AeroMACS Overview and Update

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Aviation Working Group, WiMAX Forum

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The Problem…

- Four US airports are slot-limited
- More than Ninety European airports are slot-limited
- If NextGen increases the capacity of the sky and of the flow to and from the airport, the airport itself becomes the bottleneck throughout the civil aviation industry

The only way to increase capacity at these airports and avoid this global bottleneck is technology, and not concrete.

AeroMACS is a large part of the Solution…

A “Tall Pole” that is Critical to Address - FCC Docket 12-338

- Must file a petition to prompt the FCC to address AeroMACS Service Policy so that commercial users can get licenses.

- FCC AeroMACS Service Policy is a critical long lead-time work item that is currently not expected before 4Q2016, and that may be a year late…

How can you help with this petition?

Agenda

- What is AeroMACS?
- AeroMACS Applications
- AeroMACS Standardization
- AeroMACS Past Activities
- AeroMACS Deployments - Current and Future
- The WiMAX Forum

What is AeroMACS?

- Aeronautical Mobile Airport Communications System
- 5030 MHz - 5150 MHz (C-Band) ITU Regulated Spectrum shared with AM(R)S
- Facilitate communication on the airport surface for safety of life and regularity of flight

AeroMACS - Key Characteristics

- WiMAX - IEEE 802.16e 2005
- C-band 5091 MHz - 5150 MHz US allocation
- 5 MHz Channels
- TDD, OFDMA, IP architecture
- Adaptive modulation techniques - QPSK, 16QAM, 64QAM
- DL Data Rates from 1.8 Mb/s to 9.2 Mb/s possible
- P_{EIRP} < 23 dBm, 15dBi gain BS antenna, 6dBi gain MS antenna (1 Km to 3 KM radius of coverage)
- Service priority levels
- Real-time and Best-effort services
- Advanced security features

AeroMACS has Heavy-Weight Security Features

- A High-Level Security Features List – the Architecture:
  - **Security Associations** for Authorization and Data
  - **PKMv2** Pair-wise Privacy Key Management
  - **EAP-TLS** Authentication (Extensible Authentication Protocol - Transport Layer Security)
  - **KEK** (Key Encryption Key) with 3-way handshake
  - **TEK** (Traffic Encryption Key)
  - **AES-128** CCM-mode Encryption with key-wrap
  - **X.509 PKI** (Public Key Infrastructure)

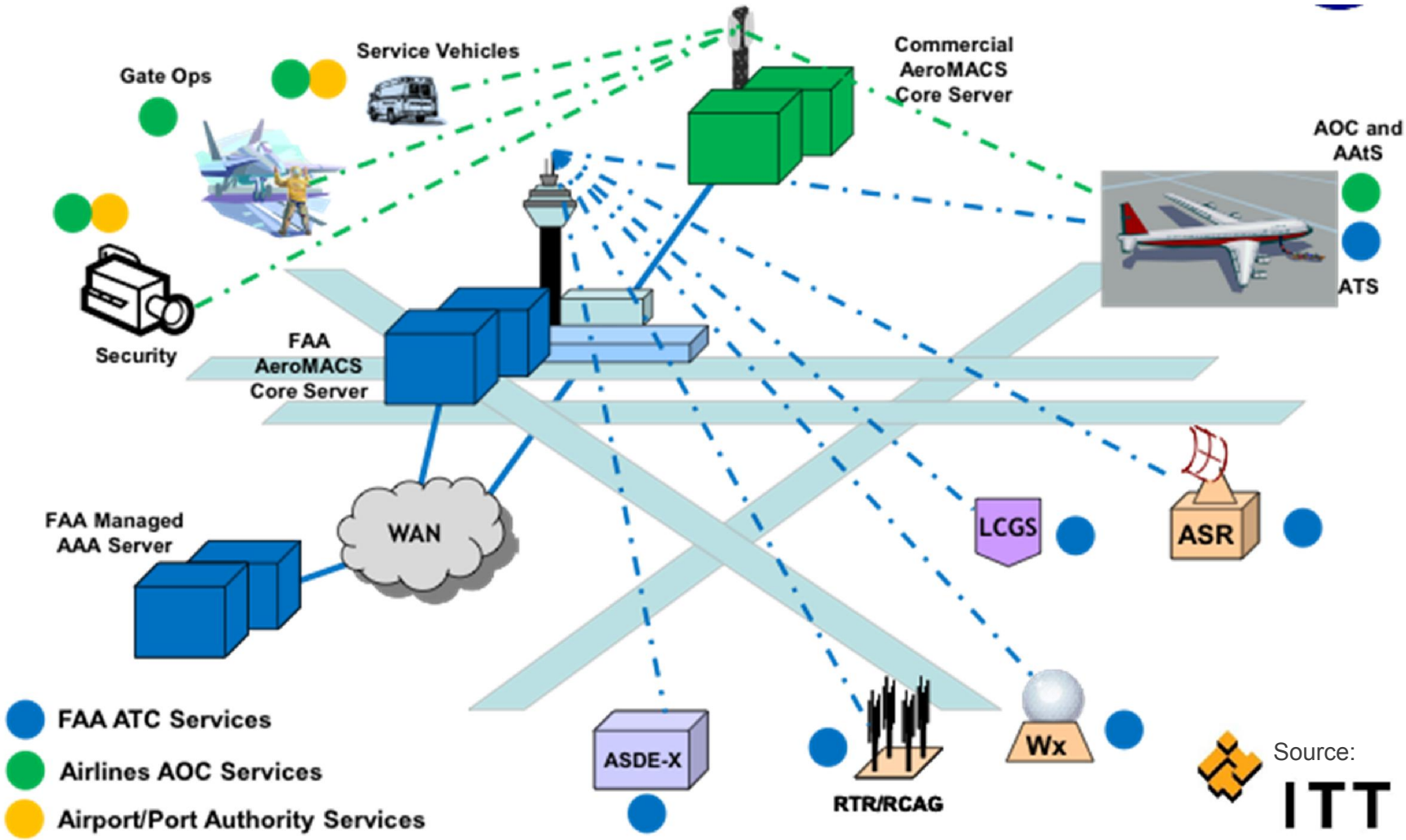
AeroMACS makes use of the strongest security feature choices available for the wireless media!

AeroMACS Applications

Applications - Mobile and Fixed, ATC, AOC and Airport Ops

- Mobile Services
  - Air Traffic Control (ATC) to/fr runways and taxiways
  - Airline Operations and Control (AOC)
  - Airport Operations
- Fixed Services
  - Airport Video Surveillance
  - Multilateration
  - Wireless backhaul
- Other Applications
  - DHS / TSA
  - … lot's of applications - hundreds…

Example AeroMACS Application



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Air Traffic Control / Air Traffic Management Applications

Name	Mobile/Fixed	Description
Current ACARS		
OOOI	M	Provides time of out, off, on, in
Pre Departure Clearance	M	Departure clearance information
SC-214 CPDLC Services		
D-TAXI – Update Service	M	Update continuation to any previous delivered taxi route clearance
4DTRAD	M	Trajectory negotiation
D-TAXI Graphical Msg Service	M	Transmit a representation of the taxi route to aircraft for display
COCR Services		
D-SIG Surface information Guidance	M	Status of airport elements required for movement
OTHER		
D-LIGHTING	M	Active runway lighting systems from the cockpit

*** 47 potential applications currently identified**

http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/swim/documentation/media/demo_t

Aviation Information Systems / Meteorology Applications

Name	Mobile/Fixed	Description
Flight Deck		
D-AUS	M	Data link Aeronautical Update Services
D-OTIS	M	Airport/Runway configuration information
Convection products		
Convective SIGMET	M	In-flight aviation weather advisory
Forecast	M	Forecast meteorological information
AIS Baseline Synchronization Service		
FMS and GPS navigational databases	M	Data base uploads to aircraft avionics
Aerodrome Charts	M	Data base updates for EFB
Turbulence		
GTG	M	Graphical Turbulence Guidance data/map

*** 96 potential applications currently identified**

http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/swim/documentation/media/demo_t

Airline Operations Applications

Name	Mobile/Fixed	Description
Ground Operations & Services		
Fueling	M	Coordination of fueling operations.
De-Icing	M	Coordination of De-Ice operations
Maintenance Information		
FOQA	M	Offload of flight operational quality assurance data
Aircraft Maintenance	M	Unscheduled maintenance coordination
Aircraft & Company Operations		
Flight Operations Manuals	M	Updates to documents (EFB)
Weight & Balance	M	Information for pilot takeoff settings

*** 123 potential applications currently identified**

http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/swim/documentation/media/demo_t

Airport Operations Applications

Name	Mobile/Fixed	Description
FAR 139 Safety Self Inspection		
Navigational Aids System Maintenance	M	Reporting status of airport runway/taxiway lights, monitor repair status.
Signage	M	Issue manage and verify time critical airfield inspection defects
RFID-Real time reporting		
Parking Decal Monitoring	M	Monitor compliance
Asset Inventory	M	Read utility meters, and fixed assets
Public Safety		
Police & SWAT	M	Live wireless video feed to EOC and chief office for recording purposes.
Fire	M	Stream video feeds during fire events.

*** 33 potential applications currently identified**

http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/swim/documentation/media/demo_t

FAA Airport Infrastructure Applications

Name	Mobile/Fixed	Description
Airport Surface Infrastructure		
Airport Surface Detection (ASDE-X)	F	Surface Movement Data
Airport Surveillance Radar	F	Short Range Radar Data
Far Field Monitor (FFM)	F	ILS monitoring system Data
Glide Slope	F	Instrument Landing System Data
Remote Maintenance & Monitoring (RMM)	F	Electronic Equipment Performance Data
Medium Intensity Approach Lighting System	F	System control Data
Runway Visual Range (RVR)	F	Visibility Data
Remote Transmitter Receiver	F	Pilot Controller voice communications

*** 33 potential applications currently identified**

http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/swim/documentation/media/demo_t

AeroMACS Standardization

Standardization Organizations

- **UN International Telecommunications Union (ITU)** Terrestrial Services Department (TSD) / Fixed and Mobile Services Division (FMD) & the World Radiocommunications Conference (WRC)
- **UN International Civil Aviation Organization (ICAO)** Aeronautical Communications Panel - Surface (ACP-S)
- **Radio Technical Commission for Aeronautics (RTCA)** Special Committee SC-223 Aeronautical Mobile Communication Systems
- **European Organization for Civil Aviation Equipment (EuroCAE)** Working Group WG-82 New Air-Ground Data Link Technologies
- **Airlines Electronic Engineering Committee (AEEC)** Systems Architecture and Interfaces (SAI) Subcommittee
- **WiMAX Forum Aviation** Working Group (AWG)

Standards Documents Approved

- RTCA DO-354 Aeronautical Mobile Airport Communications System (AeroMACS) Profile (12/2013)
  - EuroCAE 136 / ED-222
- RTCA DO-346 Minimum Operational Performance Standards (MOPS) for the Aeronautical Mobile Airport Communications System (AeroMACS) (12/2013, Rev 01/2014)
  - EuroCAE 137 / ED-223
  - Focus on the ground infrastructure
- WiMAX Forum AeroMACS Protocol Implementation Conformance Statement (PICS)
- WiMAX Forum AeroMACS (Certification Requirements Status List (CRSL)

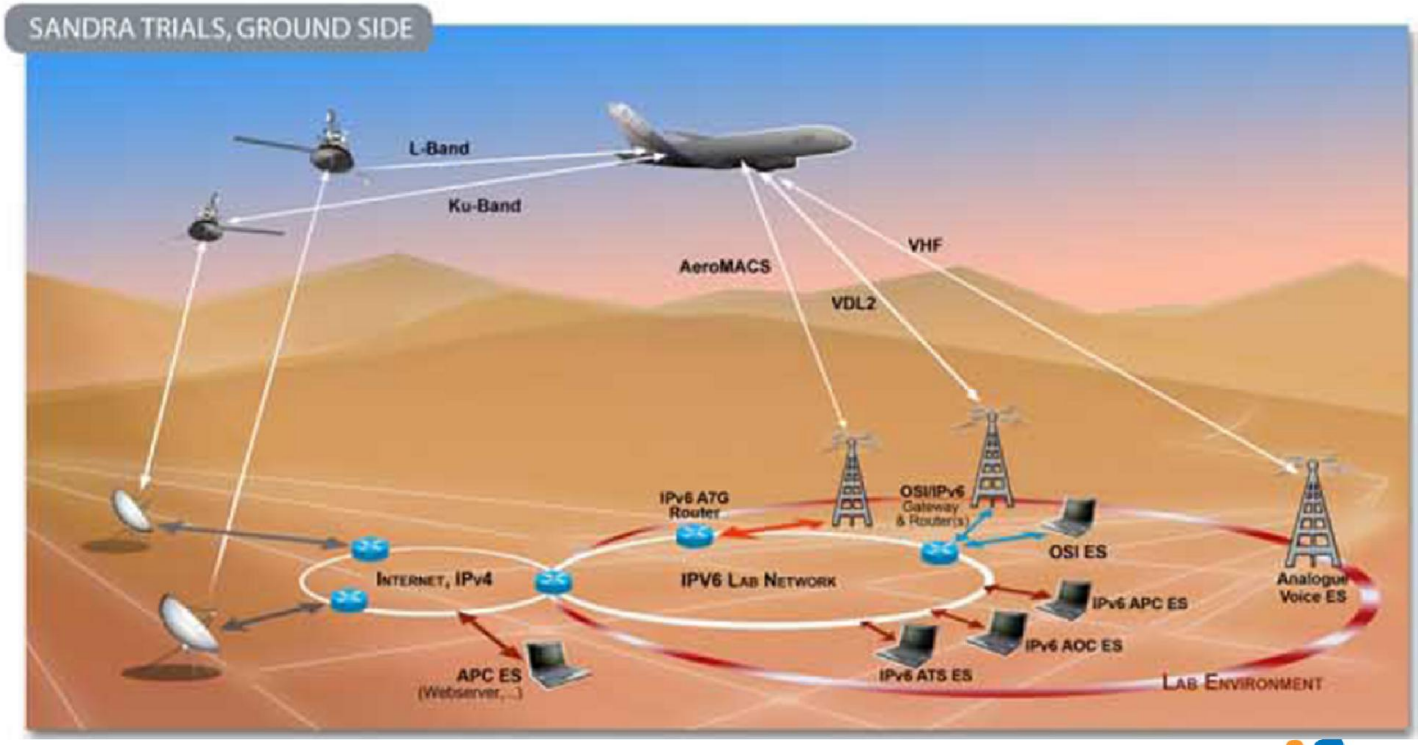
Standards Documents In Process

- ICAO ACP-S Aeronautical Mobile Airport Communications System (AeroMACS) Standards and Recommended Practices (SARPS) and Guidance Material
  - To be completed 3Q2014 / Approved 2015
- EuroCAE Minimum Aviation System Performance Standards (MASPS) for the Aeronautical Mobile Airport Communications System
  - Focus on the mobile station application
  - To be completed 4Q2014 / Approved 2015
- AEEC SAI - AeroMACS Avionics Specification
  - Starting this month…
  - To be completed 2Q2016 / Approved 2016

AeroMACS Past Activities and AP17

A Little Bit of History… SANDRA

- Europe - SANDRA Project (2000 - 2013)
  Seamless Aeronautical Networking through integration of Data links, Radios and Antennas, an Industry Consortium with 29 members lead by SELEX



More History... SESAR

- Europe - SESAR Joint Undertaking (SJU 2004-2014) Single European Sky Air Traffic Management (ATM) Research (SESAR) Public-Private Partnership (PPP) lead by EuroCONTROL

SESAR AeroMACS Projects:

P9.16 Airborne Integration (Toulouse Test Bed)
- Specify and assess BS and MS prototypes
- Verify and Validate requirements

P15.2.7 System Aspects and Ground Component
- Study the overall AeroMACS system
- Coordinate with standards bodies

http://www.sesarju.eu

More History... AP17

- FAA / EuroCONTROL / NASA - Action Plan 17, Future Communications Study (2007)

Future Communications Infrastructure (FCI) Scope:

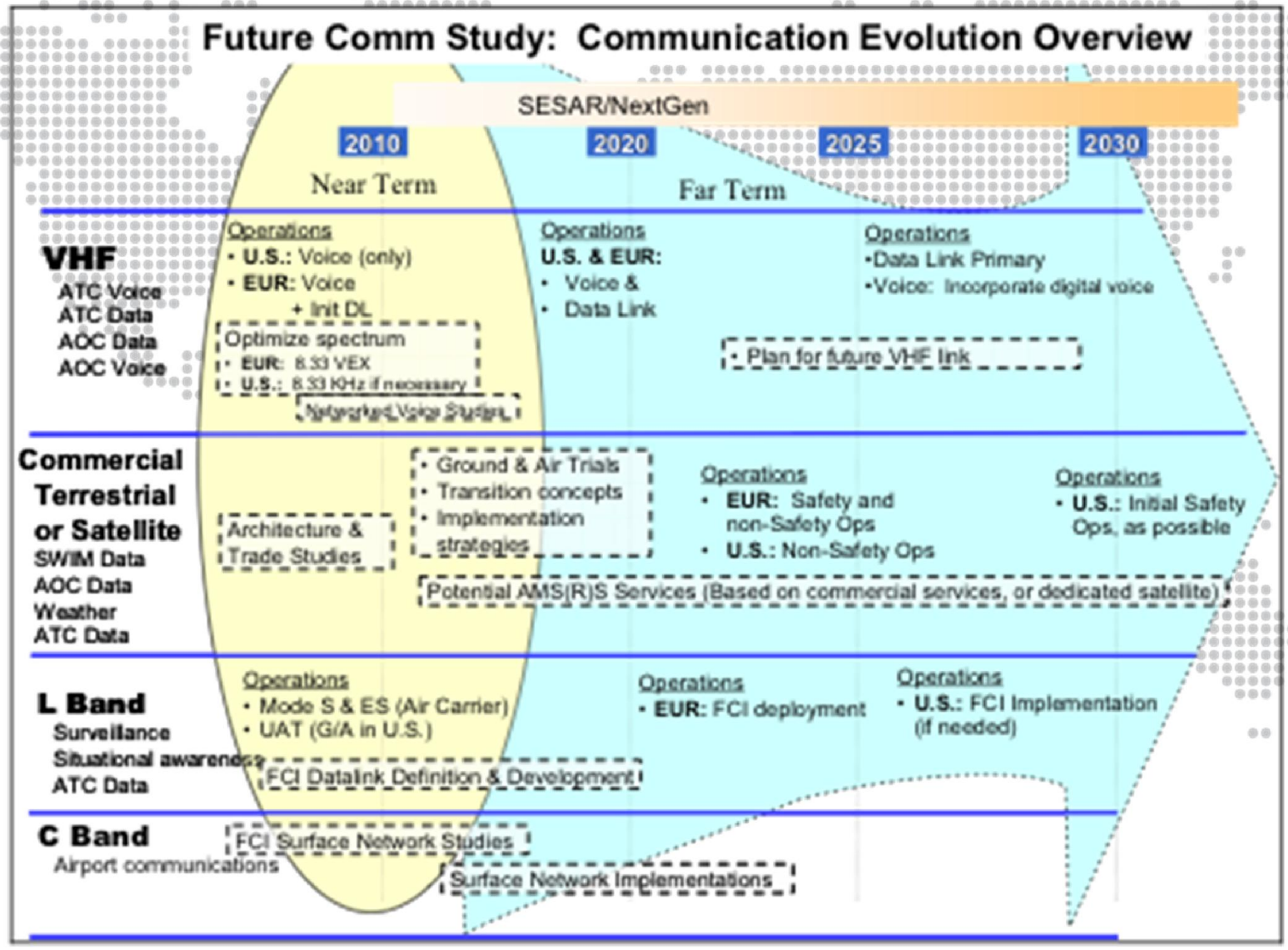
- Continental
- Ocean/Remote
- Airport

The C-band recommendations are to:

- Identify the portions of 802.16e best suited for airport surface wireless mobile communications
- Evaluate and validate the performance of the aviation-specific standard
- Propose a channelization methodology

https://acast.grc.nasa.gov/documents/fcs/
https://www.eurocontrol.int/articles/airport-surface-data-link-aeromacs
https://acast.grc.nasa.gov/files/Future_Communications_Study-Action_Plan_17_DASC_2007_Fistas_Phillips_Budinger.pdf
http://www.eurocontrol.int/sites/default/files/content/documents/communications/112007-ap17-final-report.pdf

AP17 - The Plan…



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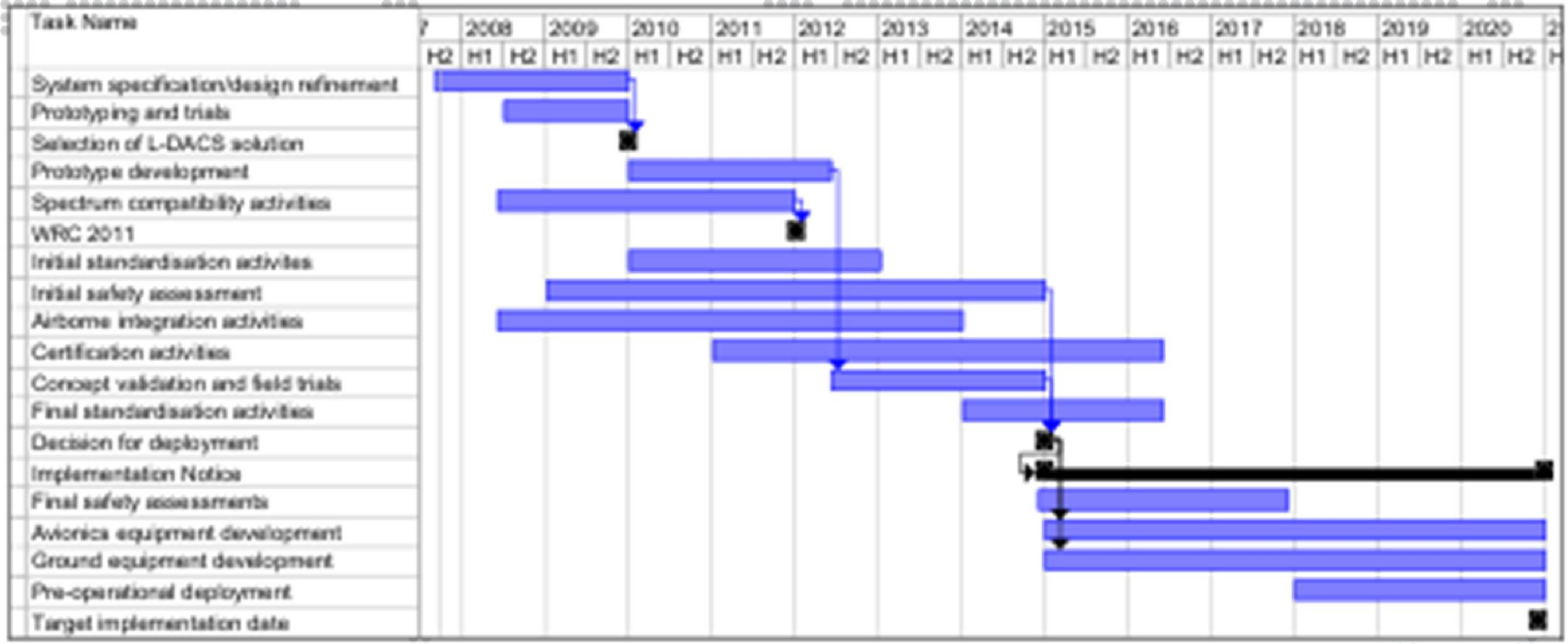
AP17 - The Plan…



US AeroMACS Proofs of Concept (2008 - 2013)

- Daytona Airport (Harris)
- Melbourne Airport (Harris)
- Atlantic City Airport - FAA Flexible Terminal Sensor Network (FTSN) Program prototype network
- Syracuse Airport - FAA Airport Surface Surveillance Capability (ASSC) Program prototype network
- Cleveland Airport - AeroMACS Test Bed (NASA GRC)

Note that these trials were proofs of concept, not AeroMACS compliant.

Current AeroMACS Test Beds and Trials,and Future AeroMACS Deployments

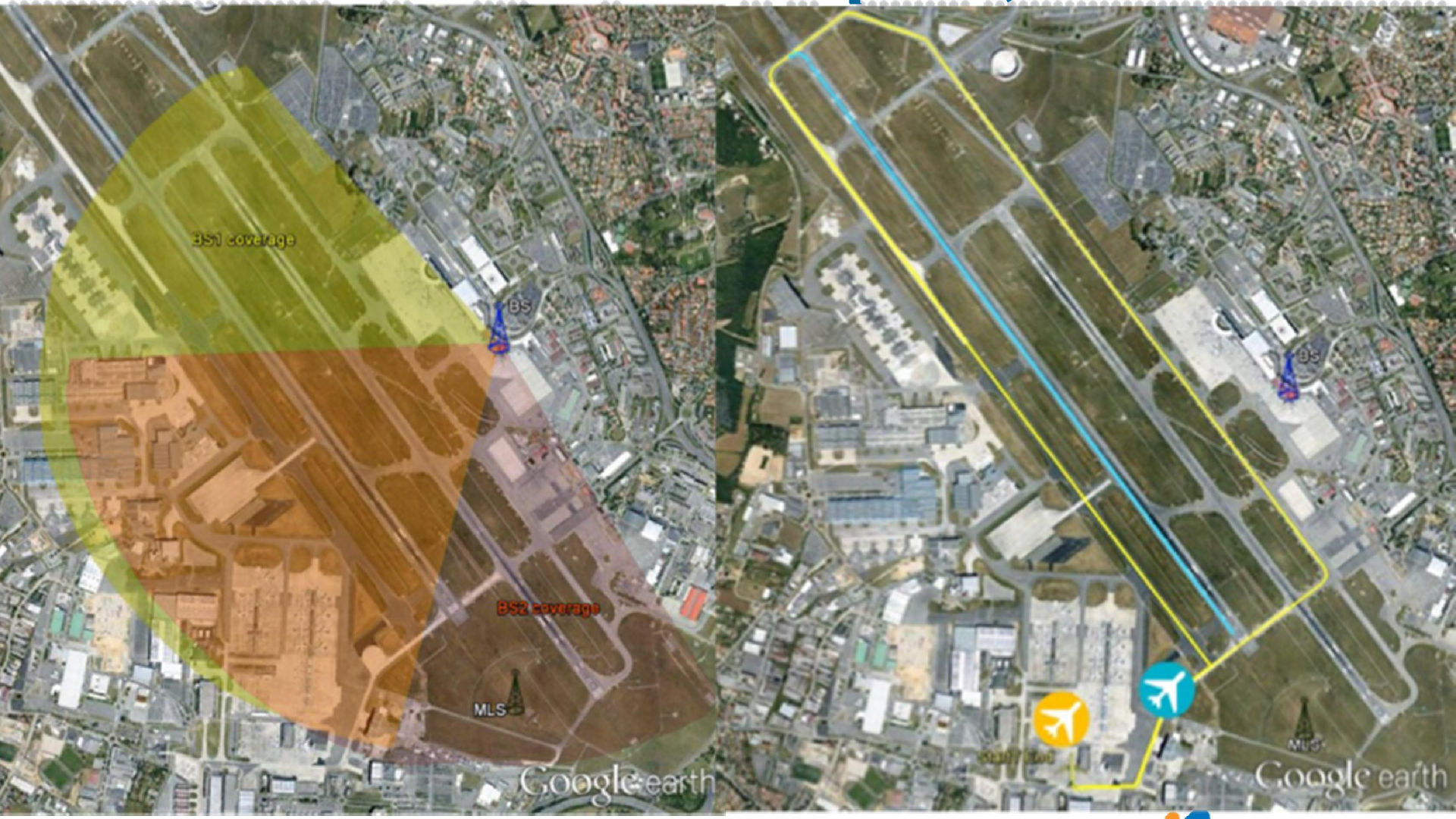
SESAR P9.16 AeroMACS Test Bed at Toulouse Airport, France

- EuroControl, Airbus, INDRA
- SELEX BS / Thales MS
- Aircraft Static Tests - Line of site
- Aircraft Mobile Tests - 30 kph / 65 kph

Example Test Coverage:

- Doppler effects
- Handover
- Data rate / Quality of Service (QoS)

SESAR P9.16 AeroMACS Test Bed at Toulouse Airport, France



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NASA Glenn Research Center AeroMACS Test Bed

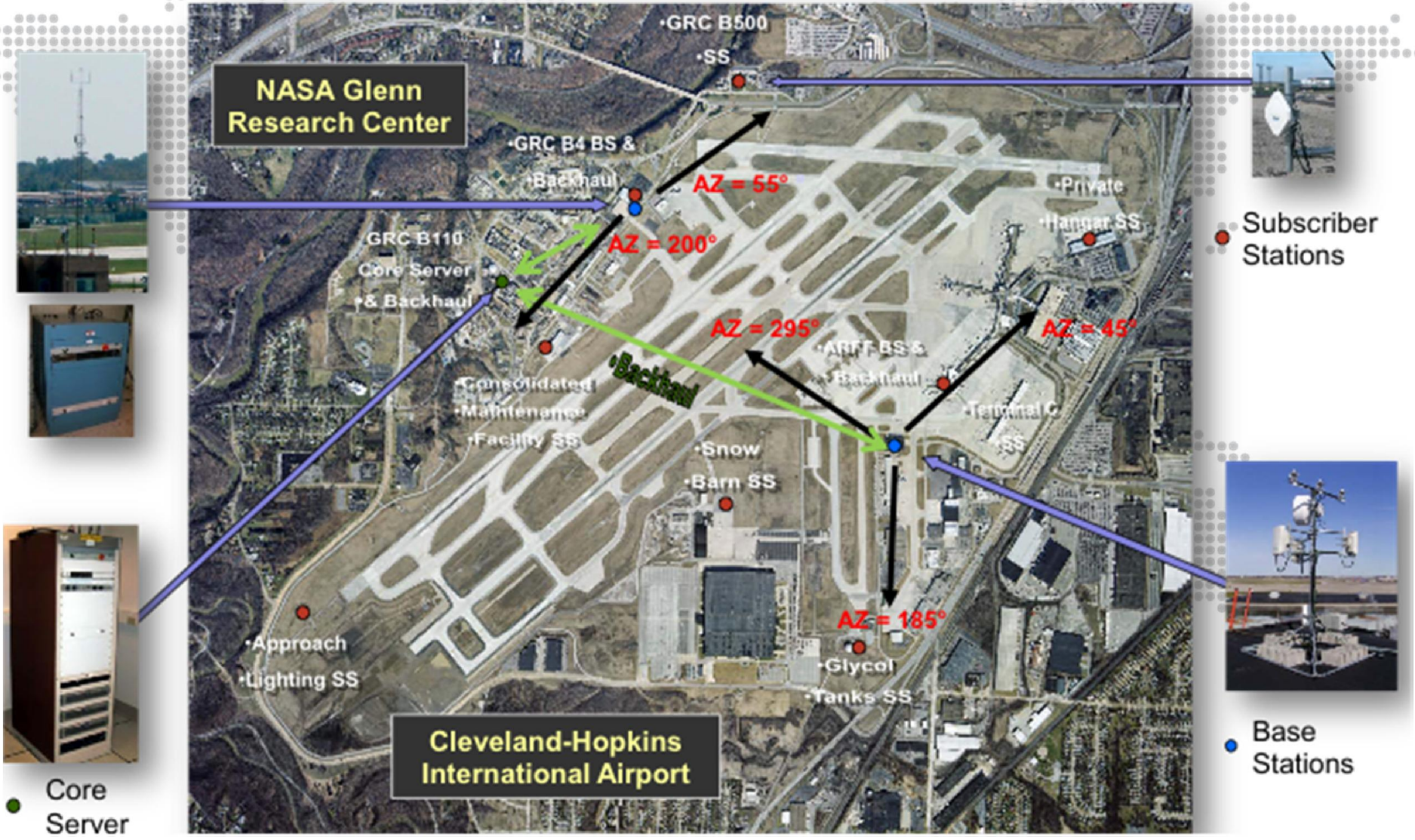
- Proof of Concept, Cleveland Airport (2010 to 2013)

  - Alvarion BS and MS (not AeroMACS Compliant)

  - Demonstrated an AeroMACS radio installed in a commercial aircraft that taxied at various speeds on the runway and on operational areas. Graphical aviation weather information was transmitted from NASA's communications, navigation and surveillance technologies testbed at the airport to an electronic flight bag on the aircraft

  - Demonstrated the transfer of data between the Cleveland Hopkins Airport Surveillance Radar-9 (ASR-9) station and air traffic control

NASA GRC AeroMACS Test Bed



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NASA GRC CLE AeroMACS Trial

- Verification and Validation of A number of MOPS and SARPS Requirements (2014 - Testing just started...)
  - Hitachi BS and MA (AeroMACS Compliant)
- Demonstrated capabilities so far:
  - Spectrum mask
  - Network entry
  - File transfer

Challenges in the requirements not a problem for Hitachi:

- Efficient Channel Scanning
- First Time Network Entry Time

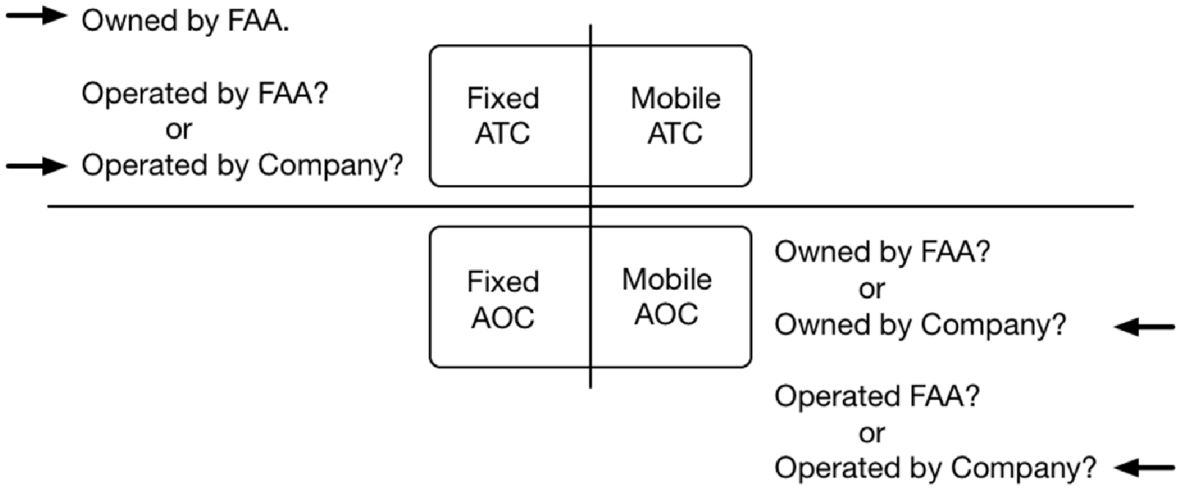
Potential Near Term AeroMACS Deployments (2014 - 2015)

- Embry-Riddle AeroNautical University AeroMACS Test Bed at Daytona Beach, FL (Dr. Remzi Seker)
  - Remzi needs infrastructure money and equipment
- Electronic Navigation Research Institute (ENRI) AeroMACS Test Bed at Sendai Airport, Sendai, Japan
- Airport Surface Surveillance Capability (ASSC) Program
  - First deployments are not AeroMACS compliant
  - Future deployments may be AeroMACS compliant

How will AeroMACS Roll Out (2016 - 2020)?

- It is not clear who will own and operate the ATC network
- It is not clear how the AOC network will deploy
- It is not clear how the airports will participate…

	Fixed	Mobile
ATC	1st to Deploy	Last to Deploy
AOC	Depends on FCC	Depends on FCC



The WiMAX Forum

Service Provider View

- Spectrum ownership
  - *477 WiMAX operators own spectrum all over the world (regional/national)*
  - *10+ years of accumulation*
  - *30-60MHz bandwidth and low spectrum acquisition cost*

Frequency	Total
2.3	48
2.5	113
3.3	10
3.5	309
5+	21

4G Service Profiles for Industrial Markets

Smart Grid

Oil & Gas

High Speed Rail

Aviation

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AeroMACS EcoSystem View

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The Aviation Working Group (AWG)

- Aviation Working Group facilitates regional Aviation events:

  - Aviation 2013, September 2013, Washington DC

  - Aviation Europe (hosted by EuroCONTROL), May 2014, Brussels, Belgium

  - Aviation Japan (hosted by Hitachi, JCAB and ENRI), November 11-12, 2014, Sendai, Japan

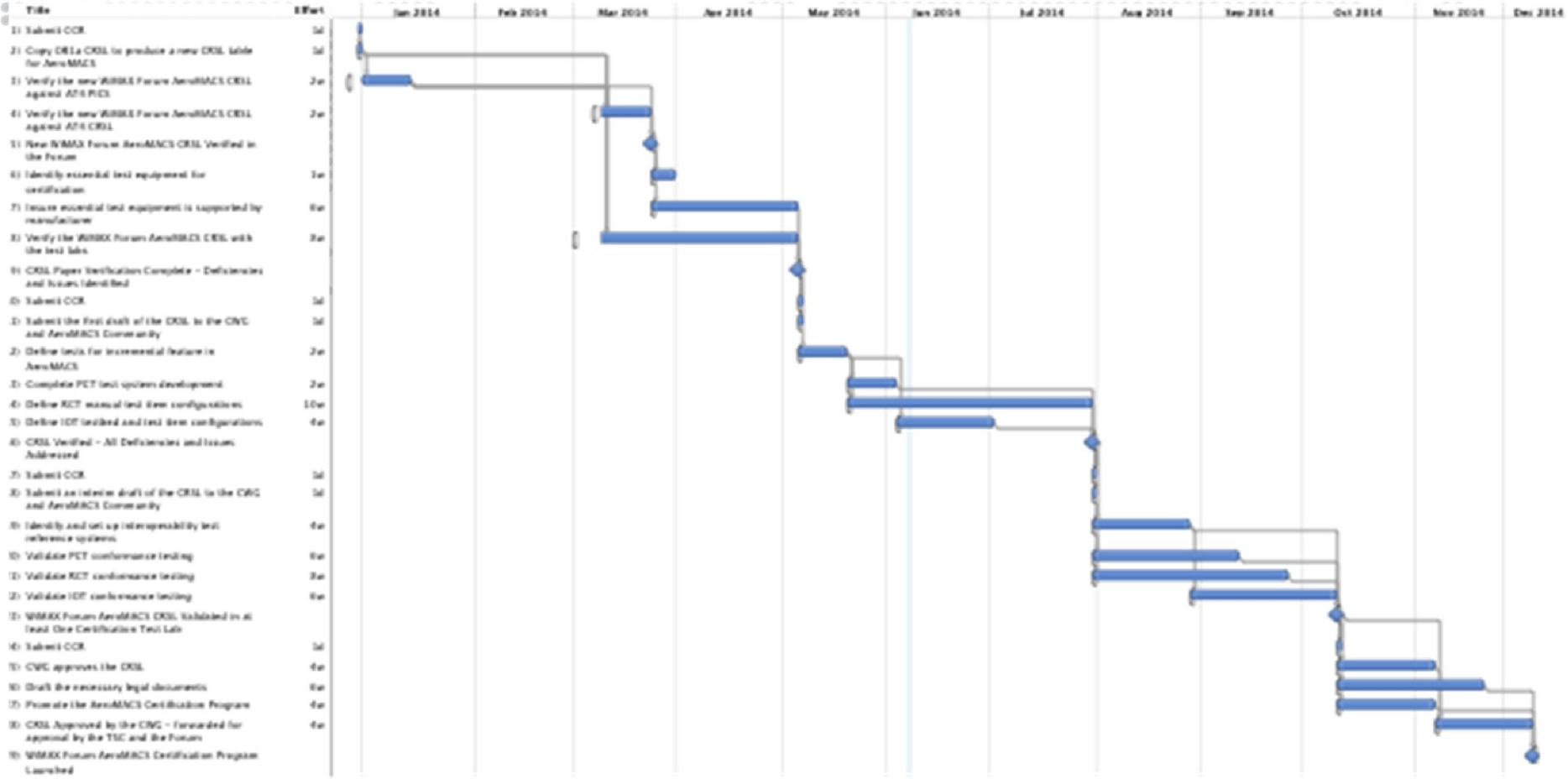
- Aviation Working Group AeroMACS projects in process:

  - AeroMACS Certification

  - AeroMACS X.509 Public Key Infrastructure (PKI)

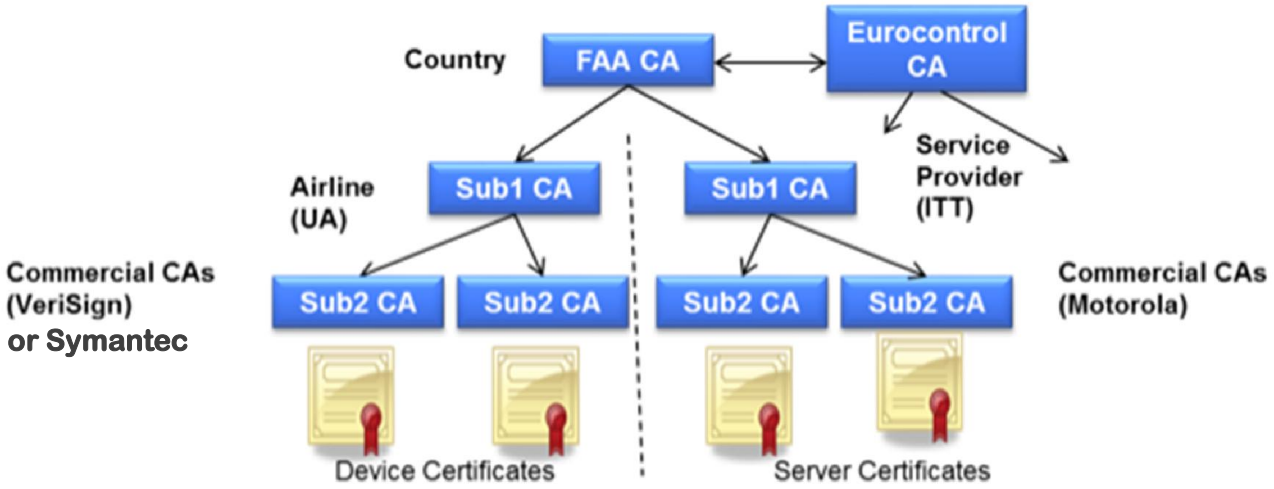
  - AeroMACS FCC Service Policy Petition

WiMAX Forum AeroMACS Certification

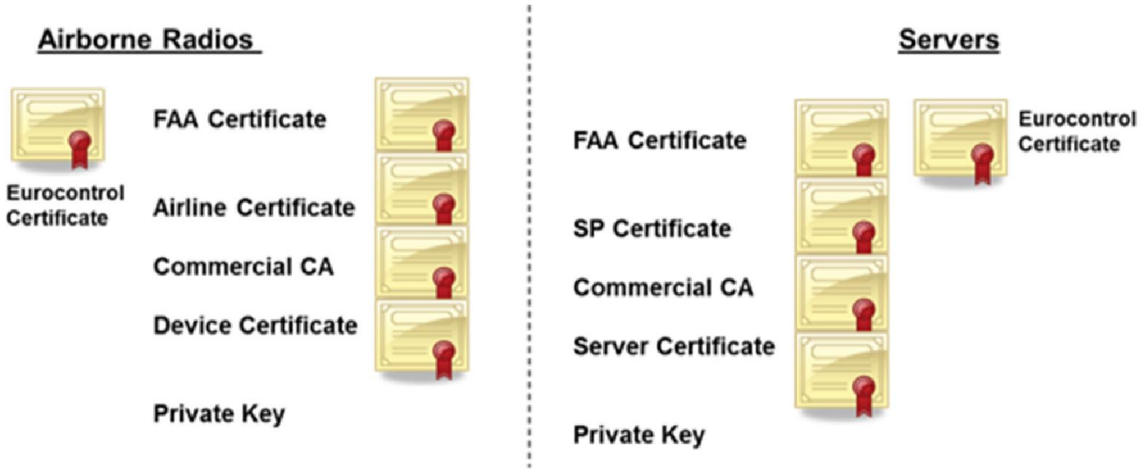


WiMAX Forum AeroMACS X.509 PKI Structure

ICAO ACP-S WP from Honeywell / DFS



Must support a Certificate Hierarchy



Must support a Certificate Chain

AeroMACS X.509 PKI Use Cases

UC-1	M	Base Station Joins Network
UC-2	M	Airplane Subscriber Station Joins ATC Network
UC-3	M	Airplane Subscriber Station Joins AOC Network (Principle Case)
UC-4	M	Airplane Subscriber Station Joins AOC Network (Partner Case)
UC-5	O-1	Airplane Subscriber Station Joins AOC Network (Roaming Case)
UC-6	M	Multilateration Subscriber Station Joins ATC Network
UC-7	M	Airline Subscriber Station Joins AOC Network (Principle Case)
UC-8	M	Airline Subscriber Station Joins AOC Network (Partner Case)
UC-9	O-1	Airline Subscriber Station Joins AOC Network (Roaming Case)
UC-10	O-2	Airline Subscriber Station Joins ATC Network (Roaming Case)
UC-11	M	Service Provider Subscriber Station Joins AOC Network (Partner Case)
UC-12	O-1	Service Provider Subscriber Station Joins AOC Network (Roaming Case)
UC-13	O-2	Service Provider Subscriber Station Joins ATC Network (Roaming Case)
UC-14	M	TSA / Police Subscriber Station Joins Airport Operations Network (Principle Case)
UC-15	M	Other Airport Operations Subscriber Stations Join Airport Operations Network (Principle Case)
UC-16	M	TSA / Police Subscriber Station Joins AOC Network (Roaming Case)
UC-17	O-1	TSA / Police Subscriber Station Joins ATC Network (Roaming Case)
UC-18	O-1	Other Airport Operation Subscriber Stations Join AOC Network (Roaming Case)
UC-19	O-2	Other Airport Operation Subscriber Stations Join ATC Network (Roaming Case)

AeroMACS Example Use Case

Use Case Name:	Base Station Joins Network
Use Case Number:	UC-1
Priority:	Mandatory
Actor(s):	Base Station
Purpose:	Join the network
Data Source:	
Pre-condition(s):	Credential is stored by the AAA server
Post-condition(s):	In case of success: Authorized to join the network.
	In case of failure: Not authorized to join the network.
Target Service:	Authorized by the AAA Server via Radius / Perimeter service
Output:	
Notes:	
References:	

Typical Course of Events:

Actor	System
1. Base station auto-logs into the AAA on power up.	AAA server admits the base station into the network.

WiMAX Forum FCC Service Policy Petition

- FCC Docket 12-338
- FCC focus is commercial policy considerations
- FCC concern is to protect Federal applications and insure sufficient bandwidth for ATC
- FCC priority is to enable competition for application service providers at an airport
- WiMAX Forum objective is to enable as many applications as possible for the greatest population of subscriber stations possible

FCC AeroMACS Service Policy is a critical long lead-time work item that is currently not expected before 4Q2016.

The Choice for the Future of Airport Wireless Communications is AeroMACS

AeroMACS *is the EuroControl / FAA selected wireless solution for the provision of dedicated aeronautical communication services for safety and regularity of flight on the airport surface globally*