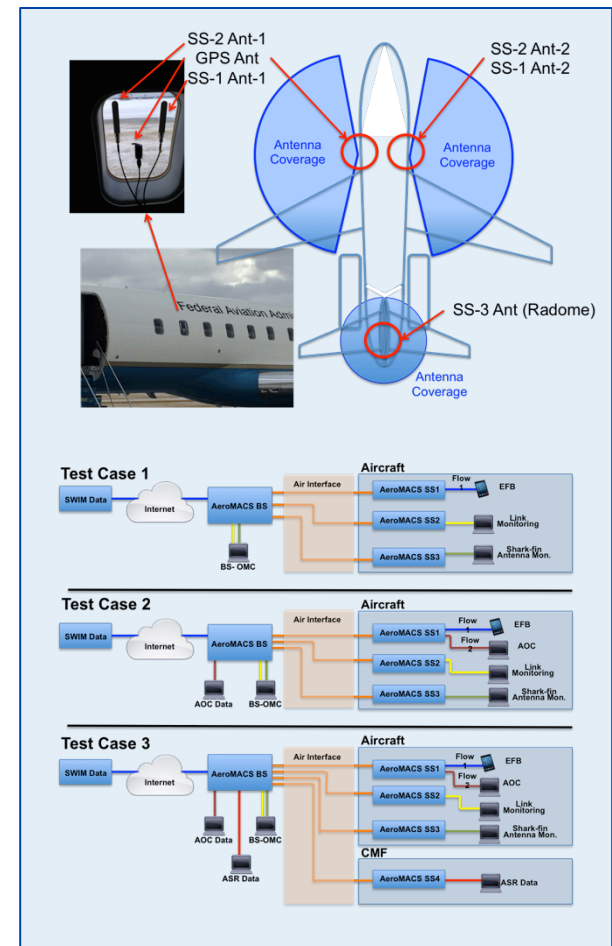
- **Throughput Test:**
  - 5MHz channel can provide total throughput of 11 Mbps (Downlink + Uplink)
- **Quality of Service (QoS) Test**
  - Technical Standard (Network) was validated: the reserved bandwidth is guaranteed.
  - It was validated that a single MS accommodates multiple QoS class communication links
- **Initial Network Entry (INE) Test**
  - INE time depends on scan step and range
  - INE on the Runway succeeded and the necessary INE time was a bit longer (5MHz step: 4.50 sec, 250kHz step: 26.67 sec) because of longer T2 time
  - SARPs requirement (90 seconds) can be realized (maximum 26 sec at the Field Trial)
- **Mobility and Handover Test**
  - Mobility validation: AeroMACS link maintained throughout Runway drive @50/22 knots with handover. Latency: 200 msec.





# SWIM Data over AeroMACS

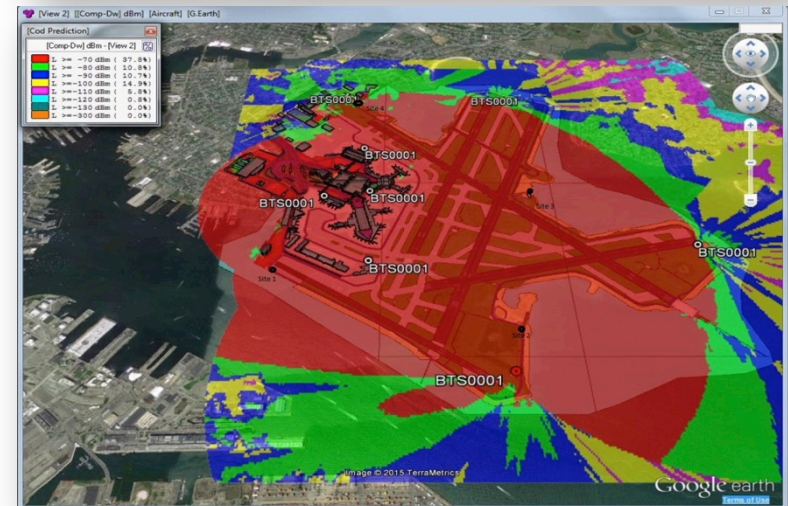
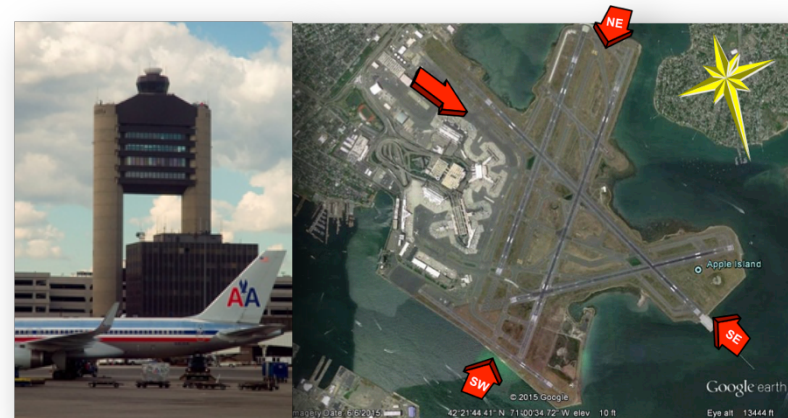
- **Test Case 1**
  - This test case transports SWIM data over AeroMACS.
  - SWIM Accessibility
  - Data Throughput
  - Aircraft runway speed: 45 Knots.
- **Test Case 2**
  - This case will exchange SWIM data plus emulated airline data communications with AOC.
  - Radome antenna evaluation
  - Aircraft runway speed: 55 Knots
- **Test Case 3**
  - This case will exchange SWIM data plus emulated airline data communications with AOC and emulated radar data exchange.
  - Handover performance
  - Aircraft runway speed: 60 Knots





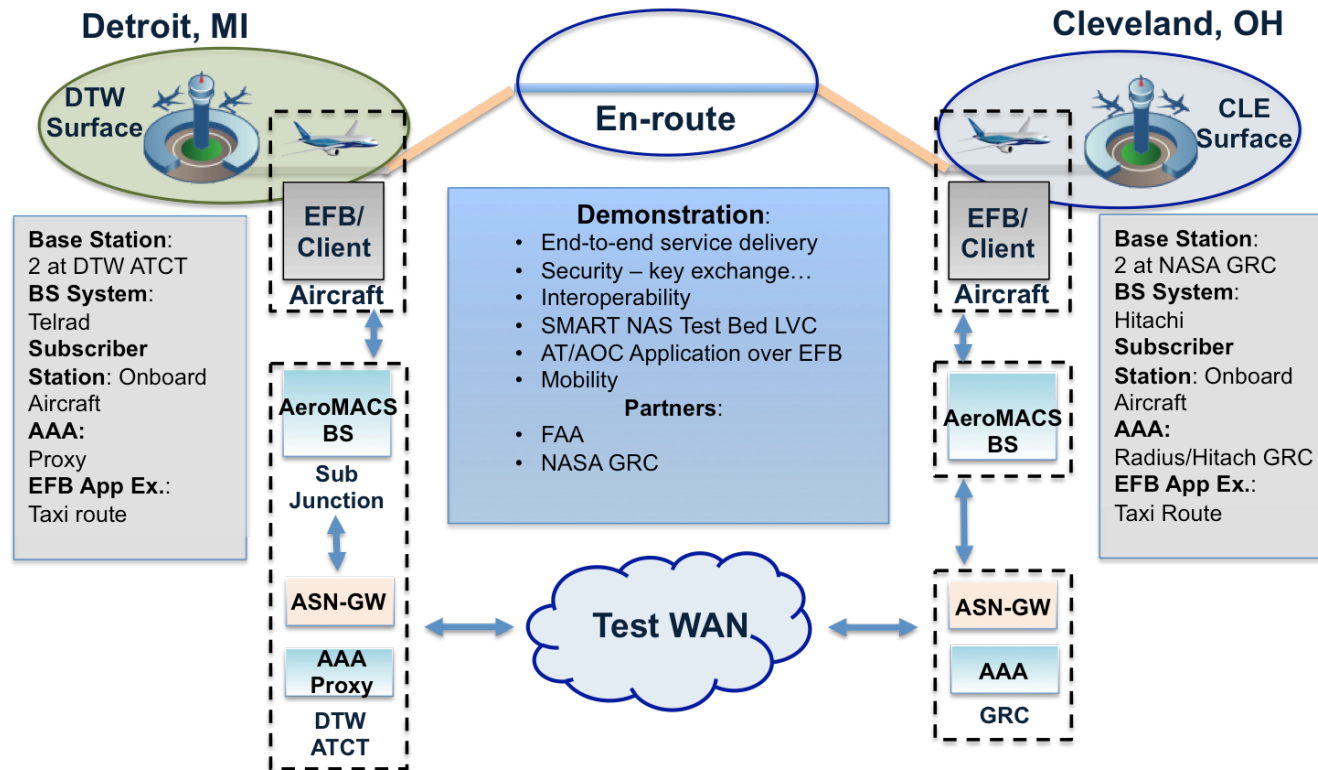
# AeroMACS test at Boston Logan Airport

- FAA Airports, FAA Technical Center
- 1<sup>st</sup> Airport\Airline Operational Use
- Test Representative Uses
  - Radar (Ship or Bird Radar)
  - Video
  - Weather
  - Security\Perimeter Monitoring
  - Airline Use
- Preliminary Site Survey
- MOA with FAA
- MPA/FAA/Airline partnership
- ~2-year effort

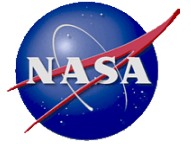




# NASA Future Trial and Testing



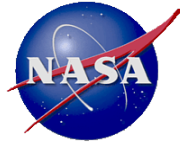
- **Interoperability:** Hardware and software subscriber station compatibility
- **Security:** Evaluate different system security concepts and configurations (Authentication, authorization, etc.)
- **Application performance test:** VoIP
- **Internet Protocol Suite Trial and Evaluation:** IPV4/6, Roaming, etc.
- **End-to-end Service Delivery:** Latency, Jitter, etc.



# AeroMACS Standards Development

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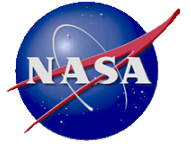
- Started in **2009** with the RTCA Special Committee 223 (SC-223) and the European Organization for Civil Aviation Equipment (EUROCAE) Working Group 82 (WG-82). They published a **MOPS** and **Profile** for AeroMACS based on IEEE std 802.16-2009 in **2014**.
- EUROCAE is continuing development of the AeroMACS Minimum Aviation System Performance Standards (**MASPS**).
- ICAO ACP WGS finalized the AeroMACS **SARPS** and completed development of AeroMACS Technical Manual.
- Finally, the WiMAX Forum's Aviation Working Group (AWG) has been engaged throughout AeroMACS development process, releasing AeroMACS Certification Requirement Status List (**CRSL**) and Protocol Implementation Conformance Statement (**PICS**).



# WiMAX Forum

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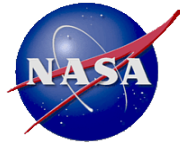
- **Industry-led**, not-for-profit organization, certifies and promotes the compatibility and interoperability of certain wireless broadband technologies across various industries ranging from Telecommunications (WiMAX) up to **Aviation** (AeroMACS) since **2001**.
- With regards to Aviation industry, the WiMAX Forum has been instrumental in **all stages** of AeroMACS' growth, from its initial launch, when we facilitated the development of a system profile, to current global expansion efforts.
- Key authorities such as the **FAA**, **EUROCONTROL**, and the **ICAO** regularly attend Forum aviation-centric events in which industry leaders, experts and technology providers are able to collaborate and share real-world knowledge, focused specifically on the deployment of standardized broadband networks for the aviation industry.



# WiMAX Forum Members

## Key Members in Aviation

- Aviation Data Communication Corporation, China (ADCC)
- Civil Aviation Safety Authority of Australia
- CelPlan
- ConvergenX Technologies
- DFS Deutsche Flugsicherung
- Embry Riddle Aeronautical University
- EUROCONTROL
- FAA
- Gemtek
- Harris
- Hitachi
- Honeywell
- Leonardo (Finmeccanica/SELEX)
- Metropolitan Washington Airport Authority
- MITRE Corporation
- NASA
- Powertech Labs
- Sequans
- Shinsei Corporation
- Siemens
- Symantec
- Telrad Networks
- United Airlines



# Aviation Working Group (AWG)

WiMAX Forum® AWG has facilitated a number of regional aviation events such as:

**Aviation Washington**

September 2013, Washington DC, USA

**Aviation Brussels**

Hosted by EUROCONTROL  
May 2014, Brussels, Belgium

**AeroMACS Track**

Hosted at Wireless China Summit  
September 2014, Beijing, China

**Aviation Sendai**

Hosted by Hitachi, JCAB and ENRI  
November 2014, Sendai, Japan

**Aviation Madrid**

Hosted at World ATM Congress  
March 2015, Madrid, Spain

**AeroMACS Track**

Hosted at Wireless China Summit  
September 2015, Beijing, China

**AeroMACS National Harbor**

Hosted at ATCA Congress  
November 2015, National Harbor, USA

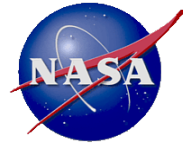
WiMAX Forum® AWG AeroMACS programs in process:

AeroMACS Certification

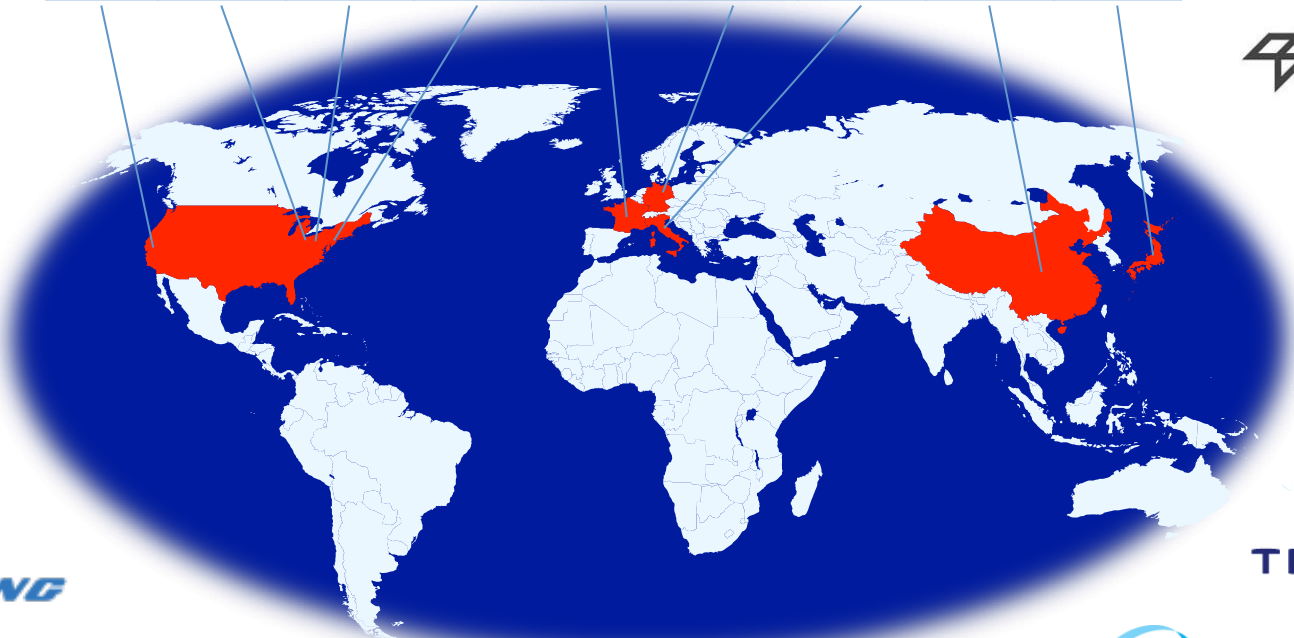
AeroMACS X.509 Public Key Infrastructure (PKI)

AeroMACS FCC Service Policy Petition

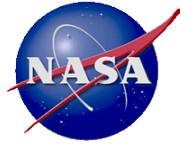
AeroMACS Seminars



SFO	CLE	SYR	ACY	TLS	OBF	MXP	CTU	SDJ
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# WORLDWIDE CONTRIBUTIONS



## Concluding Remarks

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- AeroMACS is a standardized broadband wireless communications technology for use on the airport surface.
- Design to securely meet operational needs of mobile and fixed platforms.
- Operates in protected AMR(S) spectrum: 5091-5150 MHz and 5000-5030 MHz
- Federal Aviation Administration initiated AeroMACS deployment to transport Airport Surface Surveillance Capability sensor information
- Investigation and trials taking place in different countries around the world
- AeroMACS opens up new information exchange possibilities for stake holders operating on the airport surface