

# **Interference Analysis for an Aeronautical Mobile Airport Communications System**

The next generation of aeronautical communications for airport surface applications has been identified through a NASA research program and an international collaborative future communications study. The result, endorsed by both the United States and European regulatory agencies is called AeroMACS (Aeronautical Mobile Airport Communications System) and is based upon the IEEE 802.16e mobile wireless standard. Coordinated efforts to develop appropriate aviation standards for the AeroMACS system are now underway within RTCA (United States) and Eurocae (Europe). AeroMACS will be implemented in a recently allocated frequency band, 5091-5150 MHz. As this band is also occupied by fixed satellite service uplinks, AeroMACS must be designed to avoid interference with this incumbent service. The aspects of AeroMACS operation that present potential interference to the fixed satellite service are under analysis in order to enable the definition of standards that assure that such interference will be avoided. The NASA Glenn Research Center has been involved in this analysis, and the first results of modeling and simulation efforts directed at this analysis are the subject of this presentation.

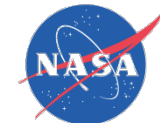


# Interference Analysis for an Aeronautical Mobile Airport Communications System

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# OUTLINE

- Introduction and Background
- Analysis Description
- Results and Discussion
- Summary and Conclusion



# Introduction

- Networked wireless communications capability for the airport surface is under development
  - Enable improvement in efficiency of operations on the airport surface for increased traffic capacity and improved safety
  - Supporting the goals of next generation air transportation system development (NextGen and SESAR).
  - Based on the IEEE 802.16e wireless standard (WiMAX)
  - Called AeroMACS - Aeronautical Mobile Airport Communications System
- Testing and demonstration of an AeroMACS prototype system is ongoing at Cleveland Hopkins International Airport and the adjacent NASA Glenn Research Center
- Development of technical standards for AeroMACS is underway through RTCA Special Committee 223 and Eurocae Working Group 82.
- Among a number of key issues in standards development is assuring avoidance of interference between AeroMACS and other systems.
- The results of a NASA AeroMACS interference analysis is the subject of this presentation.



# Background – AeroMACS Features

- AeroMACS is a multi-node wireless network, connecting one or more base stations and multiple subscriber stations covering all areas of airport surface and beyond (where required).
- AeroMACS provides for communications with aircraft in contact with the airport surface. It can also communicate with other vehicles and connect certain fixed assets.
- AeroMACS is based on IEEE 802.16e, making use of its key features:
  - Connection with moving vehicles at speeds up to 120 km/hr
  - Enables connectivity in non-line-of-sight conditions
  - Uses Orthogonal Frequency Division Multiple Access (OFDMA) with variable power, spreading and reuse
  - Supports of smart antenna technologies such as beam forming, space-time code, and spatial multiplexing
  - Support of hard-handoff, fast base station switching and macro diversity handover, multicast and broadcast service.
  - Uses adaptive modulation and coding, using QPSK, 16QAM and 64QAM, and convolutional turbo code with variable code rate are among



# Background – Spectrum and Interference

- World Radiocommunications Conference 2007 approved a re-allocation of the 5091-5150 MHz to include Aeronautical Mobile (Route) Service – for safety critical aeronautical communications.
- Originally a navigation band (Microwave Landing System Extension Band) this band also include several other allocations:
  - Fixed Satellite Service (FSS)– Mobile satellite feeder links
  - Aeronautical mobile telemetry
  - Aeronautical security
- The Mobile satellite service feeder link is the key problem. Currently Globalstar operates feeder links in the 5091-5150 MHz band.
- Only a relatively low power terrestrial system could be operated in this band without interference to the mobile satellite feeder links.
- A short-range terrestrial system such as that envisioned for the airport surface meets this criterion.
- However, given the potential number of airport installations, the AeroMACS standard must ensure that the aggregate interference stays below the interference threshold for the feeder links.



# Analysis - Approach

- To stay below the interference threshold, AeroMACS transmit power limitations need to be determined.
- The effort described herein will focus on establishing practical limits on AeroMACS transmissions from airports so that the threshold of interference into mobile satellite feeder uplink at low earth orbit (LEO) is not exceeded.
- The analysis approach used Visualyse Professional Version 7 software from Transfinite Systems Limited (UK).
- Standard parameters as defined by ITU were employed where appropriate (e.g. antenna patterns, orbital and link parameters).
- The performance of the software was benchmarked by comparing to an analysis developed by MITRE-CAASD
- After successful benchmarking, additional analyses were performed.



# Analysis - Visualyse Modeling Procedure

1. Define antennas.
2. Locate stations.
3. Specify carriers.
4. Set up propagation environment.
5. Set up links.
6. Set up interference paths.
7. Specify output desired.
8. Run.
9. Analyze results.



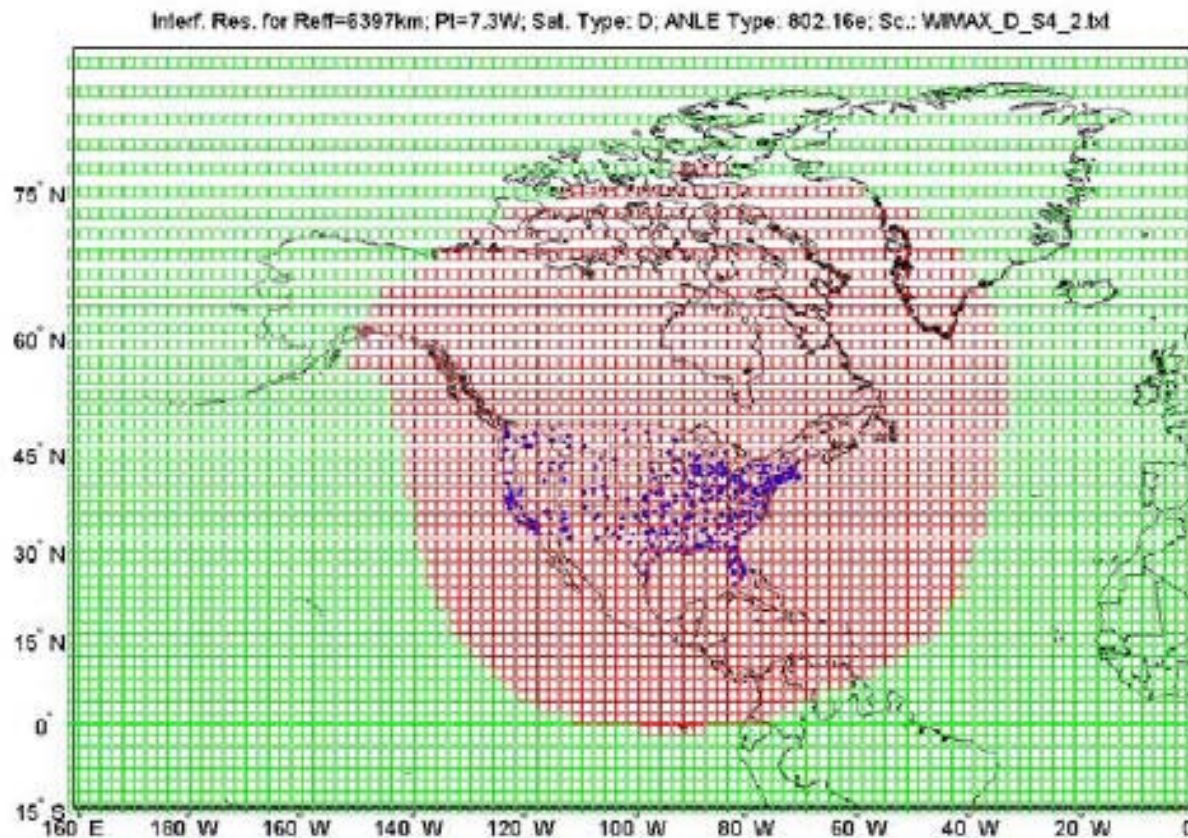


# Analysis - Benchmark Case

*Reference: Hoh, Gheorghisor, and Box, Feasibility Analysis of 5091-5150 MHz Band Sharing by ANLE and MSS Feeder Links, MITRE-CAASD Report MP 05W0000083, 2005.*

- The referenced work by MITRE-CAASD provided a benchmark test case for the Visualyse analysis approach. This analysis:
  - Investigated co-channel interference from ANLE (Airport Network and Location Equipment / now referred to as AeroMACS) system to mobile-satellite-service (MSS) feeder uplinks.
  - Assumed one transmitter with omni-directional antenna at each of 497 major airports in contiguous United States.
  - Worst case scenario: all transmitters on 100% of time.
  - Transmitted power from each airport = 5.8 watts.
  - Calculated aggregate interference power at Low Earth Orbit.

# Results: Benchmark Case (*from Hoh, et al.*)

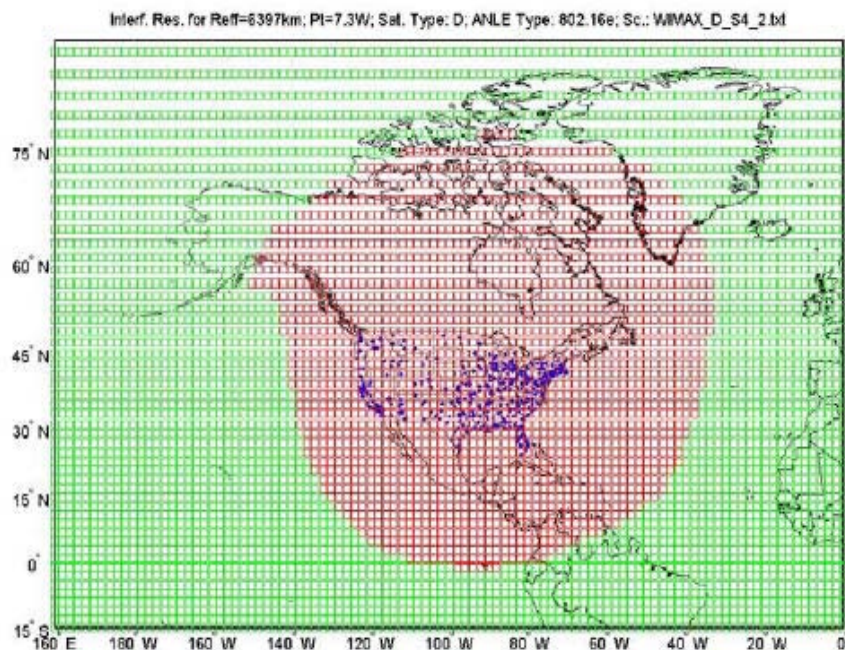


- Aggregate interference power at LEO (1414 km) from 497 airports.
- Threshold ( - 155.5 dBW) exceeded in red area\*.

\*Note threshold definition has since been tightened to -157.3 dBW corresponding to 2% increase of satellite receiver's noise temperature.

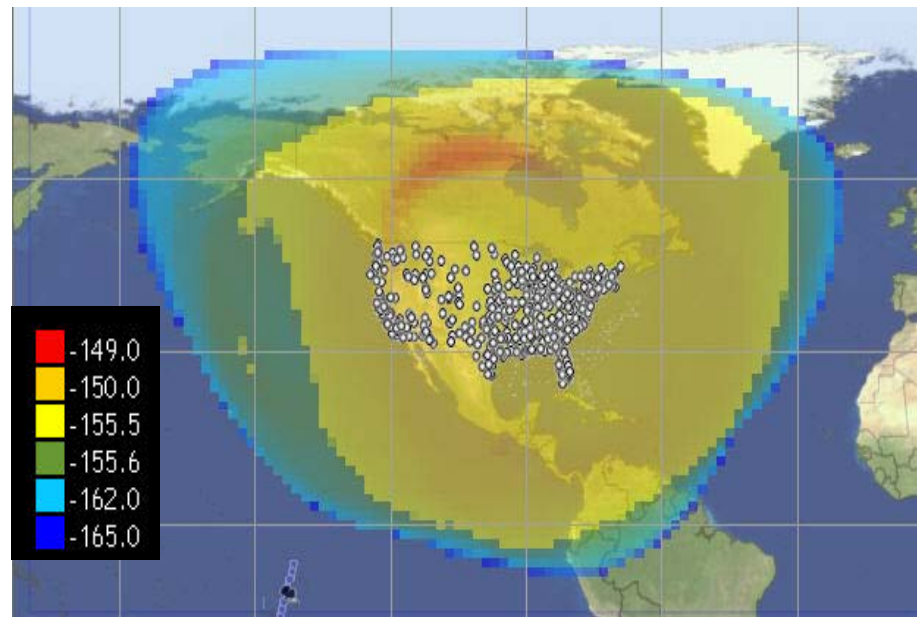
# Results: Visualyse Comparison with Benchmark

Hoh, et al.:



- Red/green border = -155.5 dBW
- Max interference = -150.0 dBW
- Max location = 67°N 104°W

Visualyse:



- Yellow/green border = -155.5 dBW
- Max interference = -149.3 dBW
- Max location = 64°N 105°W

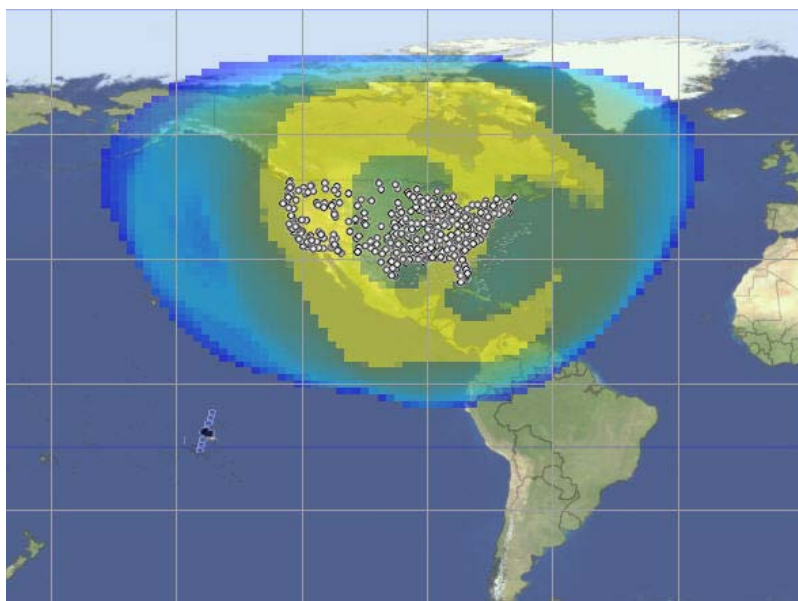
Excellent agreement between Visualyse and MITRE results.



# Results: Interference Power, 20 MHz Channel

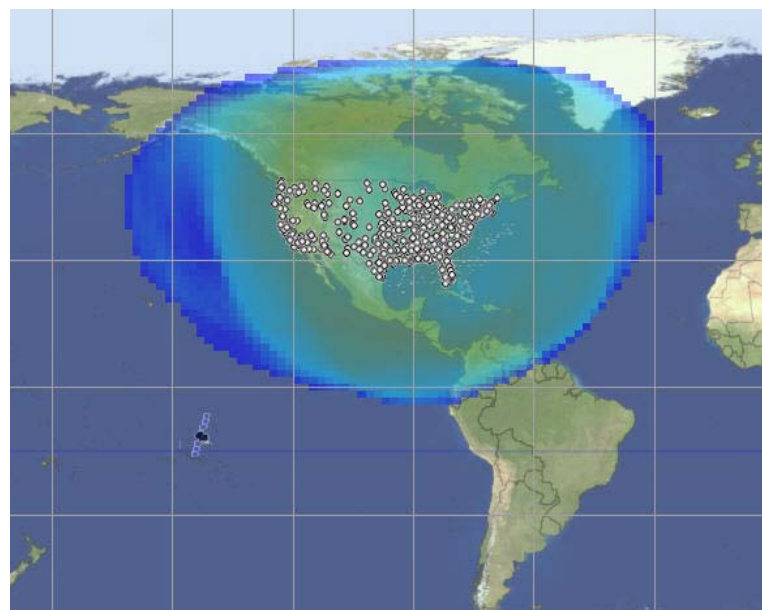
- Decrease transmitted power until interference power under threshold.
- Yellow/green border = -157.3 dBW .

1440 mW:



Below threshold in U. S. Midwest

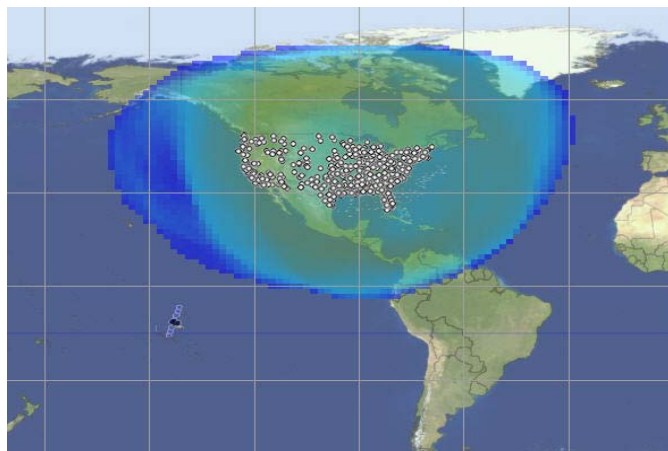
891 mW:



Below threshold everywhere

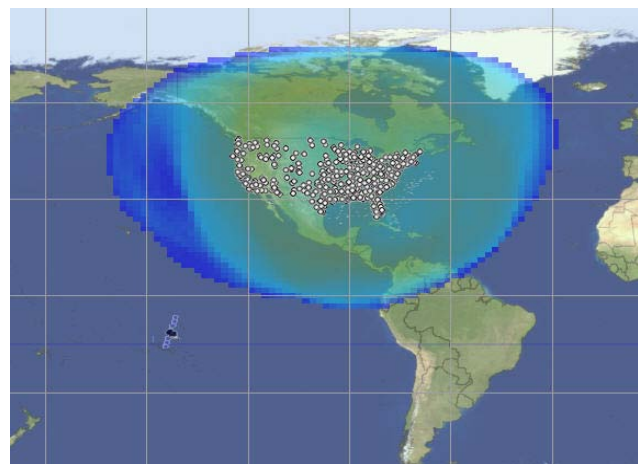
# Results: Interference Power, 10- and 5-MHz Channels

10 MHz Channels:



447 mW

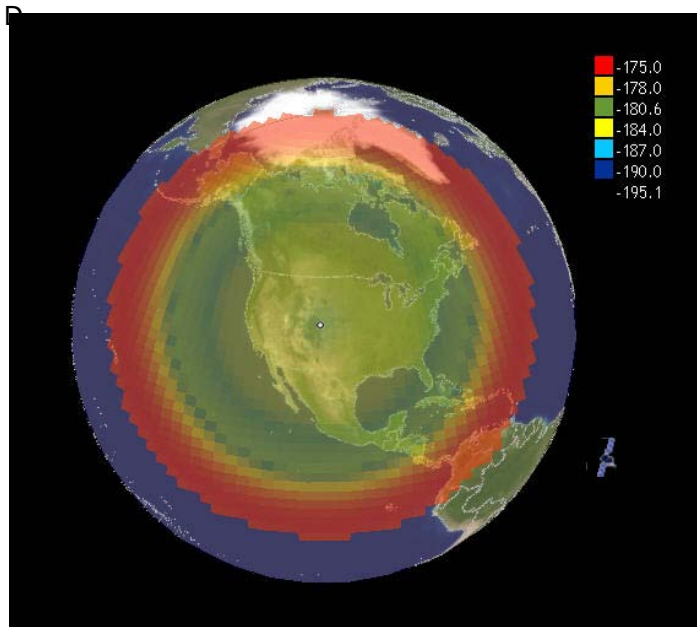
5 MHz Channels:



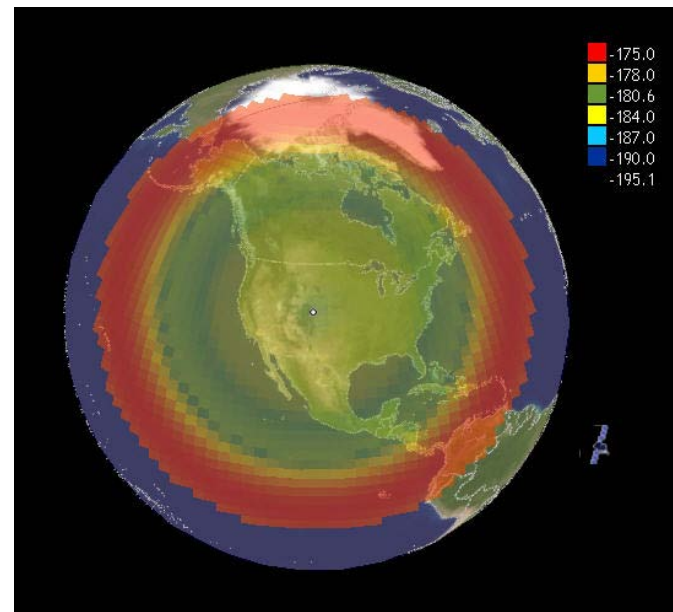
224 mW

- Maximum transmitted power proportional to channel bandwidth.
- Thus for 5-MHz channels, the transmitted power at each airport needs to be decreased to 224 mW to keep interference power below -157.3 dBW everywhere.
- Interference hot spot in NW Territories of northern Canada.

# Results: Interference Power for Single Airport Model



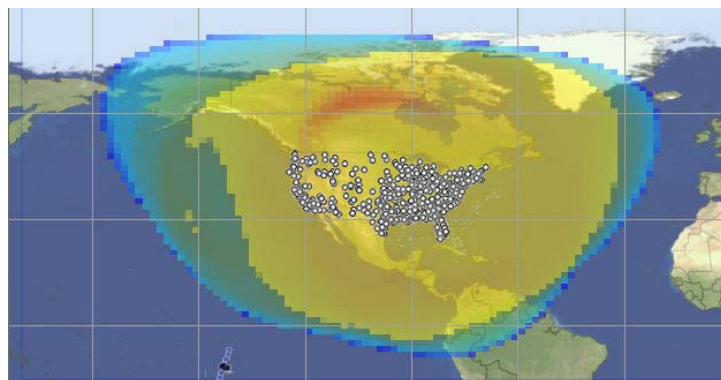
Denver (sea level)



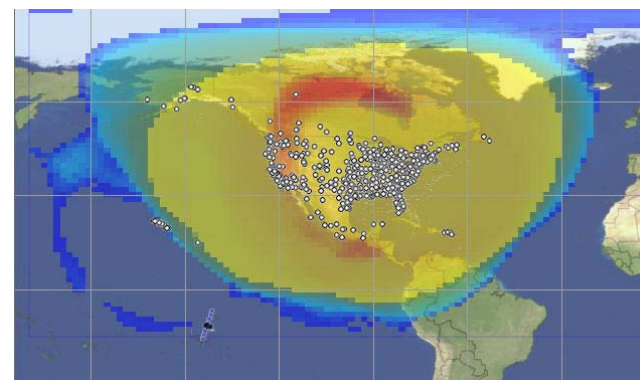
Denver ( 5431 feet)

- Max interference power -175.5 dBW in both cases.
- Antenna elevation (1.6 km) has minimal impact on interference power at Low Earth Orbit (1414 km).

# Results: Effect of Additional Airports



497 Airports



757 Airports

- 497 Airport Model includes just major contiguous US airports.
- 757 Airport Model includes all 703 FAA towered airports and heliports, adding Alaska, Hawaii, and Caribbean, plus 34 Canadian and 20 Mexican airports.
- To remain under threshold (-157.3 dBW) for 5-MHz channels:
  - 497 airports - 224 mW transmission per airport max.
  - 757 airports - 201 mW transmission per airport max.
- Maximum allowable transmission per airport decreases only 10% from increasing number of airports by 50%.

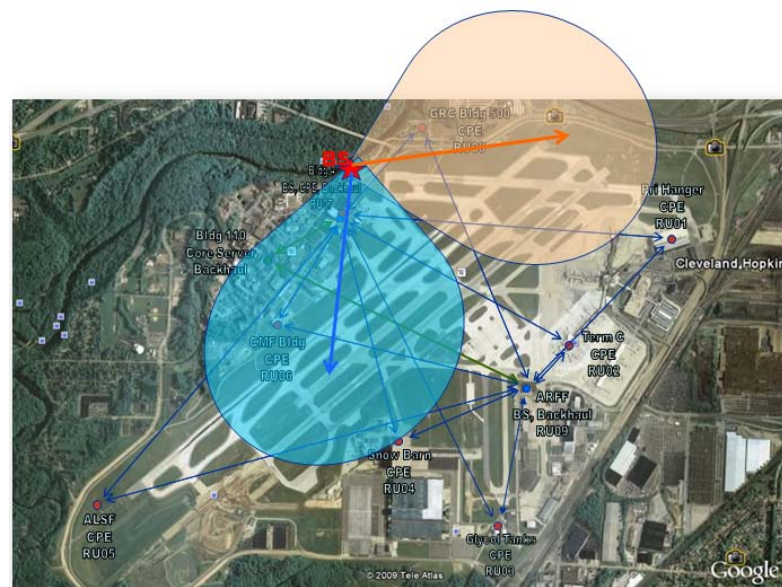


# Sectoral Antenna Configurations

- Previous simulations with omni-directional antennas.
- Sectoral antennas can provide more targeted coverage.
- Consider configurations with one, two, and three transmitters/beams randomly directed at each of 757 airports.
- In two- and three-beam configurations, beams separated by  $120^\circ$  at each of 757 airports.



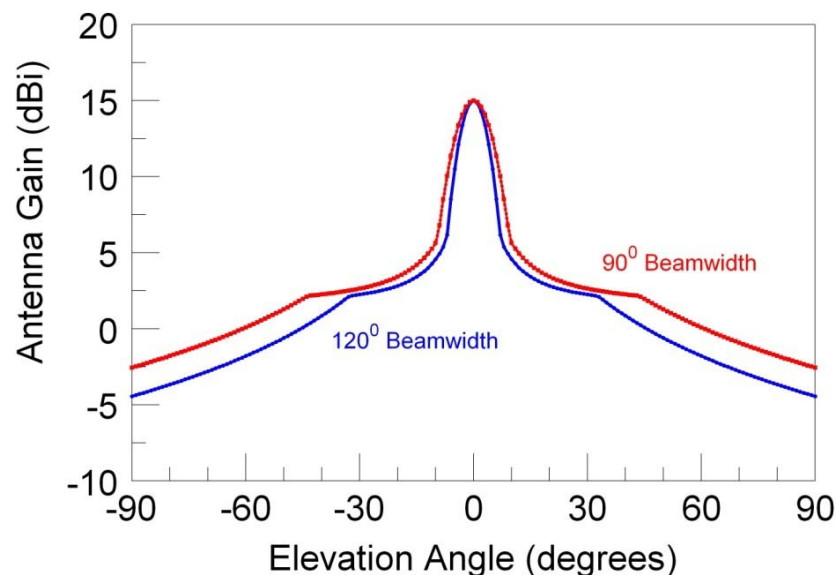
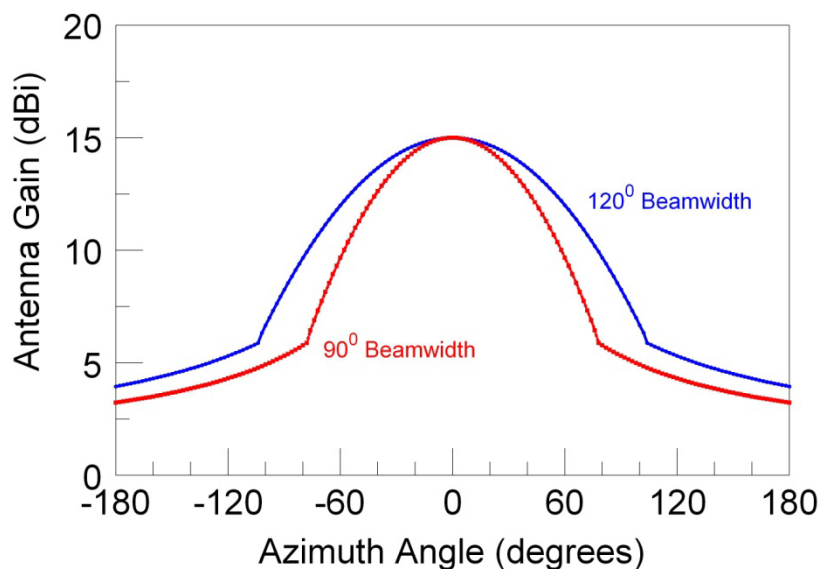
One-beam example



Two-beam example



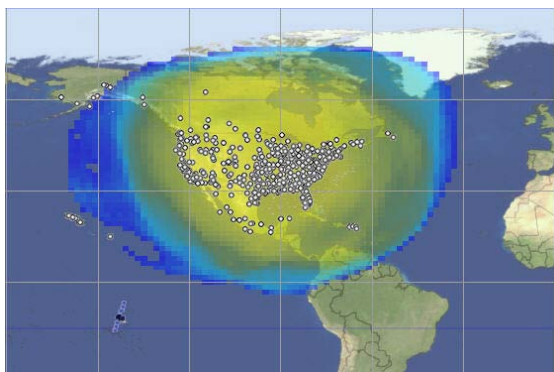
# Sectoral Antenna Beamwidths



- For each configuration considered both 90° and 120° beamwidth sectoral antennas.
- Maximum gain = 15 dBi.
- 90° beamwidth gain is narrower in azimuth, but broader in elevation – thus more radiation in upward direction.

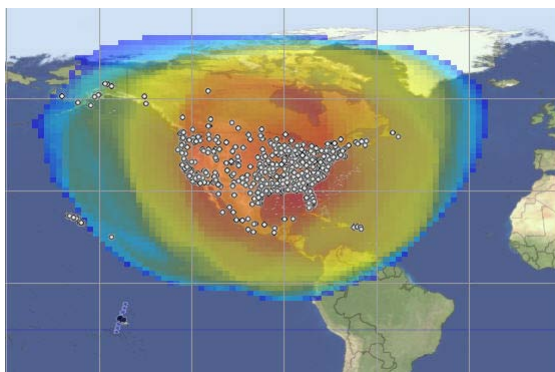
# Results: Sectoral Antenna Interference Power

- Each beam transmits -8.7 dBW (135 mW).
- Resulting interference power for 90° beamwidth:



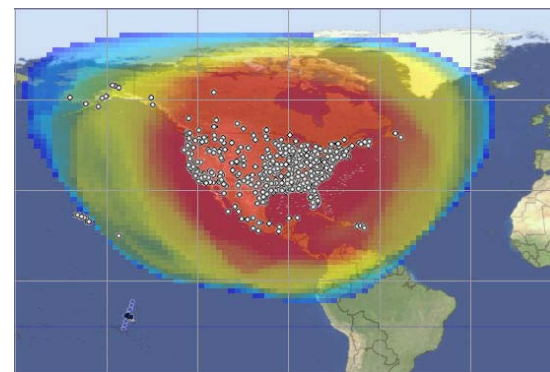
1 Beam per Airport

$P_{\max} = -160.5$  dBW  
latitude = 35°  
longitude = -79°  
(Fayetteville, NC)



2 Beams per Airport

$P_{\max} = -157.5$  dBW  
latitude = 30°  
longitude = -77°  
(150 km E of Jacksonville, FL)



3 Beams per Airport

$P_{\max} = -155.8$  dBW  
latitude = 35°  
longitude = -79°



## Results: Threshold Transmitted Power

- Maximum transmitted power per beam to remain under -157.3 dBW threshold everywhere with 5 MHz channels (double these values for 10 MHz channels):

	1 Beam	2 Beams	3 Beams
90° Beamwidth	141.8 mW	70.4 mW	47.4 mW
120° Beamwidth	166.0 mW	83.2 mW	55.3 mW

Total allowable transmitted power per airport approximately independent of number of beams.

Transmitted power can increase by 17% if beamwidth increased from 90° to 120° (less upward propagation).



# Results: Antenna Tilt Effects

- Modeled antennas with downward tilt to reduce upward propagation.
- 3 Beam configuration.
- Maximum transmitted power per beam (mW) to remain under -157.3 dBW threshold everywhere with 5 MHz channels:

tilt	0 <sup>0</sup>	-1 <sup>0</sup>	-2 <sup>0</sup>	-3 <sup>0</sup>	-4 <sup>0</sup>
90 <sup>0</sup> BW	47.4	48.9	50.0	50.5	51.0
120 <sup>0</sup> BW	55.3	60.4	63.9	67.0	68.1

Benefit from downward tilt significantly stronger for 120<sup>0</sup> beamwidth.

For example with -2<sup>0</sup> tilt, allowable transmitted power increases by only 5.5% for 90<sup>0</sup> beamwidth, but by 15.5% for 120<sup>0</sup> beamwidth.



# Summary and Conclusions

- C-band aggregate interference power at LEO was analyzed using Visualyse software for 497 and 757 airport scenarios.
- The benchmark results agree very well with MITRE-CAASD, providing confidence for further analyses to proceed.
- Key Results:
  - Antenna elevation has minimal impact on power at LEO.
  - Increasing airports from 497 to 757 has only 10% impact on threshold transmitted power.
  - Total allowable transmitted power per airport approximately independent of number of beams.
  - Transmitted power can increase by 17% if beamwidth increased from  $90^{\circ}$  to  $120^{\circ}$ .
  - Downward tilt of antennas is almost three times as beneficial for  $120^{\circ}$  compared to  $90^{\circ}$  beamwidth.



# Summary and Conclusions

- The analyses have yielded results indicating that current draft AeroMACS standards can provide effective operation of the system without interfering with the co-channel MSS uplinks.
- The maximum power transmission levels indicated by these results provide a significant constraint on the design of the system and the underlying standards
  - The number of sites, cells per site, antenna design and pointing angle need to be carefully specified within the standards.



# Future Plans

- Analysis of AeroMACS interference issues continues, in support of standardization activities.
- Planned additional analyses:
  - Improve model realism for single airport
    - Multiple base and subscriber stations
    - Transient effects
    - Terrain and building effects
    - Multipath signal propagation effects
  - Adjacent band interference from AeroMACS
  - Co-channel and adjacent band interference into AeroMACS
  - Geographically close AeroMACS implementations