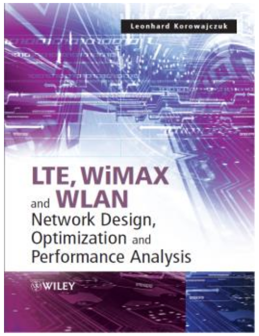
AeroMACS Applications and Lessons Learned

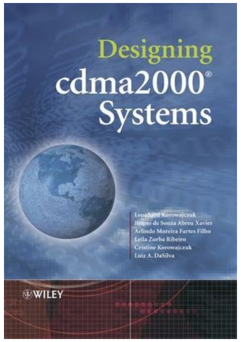
Network Design Considerations and Deployment Concerns for a Ground Aircraft Communication System

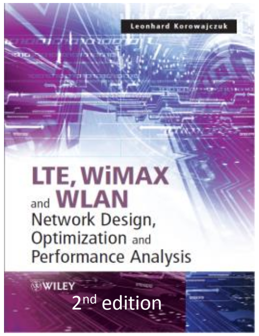
CelPlan Technologies
Leonhard Korowajczuk
CEO/CTO
sales@celplan.com
703-259-4020
www.celplan.com

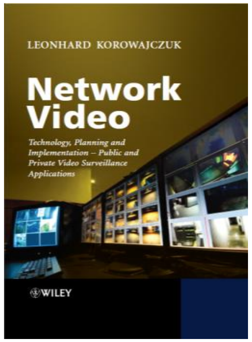
Presenter

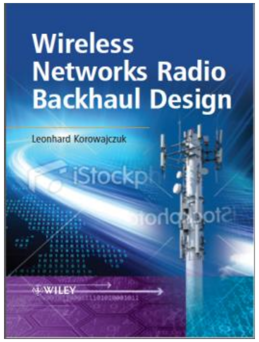
- **Leonhard Korowajczuk**
  - CEO/CTO CelPlan International
  - 45 years of experience in the telecom field (R&D, manufacturing and services areas)
  - Holds13 patents
  - Published books
    - "Designing cdma2000 Systems"
      - published by Wiley in 2006- 963 pages, available in hard cover, e-book and Kindle
    - "LTE , WiMAX and WLAN Network Design, Optimization and Performance Analysis "
      - published by Wiley in June 2011- 750 pages, available in hard cover, e-book and Kindle
  - Books in Preparation:
    - LTE , WiMAX and WLAN Network Design, Optimization and Performance Analysis
      - second edition (2014) LTE-A and WiMAX 2.1(1,000+ pages)
    - Network Video: Private and Public Safety Applications (2014)
    - Backhaul Network Design (2015)
    - Multi-Technology Networks: from GSM to LTE (2015)
    - Smart Grids Network Design (2015)

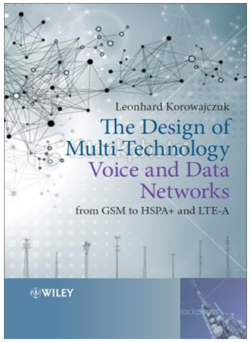












CelPlan International

- Employee owned enterprise with international presence
  - Headquarters in USA
  - 600 plus employees
  - Twenty (20) years in business
- Subsidiaries in 6 countries with worldwide operation
- Vendor Independent
- Network Design Software (CellDesigner has AeroMACS module)
- Network Design Services
- Network Optimization Services
- Network Performance Evaluation
- Have designed and deployed many WiMAX and LTE networks
- Services are provided to equipment vendors, operators and consultants
- High Level Consulting
  - RFP preparation
  - Vendor interface
  - Technical Audit
  - Business Plan Preparation
  - Specialized (Smart Grids, Aeronautical, Energy, …)
- Network Managed Services
- 2G, 3G, 4G, 5G Technologies
- Multi-technology / Multi-band Networks
- Backhaul, Small cells, Indoor, HetNet

Network Design Considerations for a Ground Aircraft Communication System

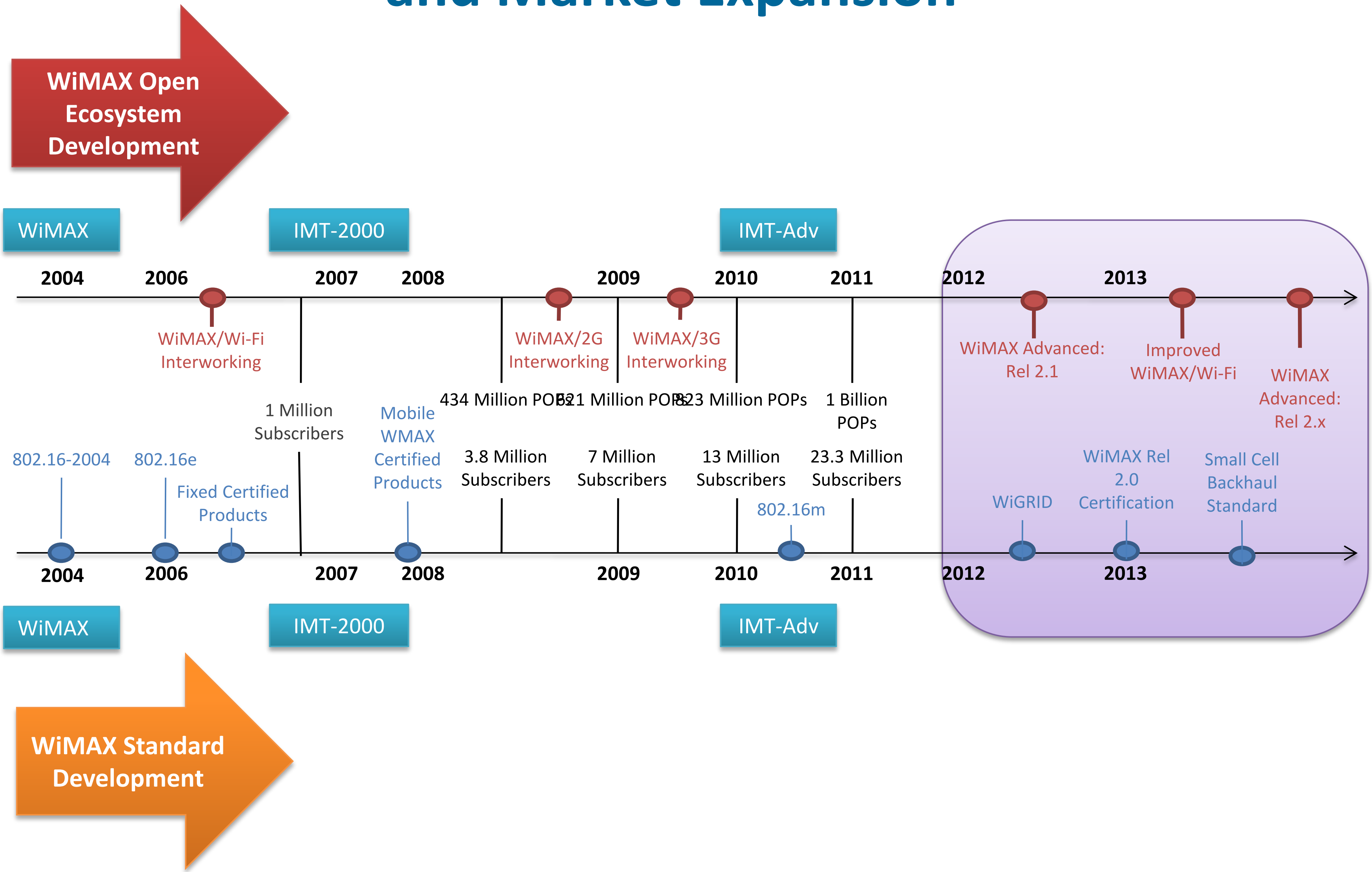
Agenda

- Summary of AeroMACS
  - Voice in WiMAX
  - Video
- Practical Networks
  - Air Traffic Control
    - Plane to Plane
    - Plane to Ground
    - Ground to Ground
  - Airport Authority
    - Maintenance
    - Security
    - Baggage services
    - Emergency
  - Airlines
    - Ticket counter
    - Dispatch
    - Baggage
- Reliable, Redundant, Secure and Prioritized
- Devices
  - Phones
  - Modems with Wi-Fi
  - USB dongle
  - Tablets
  - Consoles
  - Embedded
- Services
  - Voice
  - Remote access
  - Video
  - Internet
  - Text
- Applications
- Wireless Communications Characterization
  - RF Channel Characterization
    - Propagation Model: K3D
    - Model Calibration
- Network Design
  - Outdoor/indoor coverage
  - Interference minimization
  - Spectrum cleaning
  - Five 10 MHz TDD channels
  - Segmentation
  - Zoning
  - PUSC
- Suggestions
  - Working Group to define the above items
  - Pilot airport

WiMAX

- WiMAX was specified by IEEE, championed by Intel and Samsung
  - Architecture was Internet based
- Traditional 2G/3G vendors opposed
  - Initiated their own specification 3GPP based (LTE)
- Greenfield and vertical operators deployed WiMAX
- Traditional operators went with LTE

WiMAX Continues its Technological Evolution and Market Expansion



WiMAX in Multi Radio Access Technology Network Deployments

Current AeroMACS Assessments

Toulouse Airport Network Trial

- **Cleveland Hopkins Airport** / NASA Glenn Research Center joint project
- **Daytona Airport** – Harris Corporation Trial
- **Melbourne Airport** – Harris Corporation Trial
- **Atlantic City Airport** – FAA Flexible Terminal Sensor Network program prototype network
- Airport Surface Surveillance Capability (ASSC) Program
  - Supported by Sensis Corporation
  - Prototype installed and tested at **Syracuse Hancock International Airport**
  - May 2013 – **SFO Installation**
  - **SFO is 1st of 9 sites**
- **Toulouse Airport –** SESAR / Airbus / Indra / EUROCONTROL project

WiMAX Summary

- OFDM based technology
  - Resolved multipath intersymbol interference for high speed data
- Stable specification not encumbered compatibility with 2G and 3G
- Internet friendly, benefits from Internet mass produced devices, applications and protocols
- Natively optimized for TDD
- Sub-carrier Permutation (PUSC) provides frequency diversity, lacking in LTE
- Frequency Segmentation and Time domain zoning allows easy resource partition

Text, Voice and Video in WiMAX

- Text, voice and video is supported by Over The Top (OTT) applications
- QoS can be applied to voice and video
- Using OTT allows for easy evolution and creation of new products
- Video requires large uplink bandwidth, which can be adjusted in TDD

AeroMACS Network Design

- Who are the users?
- What are the applications?
- Where the service has to be provided and to whom?
- What is the cell capacity?
- What is the required network capacity?
- What are the required network technical capabilities?
- What devices will be used?
- What are the deployment options?
- How does the RF propagate in the environment?

Who are the users? How many?

- Air Traffic Control (large airport= 2,000 employees)
  - Plane to plane
  - Plane to Ground
  - Ground to Ground
- Airport Authority (large airport = 40,000 employees)
  - Airport Management
  - Security
  - Maintenance
  - Baggage Service
  - Food
  - Emergency
- Airlines (large airport= 10,000 employees)
  - Ticket counter
  - Dispatch
  - Baggage
- AeroMACS users: estimated in 10,000 users at 2 GB per month

What are the applications?

- Today's applications are:
  - Text messages
  - E-mail
  - Web access (Internet)
  - Video
  - Voice applications (Skype)
  - Remote desktop
  - Meeting applications (WebEx)
  - Telemetry
  - Proprietary
- New applications will appear as soon as the network is available
- Network design and traffic considerations should be such to accommodate an increase in traffic 5 fold

Where the service has to be provided and to whom?

- Apron areas
- Taxiways
- Runways
- Gates
- Waiting areas
- Ticket counters
- Maintenance areas
- Security areas
- Fire and health safety areas

- Managers
- Personnel
- Vehicles
- Airframes

What is the cell capacity?

- AeroMACS spectrum is: 5.091 GHz to 5.150 GHz
  - 5 channels of 10 MHz
- Additional possible spectrum: 5.0 to 5.030 GHz
  - 3 channels of 10 MHz
- Assuming a spectral efficiency of 1 bps/Hz, a channel could have a capacity of 10Mbps
- The 8 channels should be enough to provide the required cellular reuse, redundancy and peak management
- Segmentation can be used for additional interference control or entity
- Zoning can be used to isolate traffic entities

What is the required network capacity?

- Large airport can have up to 10,000 users
- Assuming a tonnage of 5GB per month per user
- Assuming 10,000 users
- We will need 100+ cells (50+ sites) to provide the required traffic capacity
- Traffic can increase significantly after the network is deployed and new applications are developed
  - A mature network can have as many as 200 sites

Average tonnage per user		
month	5	GB/month
day	0.17	GB/day
hour	33.3	MB/hour
hour	266.7	Mbit/hour
second	74.1	kbps

Total tonnage for all users		
users	10,000	users
Total	741	Mbps

Network Dimensioning		
cell	10	MHz
spectral efficiency	1	bit/sec/Hz
max cell capacity	10	Mbps
average cell	7	Mbps
number of cells	106	cells
number of sites	53	sites

Traffic calculator per application

CellDesigner - Tonnage Calculator

QoS | Unitary | Tonnage | QCI Table

Service Identification		Data Rate (kbps)		AMBR (kbps)		Alloc./Retent./Prior. ARP			Packet Size (Bytes)	
Name	QCI	GBR	MBR	APN	UE	Priority	Capabilit	Vulnerab	DL	UL
Conversational Voice	1	12.5	16			2	Yes	Yes	320	320
Conversational Video (live streaming)	2	180	240			2	Yes	Yes	760	64
Real Time Gaming	3	1.5	1.6			2	Yes	Yes	80	24
Non conversational Video (buffered)	4	128	156			2	Yes	Yes	1024	128
IMS signaling	5			64	32	2	Yes	Yes	128	32
Video (buffered streaming), TCP applications	6			128	256	2	Yes	Yes	1024	128
Voice, Video Live Streaming, Interactive Gaming	7			128	256	2	Yes	Yes	760	64
Video (buffered streaming), TCP applications	8			128	256	2	Yes	Yes	1024	128
Video (buffered streaming), TCP applications	9			128	256	2	Yes	Yes	1024	128
UTP based applications	5			32	64	2	Yes	Yes	64	12
UTP based applications	6			48	128	2	Yes	Yes	128	24
UTP based applications	7			64	128	2	Yes	Yes	256	48

Overall AeroMACS Market

- Last year market estimates
- It does not include regular airport users

Base Stations	
US	12,120
EU	12,296
Subtotal	24,416
Rest of World	12,000
Total	36,416

Ground Vehicles	
US	235,705
EU	94,893
Subtotal	330,598
Rest of World	47,447
Total	378,044

Airframes	
US	6,000
EU	5,000
Subtotal	11,000
GAA aiframes	200,000
Rest of World	2,500
Total	213,500

What are the required network technical capabilities?

- The network should be overdesigned for capacity, so it can handle local traffic peaks
- The network should be redundant
  - Two sets of hardware should provide service in each location
- Network should be secure
  - WiMAX provides a layer of security by itself, not being in use by the general public
  - Encryption should be strong
- Services and users should have priority levels
- Services and users should be categorized in exclusive zones
- Zone overflow should be possible for certain categories

What devices will be used?

- Smartphones
- Tablets
- Modems
- USB dongles
- Consoles
- Embedded

What are the deployment options?

- Each entity can deploy its own network
  - Spectrum will have to be split or frequency coordination will have to be enforced
  - The total investment will be higher
- A single entity can be in charge of deploying and operating the network for all entities
  - Spectrum usage issue is resolved
  - Investment is minimized
  - Resource splitting becomes the issue
- A mixed solution, with a dedicated network for critical operations and another one for logistics

Wireless Communications Characterization

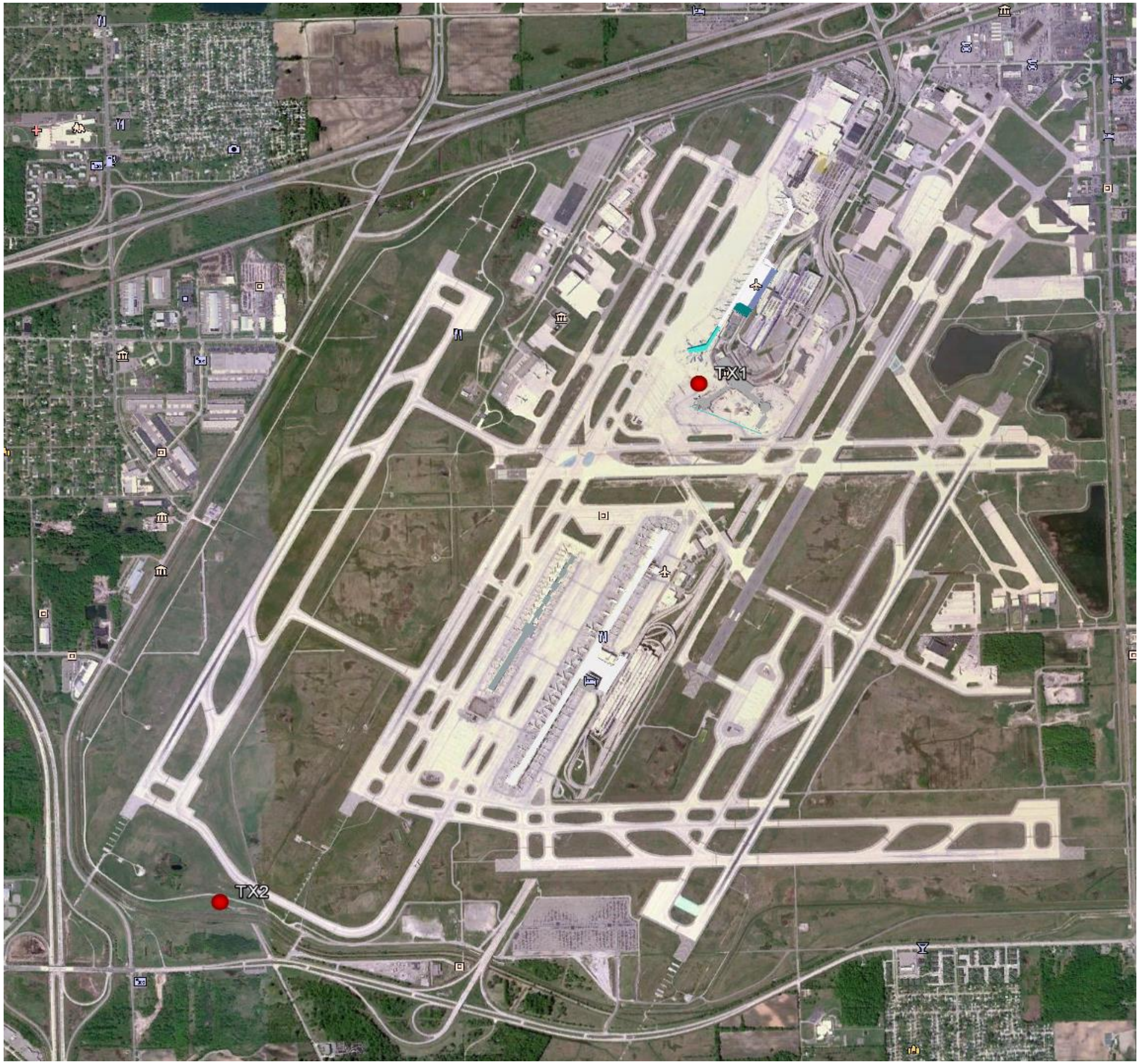
Wireless Propagation

- CelPlan have done propagation measurements at Chicago (ORD) and Detroit (DTW) airports for the NextGen Communication System, and the same can be done for AeroMACS
- CelPlan has developed 3D models of airports including moving airframes
- CelPlan has the K3D model that is recognized as the best in the industry
- CelPlan has developed a 3D scanner that characterizes the performance of OFDM in 3 dimensions

ORD Airport

- Airport and surroundings were modeled in 3 D
- Horizontal resolution of 1 m
- Vertical resolution of 0.5 m

DTW Airport

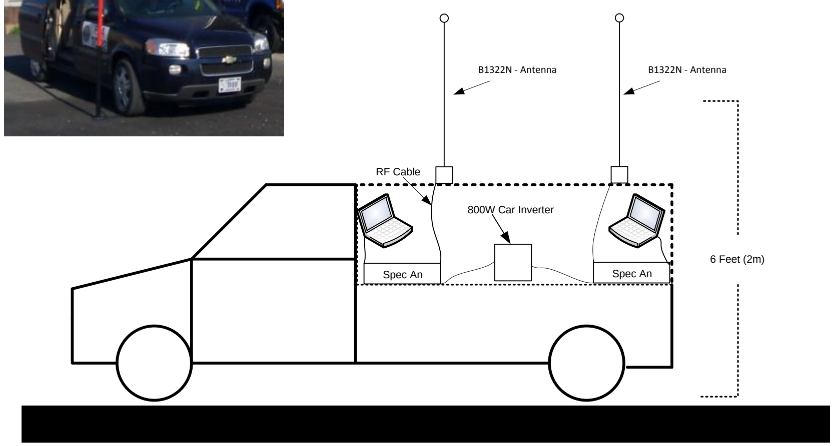


- Airport and surroundings were modeled in 3 D
- Horizontal resolution of 1 m
- Vertical resolution of 0.5 m

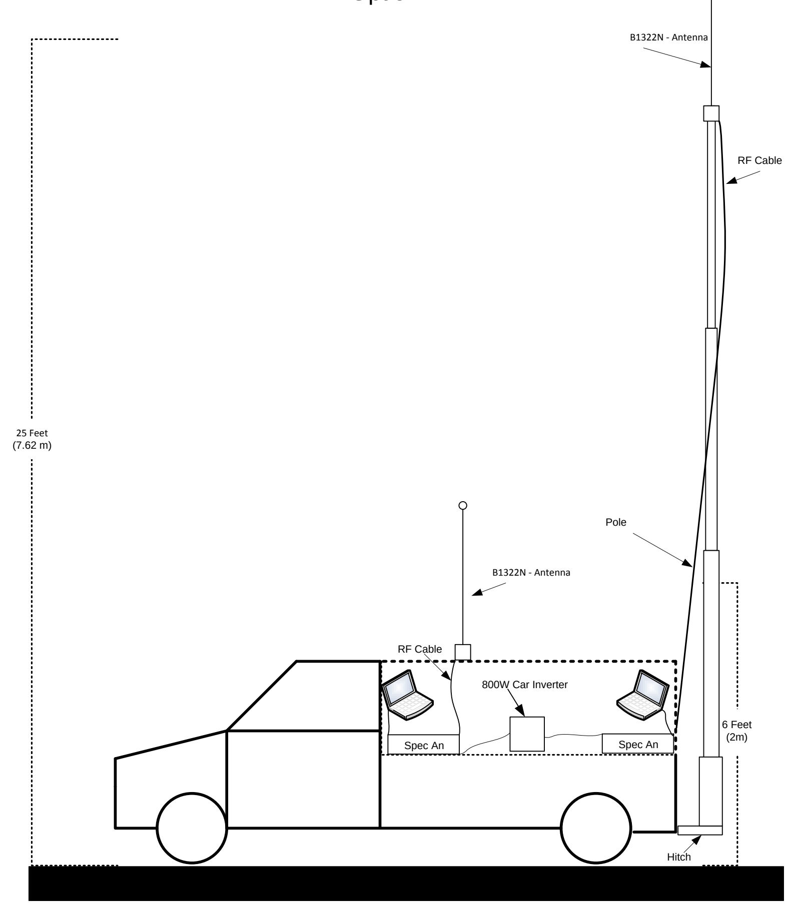
Test vehicle

- Two test vehicles were used
  - One simulated the transmitter
  - Another simulated a moving receiver

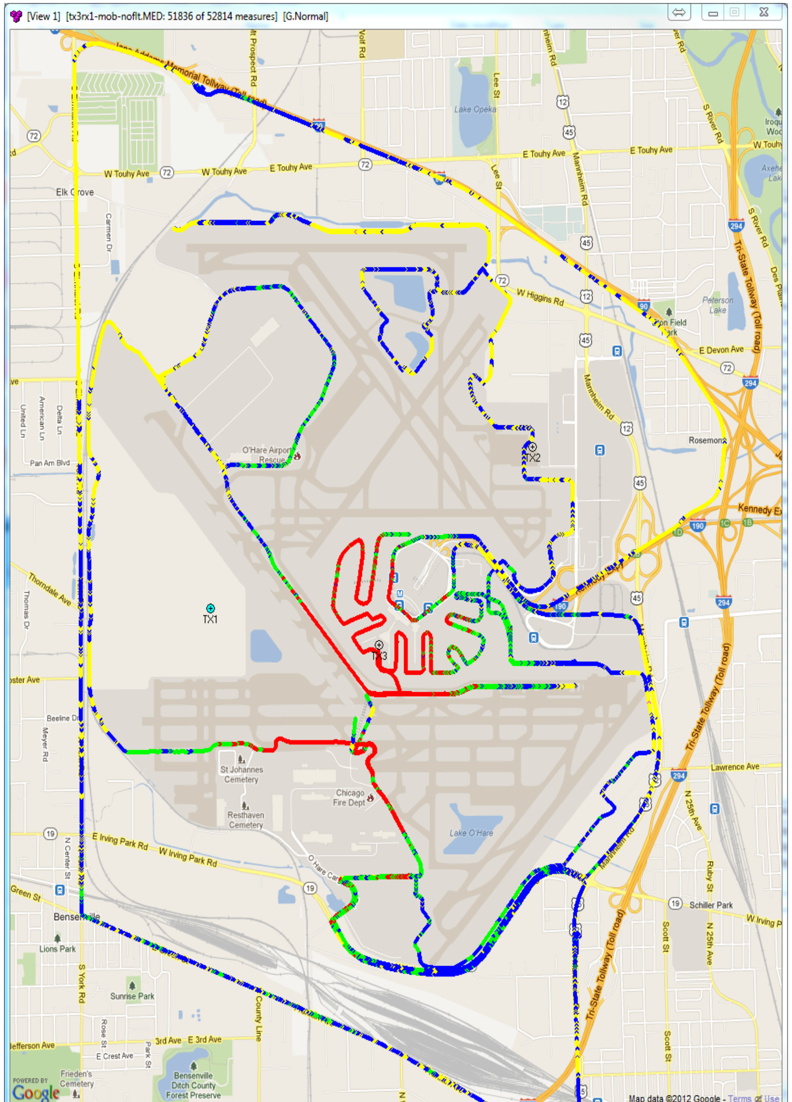
Mobile Car - RX

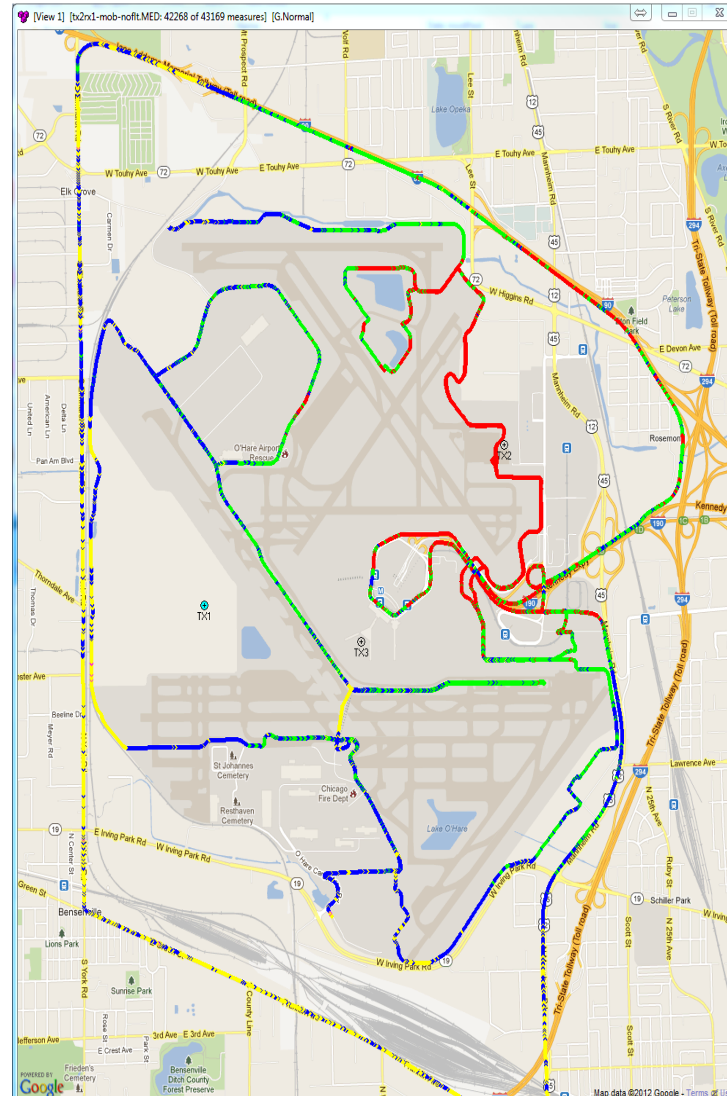


Static Car – RX
Option 2



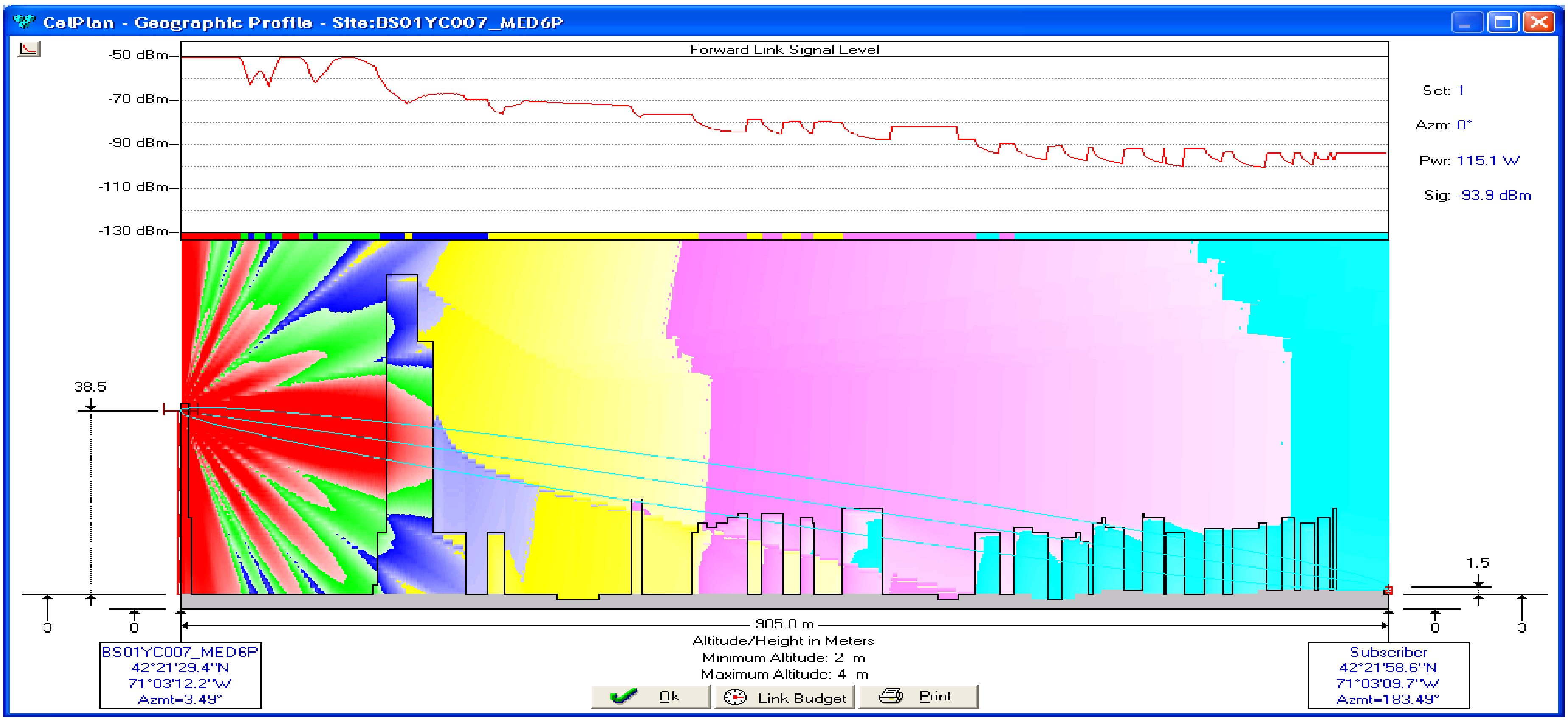
Drive Test Measurements





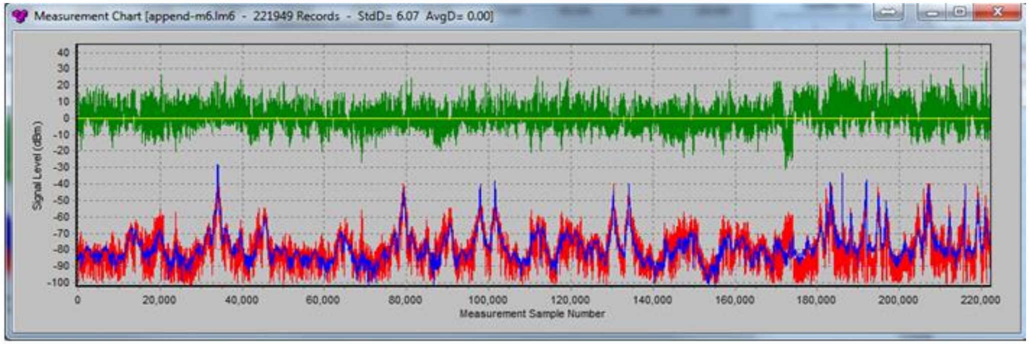
K3D Propagation Model

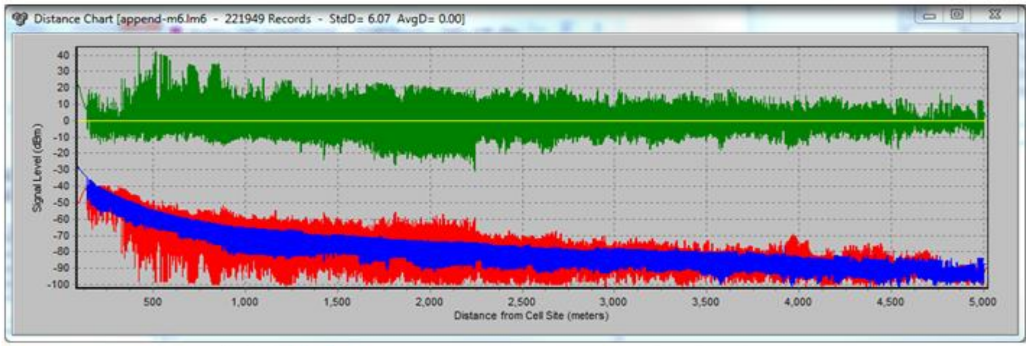
- The K3D model considers propagation in 3D and uses fractional morphology
- The model predicts outdoor and indoor coverage

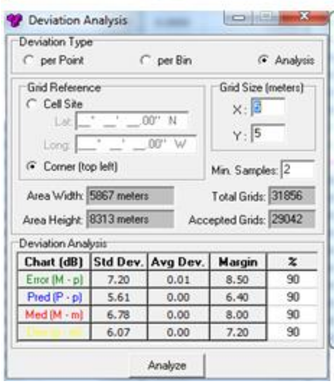


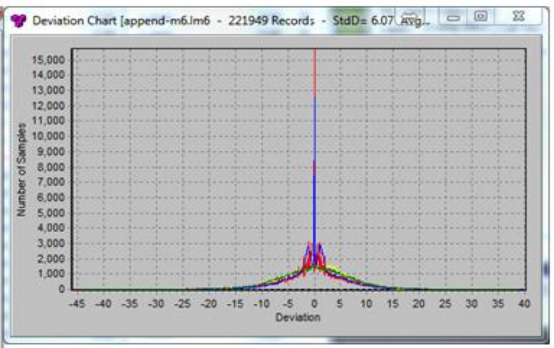
Measurement x Predictions

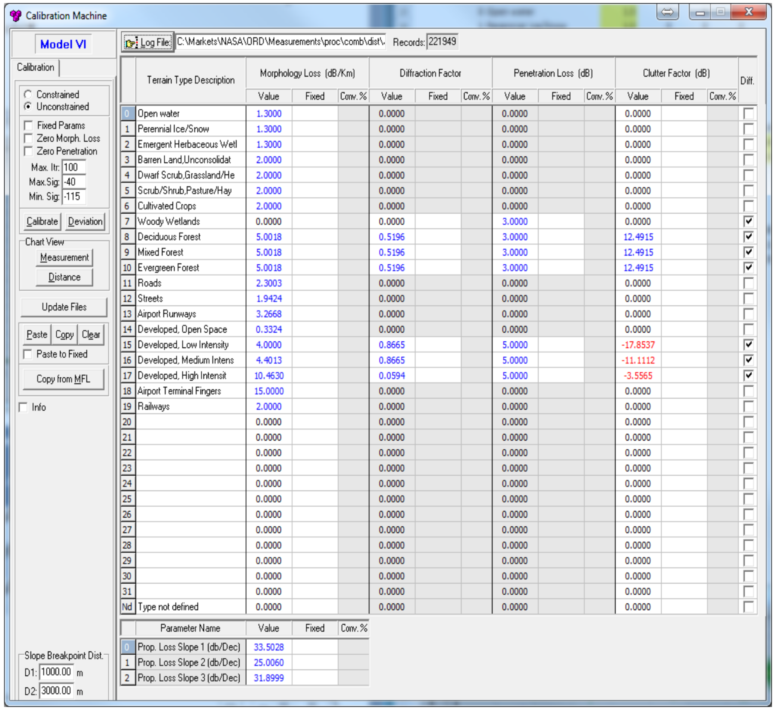
- Prediction model used was: Korowajczuk 3D





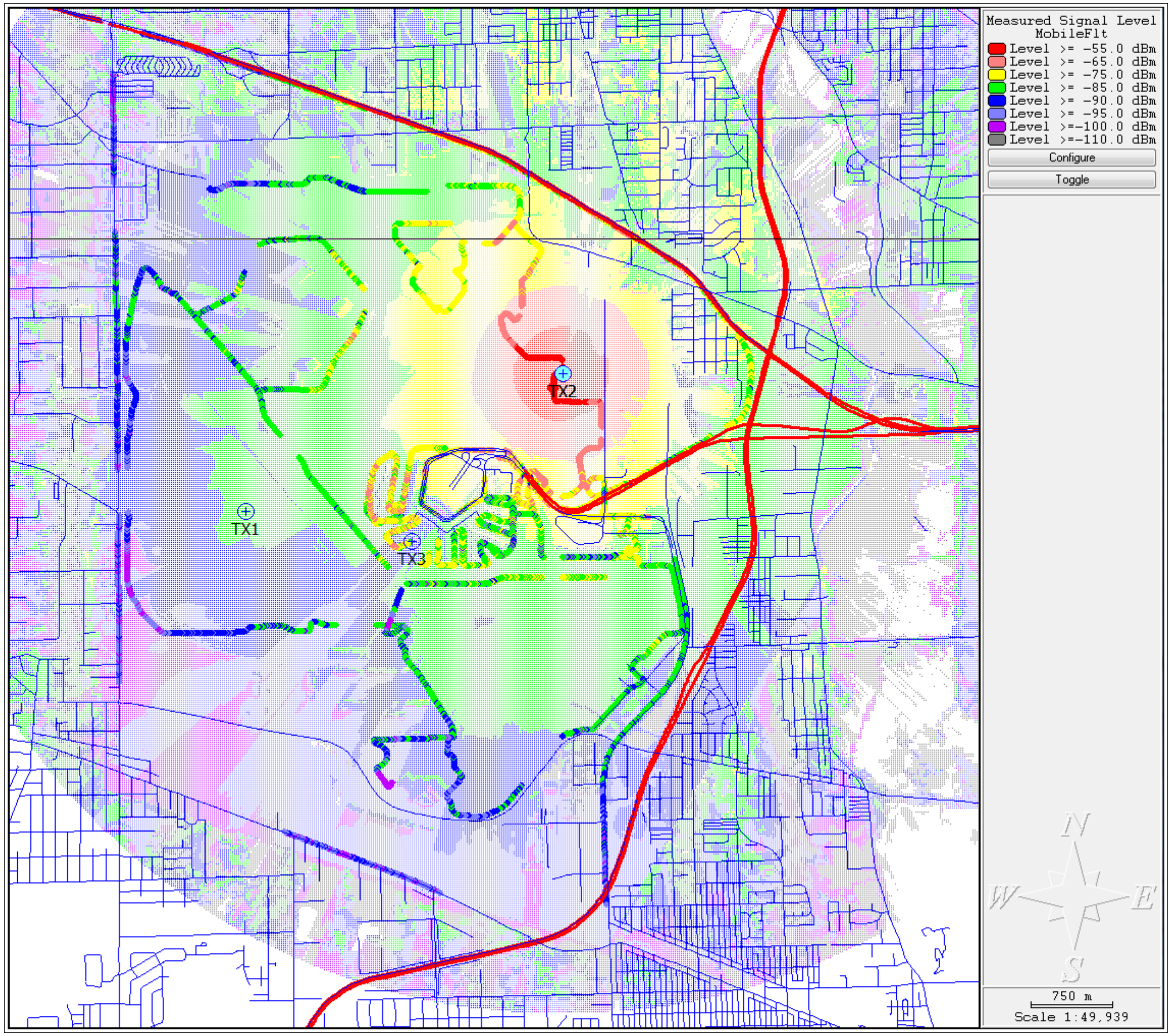




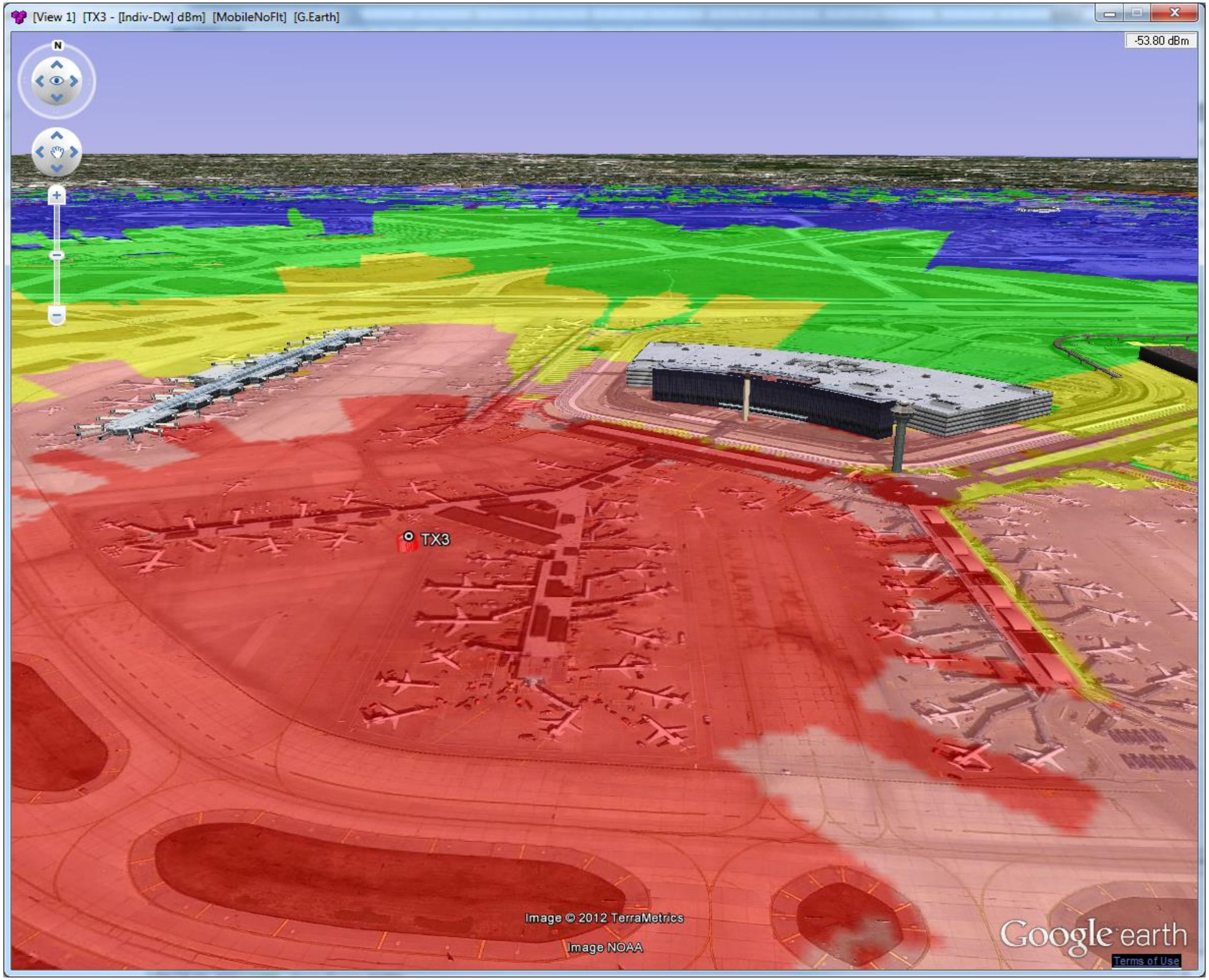


	Unconstrained Calibration Set		
	Standard Deviation [dB]	Average Deviation [dB]	RMS [dB]
Model II - 2D Korowajczuk	6.16	0.04	6.16
Model III - Microcell	6.96	0	6.96
Model VI - 3D Korowajczuk	6.07	0	6.07

Predictions x Measurements

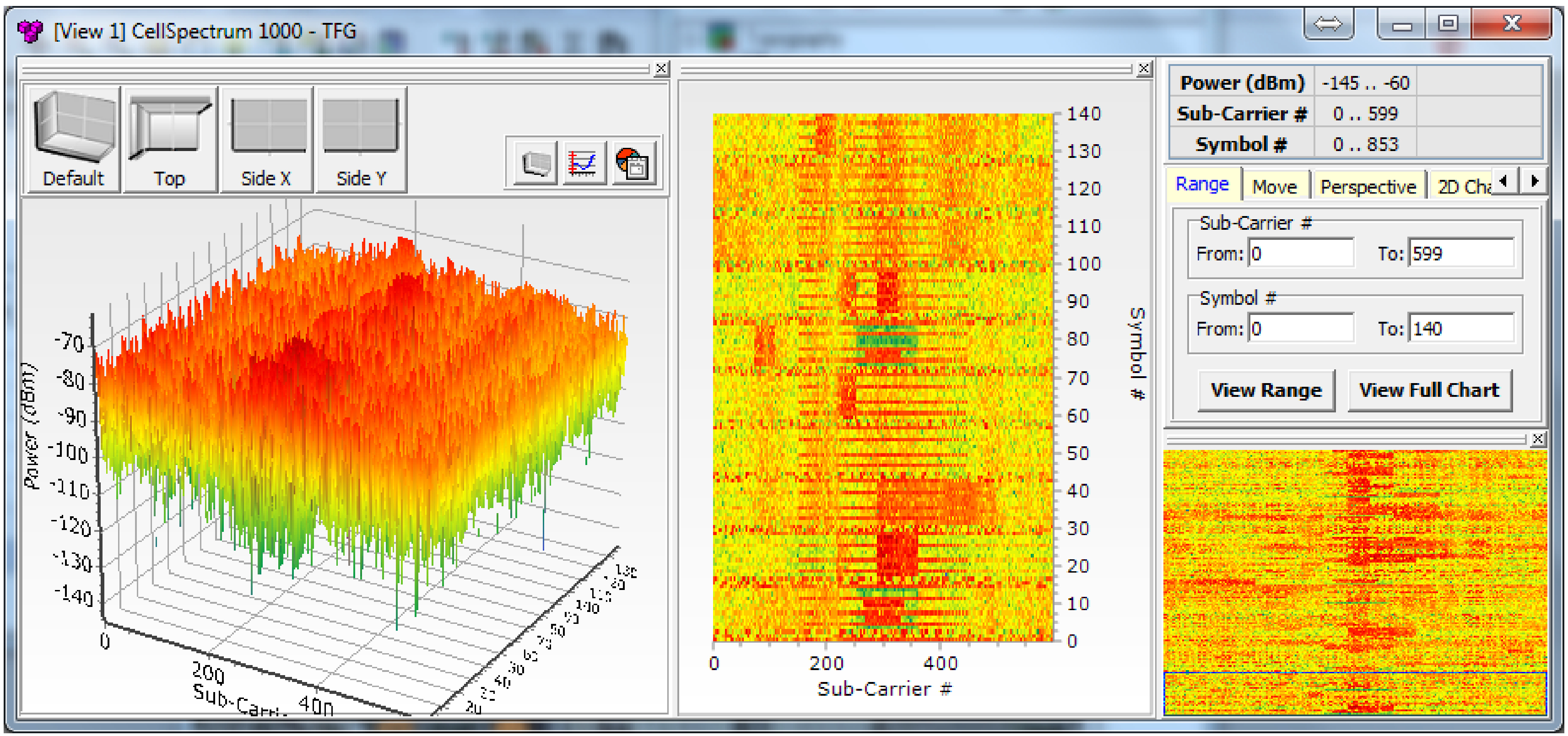


Airport 3 D Coverage view



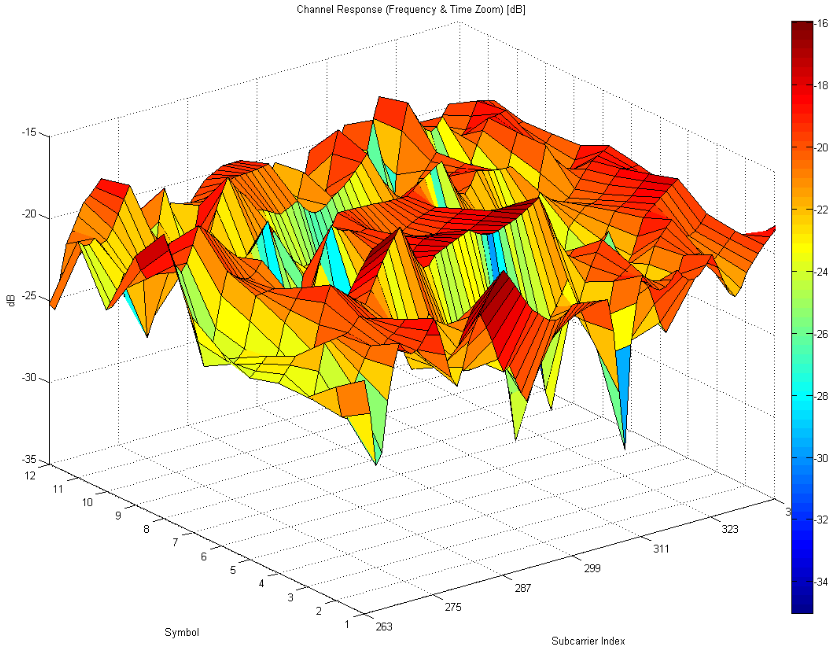
CellSpectrum

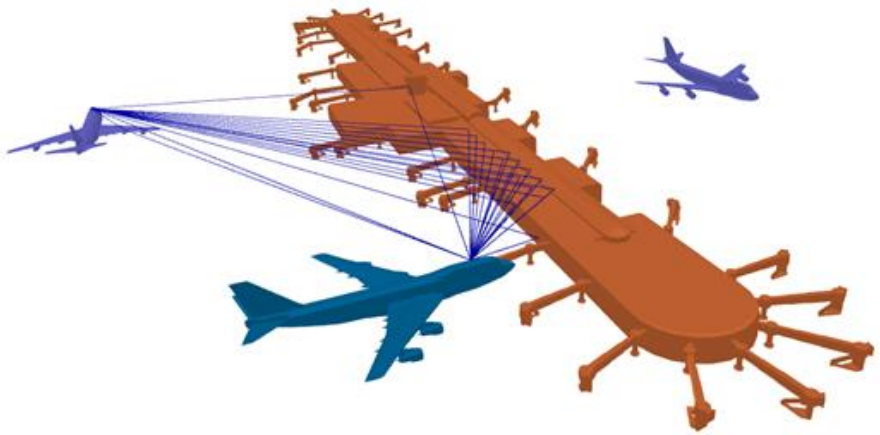
- CelPlan developed CellSpectrum that characterizes the RF channel in 3D
- An entire OFDM frame can be analyzed on a symbol basis



Multipath fading

- Multipath is a major impairment in wireless communications and should be properly characterized
- MIMO characterization can be done
- Characterization can be done using:
  - Channel response per OFDM sub-carrier
  - Ray Tracing





Conclusions

- AeroMACS network design is a complex task and requires the analysis of several scenarios
- Market research should be done to dimension user requirements at different airport sizes and locations
- RF propagation characterization should be done, a propagation model chosen and propagation parameters calibrated
- Preliminary network designs should be perform for different scenarios and capacities
- CelPlan and Senza Fili can be your partners for a reliable AeroMACS design

CelPlan Technologies
Leonhard Korowajczuk
CEO/CTO
sales @celplan.com
www.celplan.com

Questions?