Status
NextGen ATS CNS Test Bed

"The Cleveland Test Bed"

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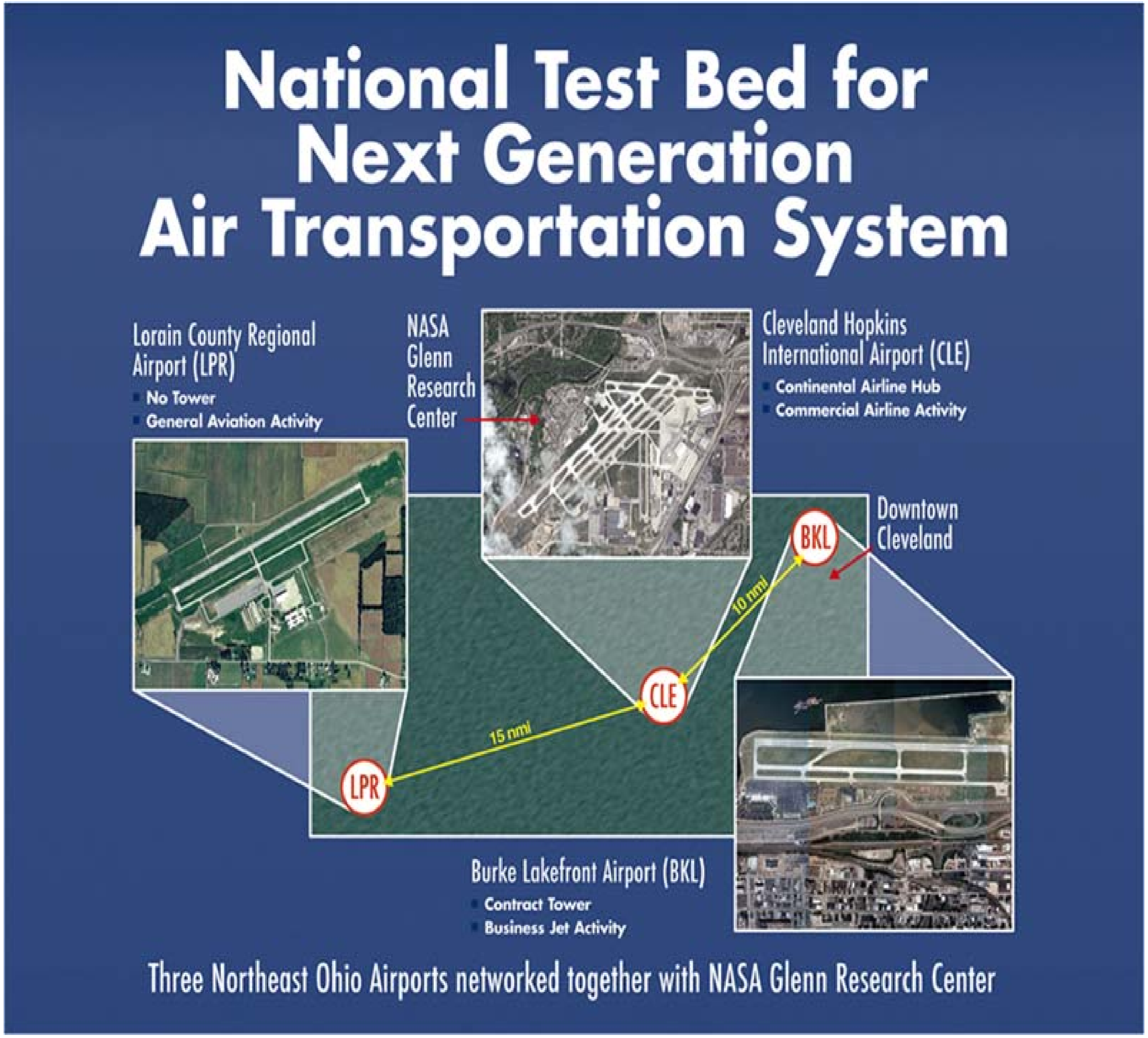
Jim Budinger, NASA Glenn Research Center

ICNS, May 2007

Presentation Agenda

- Dana (10 minutes)
  - Refresh: Test Bed what, where, why
  - Status of the surveillance, communications, & info sharing infrastructure
  - Status of the initial applications
- Jim (10 minutes)
  - NASA GRC plans for using the Test Bed
  - Insight about proposed comm technology and spectrum
  - Plans for comm network experiments
- Q & A (10 minutes)

Refresh: What, Where, Why



- 3 airports, metro region
- Represent nationwide
- Must accommodate 2x-3x more air travel

Walk, before we run….
CLE = OEP #46
then to top OEP airports

Test Bed Objectives:

- Prototype
- Evaluate
- Measure
- Wring-out
- Reduce risk

Test Bed: 1st Two Years

Prototype Applications

- *ASDE-X Generated Alerts to the Cockpit*
- *Staffed Virtual Tower*
- *4-D Departure Flow Management*

Establish Infrastructure

- *Information Sharing & Data Management*
- *Airport Surface Wireless Communications*
- *Advanced Integrated Surveillance*

Infrastructure:
Surveillance & Wireless Communications

- ***MLAT surveillance installed***

  Encompasses 3 airports

  Waiting for FAA spectrum use ok

- ***Flexibility via wireless connectivity***

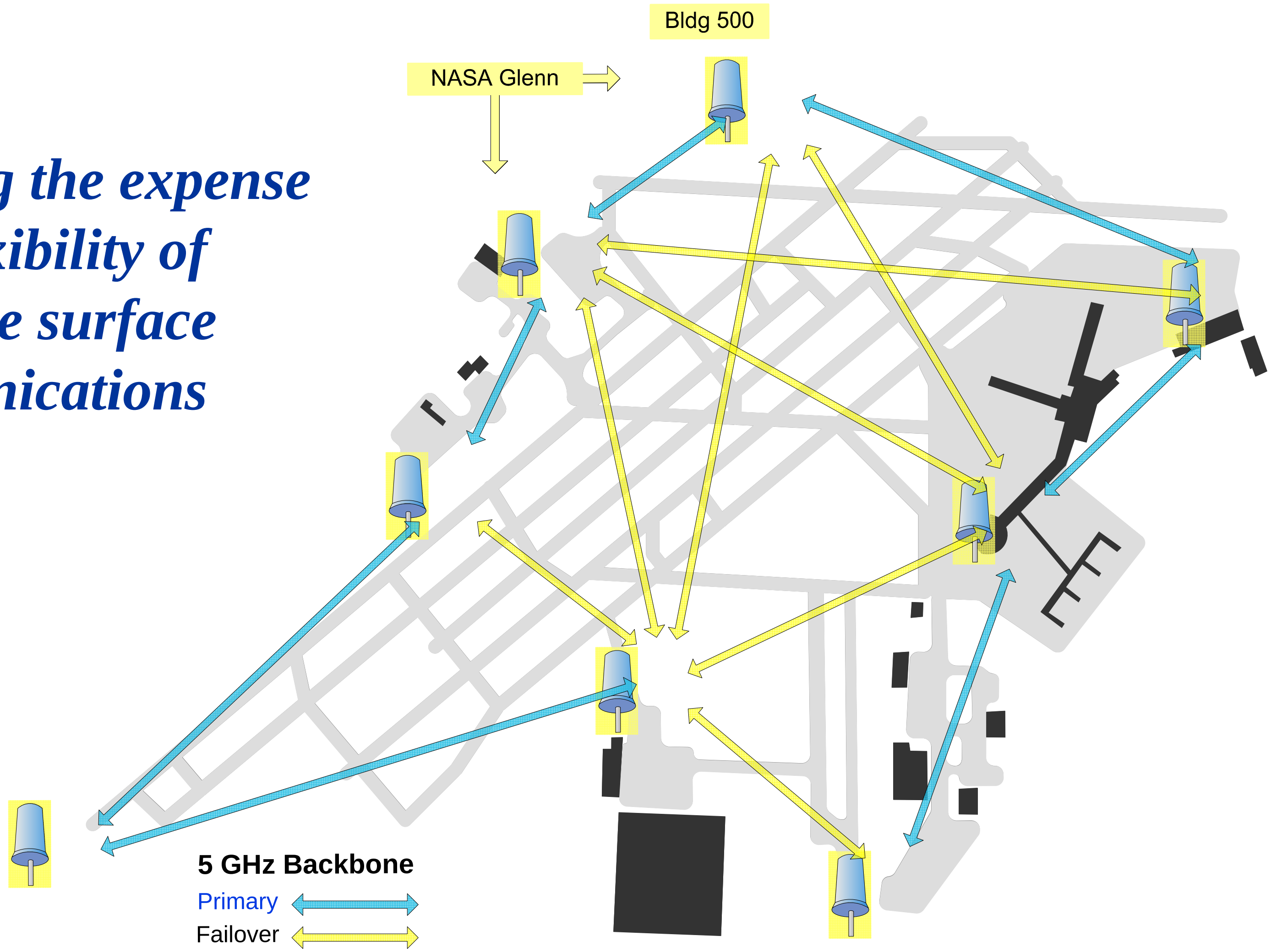
  17 remote units to central processor

- ***Remote access for monitoring, reconfiguration, and network experiments***

Sensis

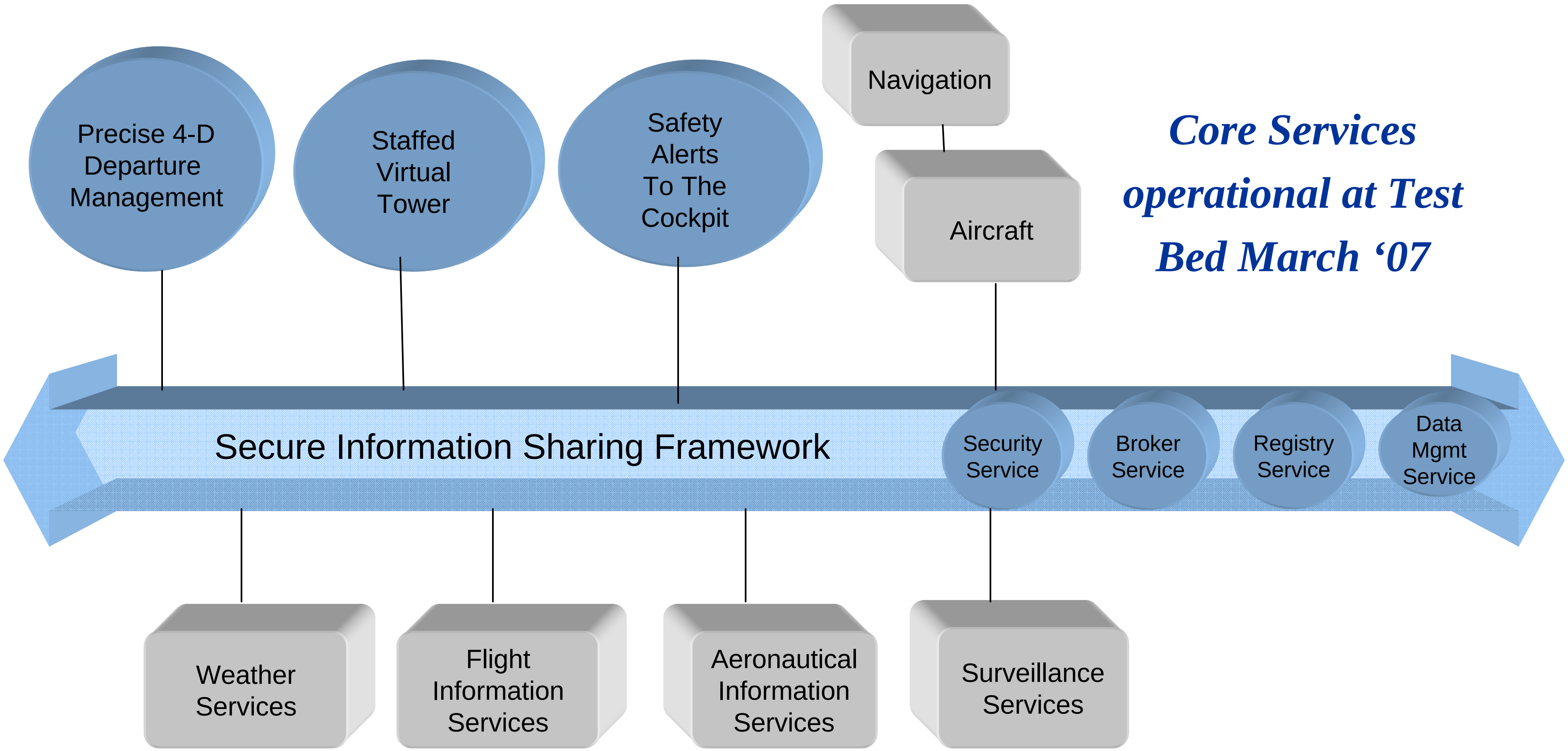
Surface Wireless Mesh Networks

Overcoming the expense & inflexibility of hard-line surface communications



Network-enabled Info Sharing

Enable NAS-wide availability of ATM data when needed, where needed, securely



Core Services operational at Test Bed March '07

Prototype Applications
ASDE-X Generated Alerts to the Cockpit

- Runway Incursions -- Major, Continuing Aviation Safety Problem
  Top 5 NTSB issue

- Potential Solution -- Integrate ASDE-X Alerting with TCAS Alerting

  - ASDE-X Safety Logic detects potential surface incidents
    Sends alert to ATC controllers

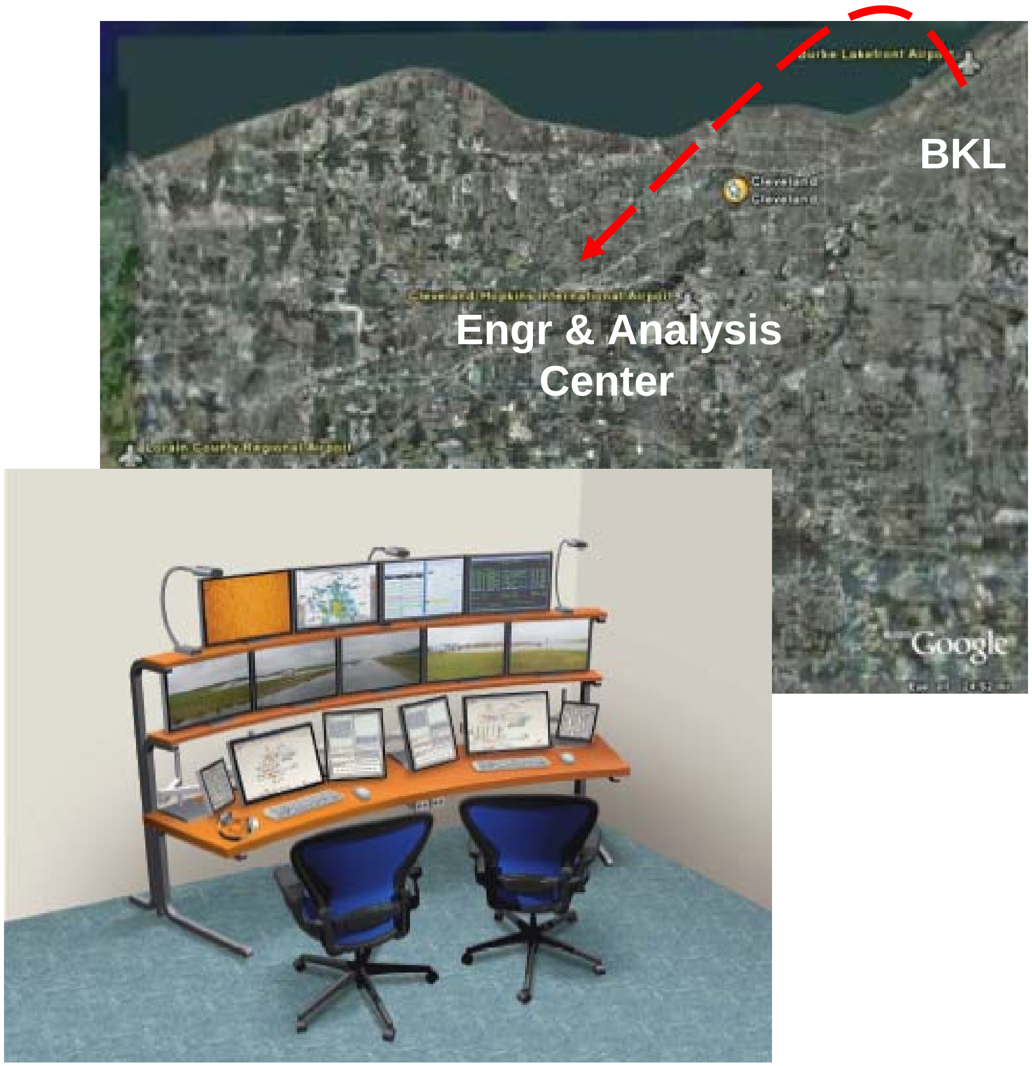
  - TCAS detects and alerts pilots about potential airside incidents

- Can We Couple the Ground View ASDE-X and the Air View TCAS?

  - Save Precious Seconds by Alerting Controllers and Both Pilots

- Sensis & Honeywell Jointly Investigating

Staffed Virtual Tower



Conceptual future controller console

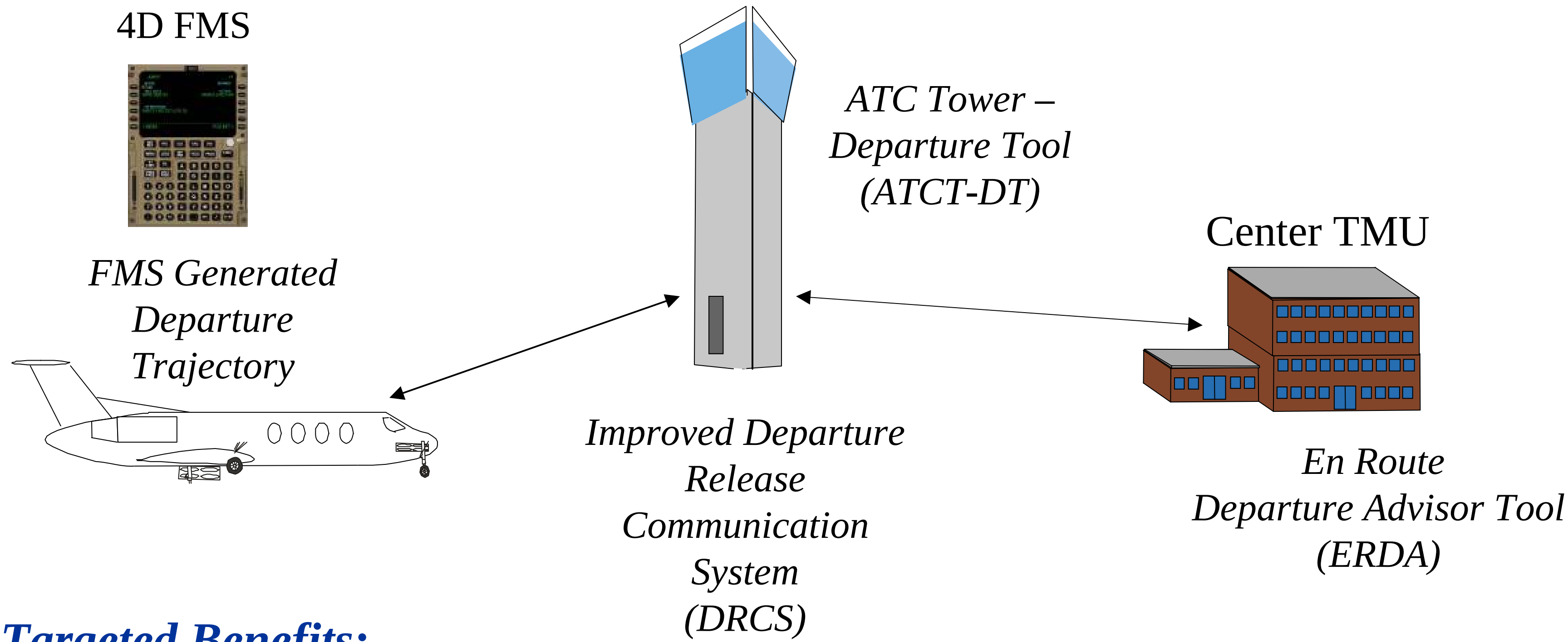
Evaluate Providing ATC Services to Non-Towered Airports

Geographically separated situational awareness

Aided by video & audio

Same or modified ATC procedures

4D Departure Flow Management



Targeted Benefits:

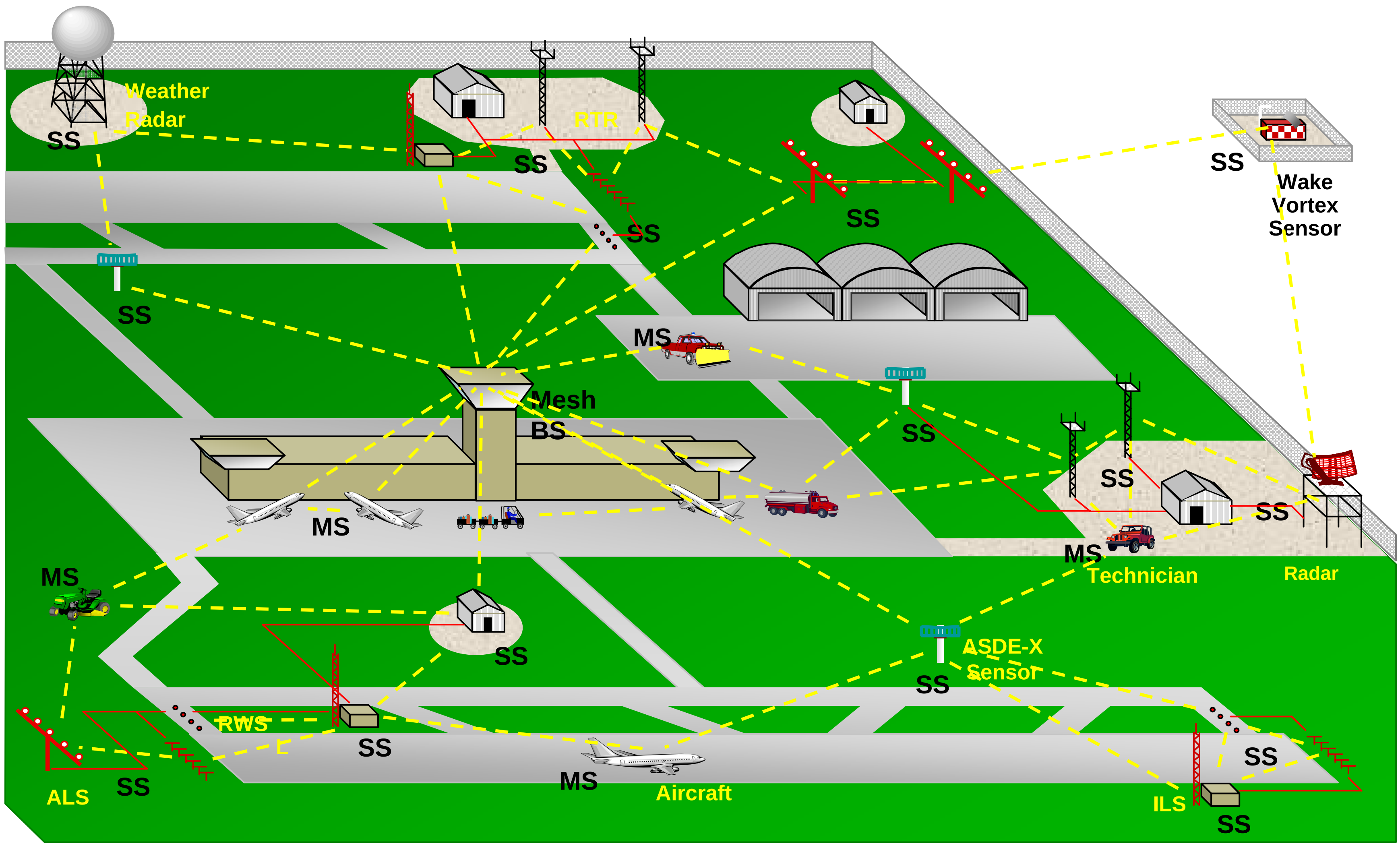
- ***Improve the accuracy and predictability of aircraft trajectories***
- ***Speed the departure release process***
- ***Reduce controller workload***
- ***Factor in airline/user preferred flight path***

Airport Surface Communications

- Existing airport communications infrastructure lacks flexibility and underground cabling is expensive to deploy
  - Aging infrastructure, costly to maintain, vulnerable
  - Existing cabling infrastructure not available at all airports
  - Limited comms integration, lack of network connectivity

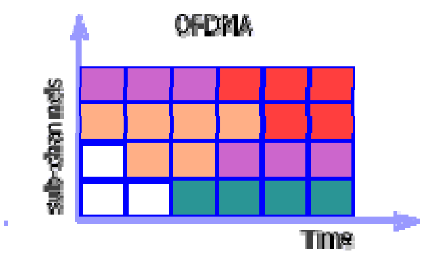
- Current NAS modernization and anticipated "NextGen" Air Traffic System increase demands for CNS information sharing stakeholders
  - ASDE-X sensors, runway incursion prevention, weather & wake sensors…
  - Controllers, pilots, airlines, ramp, de-icing, service & emergency dispatch…
- Wireless mobile airport surface communications network benefits:
  - Reliable, secure integration of voice/video/data at all airport locations
  - Enables "SWIM" networked integration of data sources and users
  - Allows flexible, expandable, affordable deployment at airports of all sizes
  - Reduces VHF spectrum congestion

Sensis Surface Mesh Network Concept

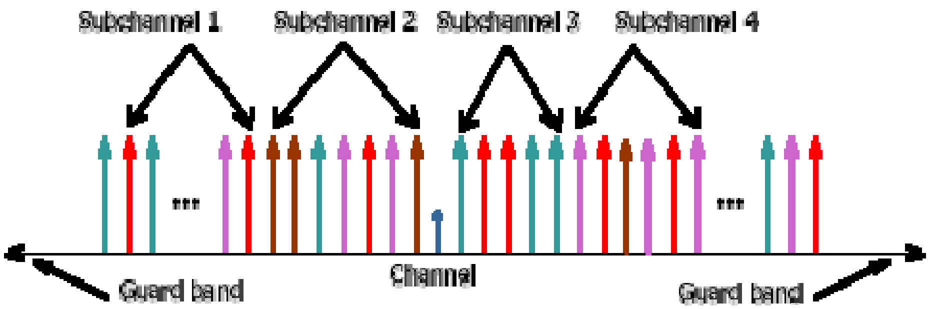


Sensis Proposed Standard Technology

- IEEE 802.16e (WiMAX) is recommended for the airport surface
  - WiMAX operates under NLOS conditions in 2-6 GHz spectrum using Scalable-OFDMA with channels from 1.25 to 20MHz to convey up to 50Mb/s within a 3 mile radius to vehicles moving up to 120Km/h
  - A commercial standard is highly desirable to reduce development costs as well as subsequent purchase, maintenance and upgrade costs
  - Detailed simulation and modeling of 802.16e against validated airport channel models shows that it meets performance requirements
  - The Eurocontrol/FAA-NASA Future Communications Study (under the auspices of ICAO) recommends IEEE 802.16e as the preferred technology for safety critical mobile communications on the airport surface



Sub-channelization in WiMAX
Users transmit in the same time slot over several sub-channels

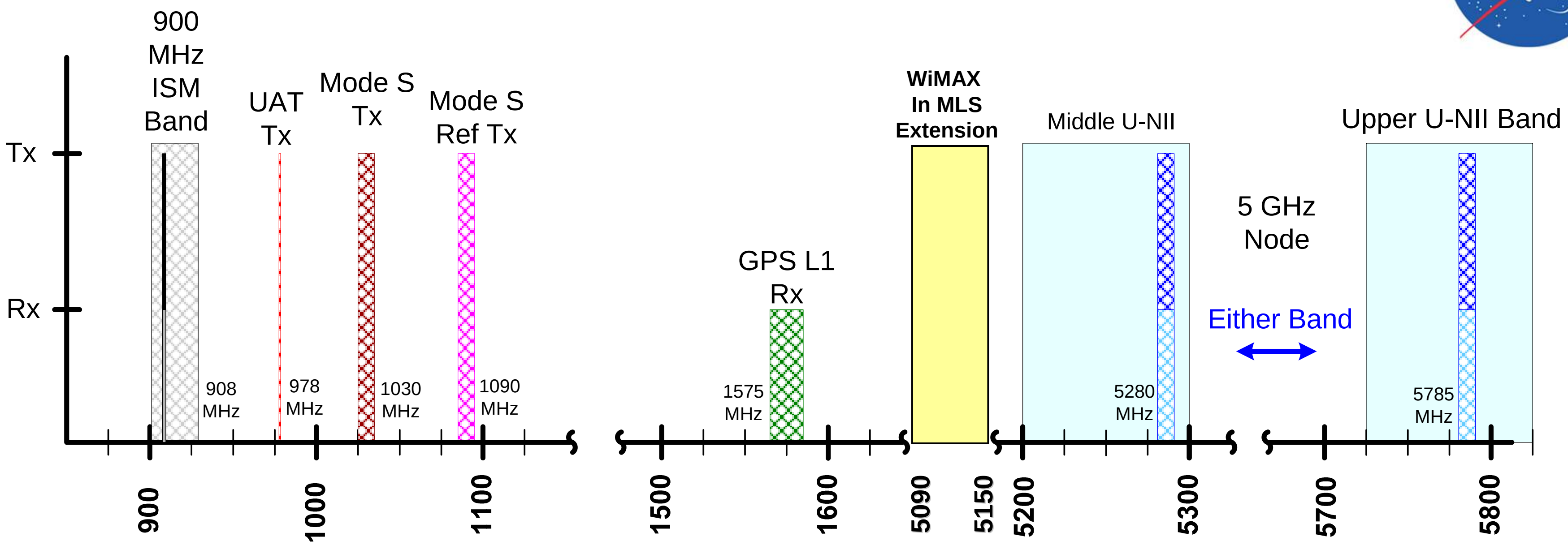


OFDMA symbol structure in WiMAX
Sub-carriers of the same color represent a sub-channel

Proposed Spectrum

- Current international allocation of 5091-5150 MHz for radio-navigation: microwave landing system and fixed satellite service (FSS) feeder links
  - Reserved for future use in U.S. and known as "MLS Extension Band"
  - Co-primary allocation with FSS limits range of MLS to prevent interference
- Upcoming World Radiocommunications Conference (WRC-07 - October 2007) will consider changes in international allocations
  - Agenda Item 1.6 considers additional allocations for aeronautical mobile route (R) service [AM(R)S] in parts of bands between 108MHz and 6GHz
  - Initial focus on current aviation bands; if not sufficient, then look elsewhere
  - AM(R)S designation is required for safety critical aeronautical comms
- The International Civil Aviation Organization (United Nations) supports adding an AM(R)S allocation for 5091-5150 MHz
  - US and many nations support this position; expect approval at WRC-07
  - Protected AM(R)S allocation enables international standardization of safety critical airport mobile surface wireless communications networks that include fixed assets

Test Bed Spectrum Plan



- 900 MHz unlicensed Tx/Rx for administration network
- 978 MHz licensed Tx for UAT ADS-B broadcast transmissions
- 1030 MHz licensed Tx for Mode S interrogation transmitter
- 1575 MHz GPS receiver
- 5 GHz bands for airport surface wireless backbone networks
  - 802.11a in unlicensed U-NII bands (5280 or 5785 MHz) for non safety-critical comms
  - ***Experiment with 802.16e in licensed band (5091-5150 MHz) for safety-critical data***

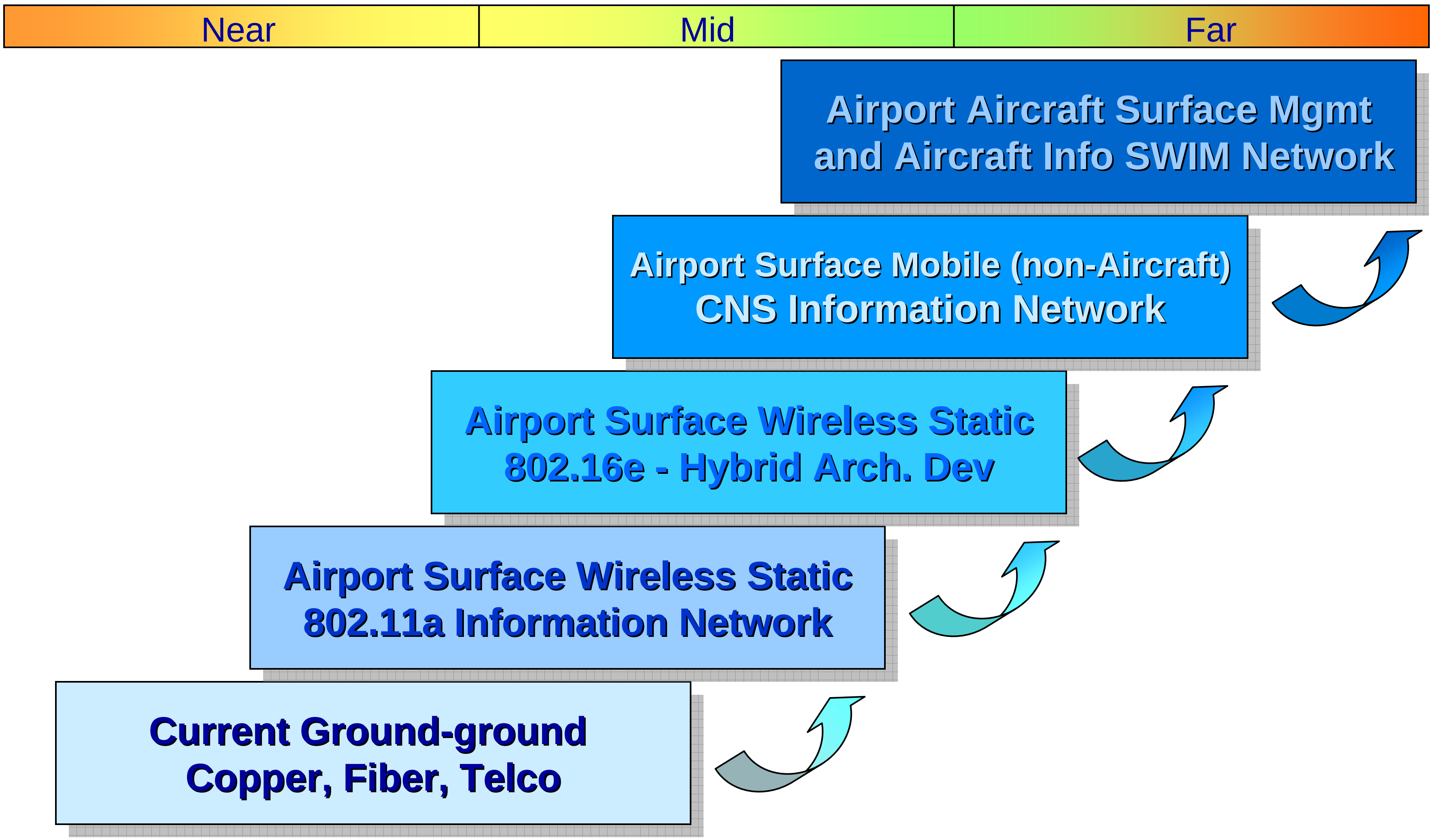
GRC Experimental Goals

- Primary goal is to develop and evaluate an 802.16e-based airport mobile surface communications network in 5091-5150 MHz band
  - Characterize 5.1 GHz spectrum propagation and interference with Ohio University and propose channelization to FAA
  - Investigate and validate applicability of IEEE 802.16e standards as basis for an international ICAO standard in airport environment
  - Demonstrate transportable infrastructure and mobile user applications

- Secondary goals are to:
  - Conduct mobile communications network architecture experiments with applications interfaces to mobile and fixed assets
  - Evaluate system security at the physical layer, alternative network architectures, network performance and optimum node placement
  - Evaluate network performance in the unique airport surface environment (e.g. capacity, latency, link performance, availability, aircraft movement, obstructions and multi-path effects)

Experimental Approach

Surface Communications Technology Evolution



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Backup Materials

Sensis

Participation or Endorsement as of early March 2007

Sensis

FAA
Technology Development Office

Rockwell Collins

smiths

Lockheed Martin

Cleveland Airport System

Frequentis

LCRA Lorain County Regional Airport

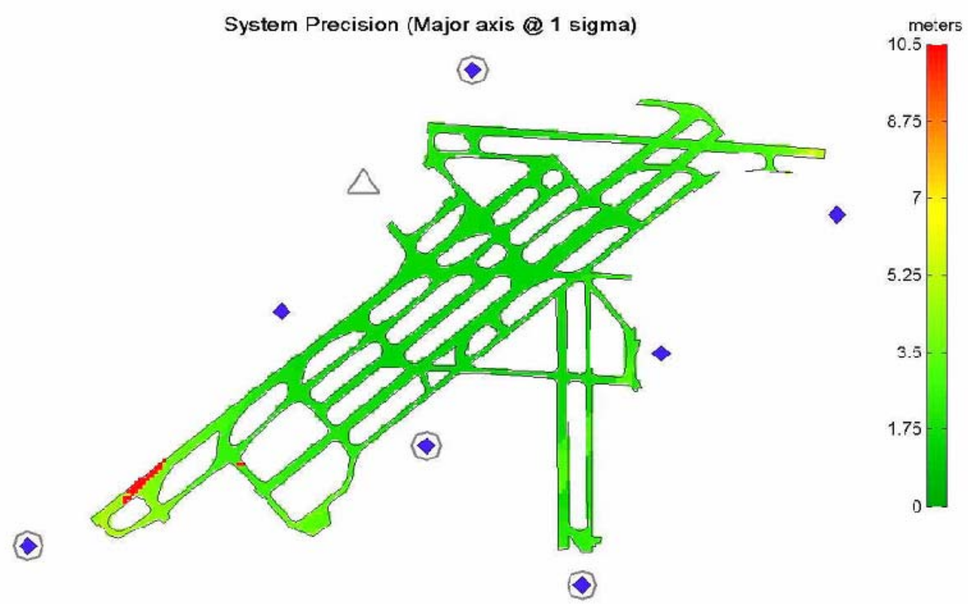
WSI

Barco Visibly yours

Honeywell

Surface & Terminal Area Surveillance Coverage

Cleveland Test Bed, Spring '07

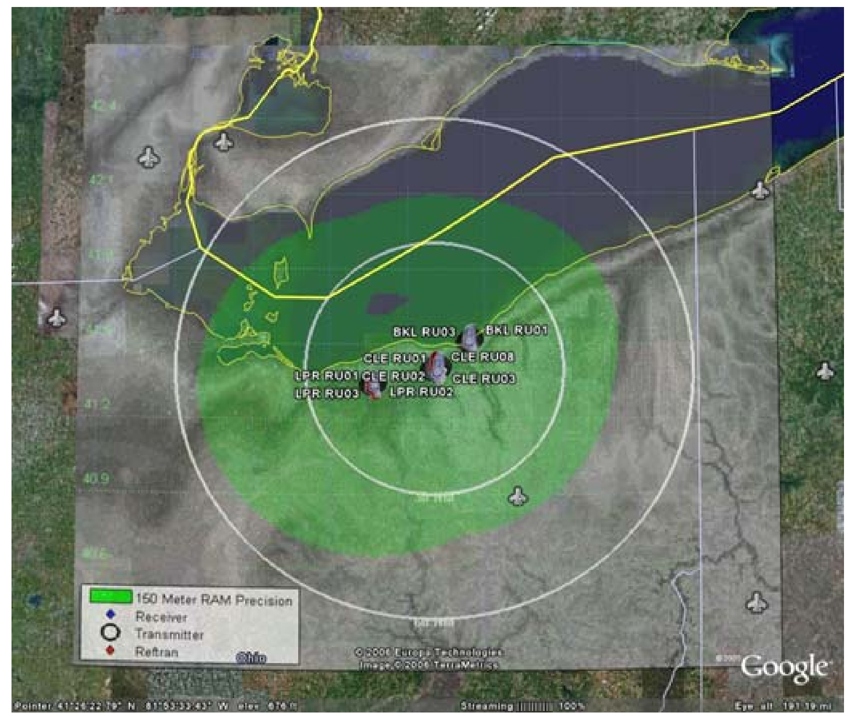


Cleveland Hopkins --- 8 MLAT sites,

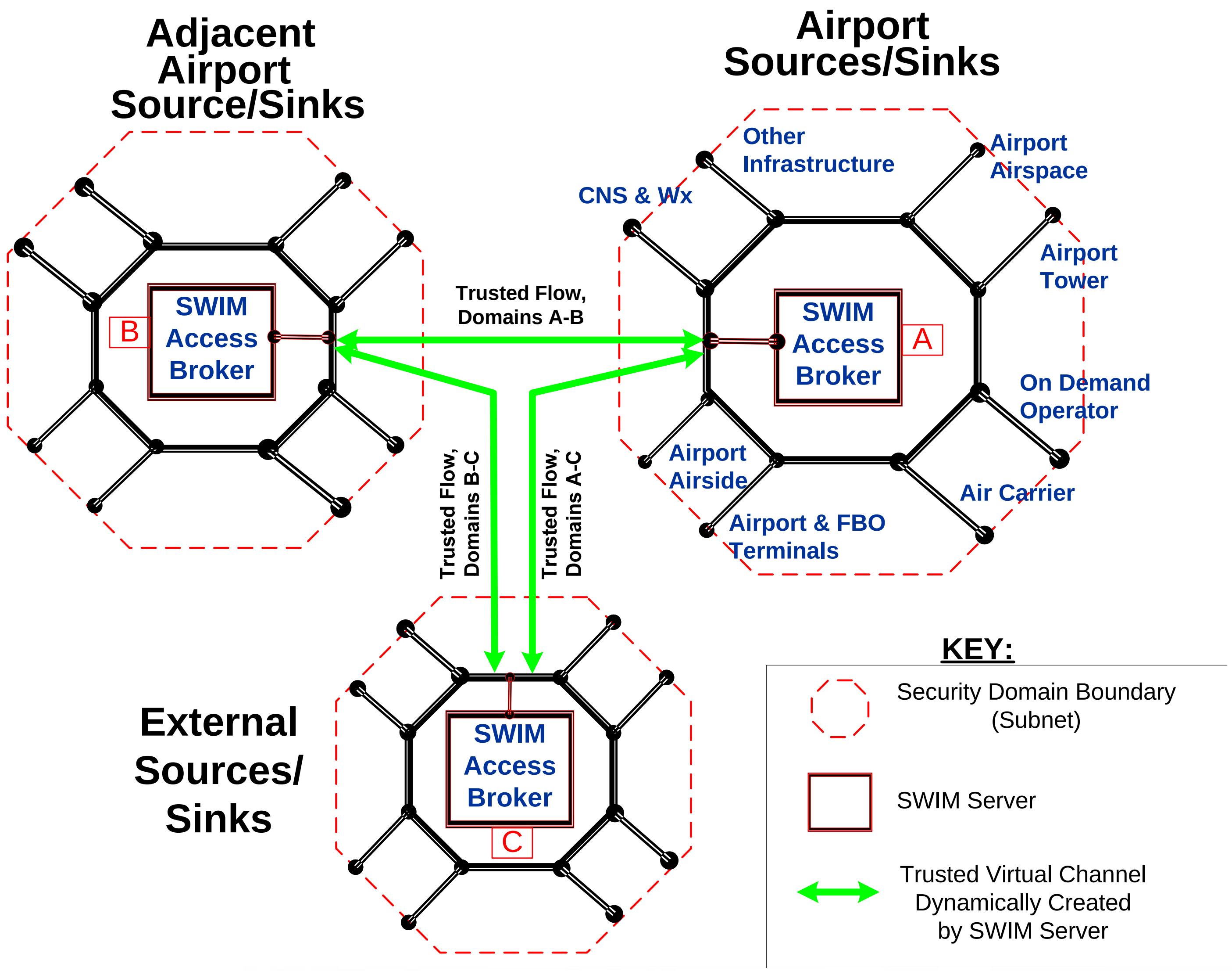
Surface Coverage

Cleveland Terminal Airspace,

ADS-B integrated with MLAT



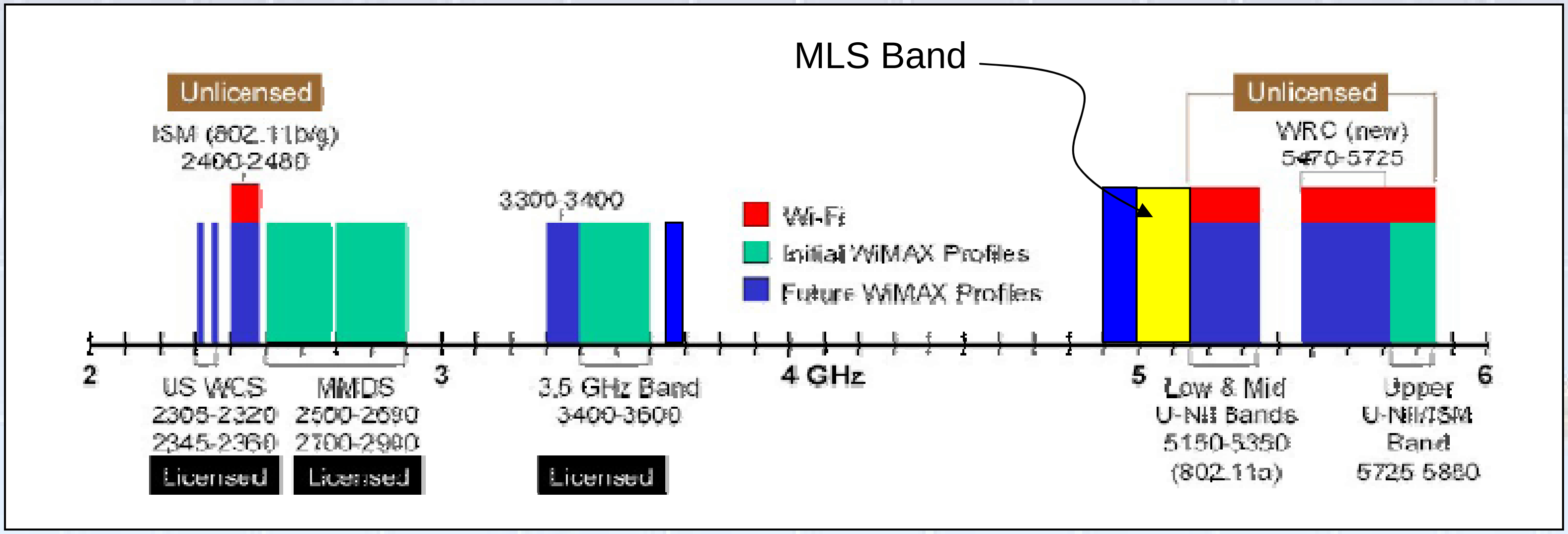
Secure Information Sharing for a Multi-Domain Metroplex



Communications Standards

	802.16/c	802.16a/REVd/2004	802.16e
Spectrum	11-66 GHz	2-11 GHz	2-6 GHz
Channel Conditions	LOS	LOS, NLOS	NLOS
Bit Rate	32-124 Mbps	1-70 Mbps	Up to 50 Mbps
Modulation	QPSK, 16QAM and 64QAM	OFDM 256 sub-carriers, QPSK, 16QAM and 64QAM	SOFDMA
Mobility	Fixed	Fixed, Portable	Mobile (upto 120Km/h)
Channel Bandwidths	20, 25 and 28 MHz	Selectable channel bandwidths between 1.5 and 20 MHz	Selectable channel bandwidths between 1.25 and 20 MHz
Typical Cell Radius	1-3 miles	3-5 miles Maximum range 30 miles based on the tower height	1-3 miles

Proposed WiMAX Spectrum



Key IEEE 802.16e Features

- Maintains user connection while moving at up to 120 km/h(75-93 mph)
- Mobile access in non-line-of-sight (NLOS) condition
- Intended to operate in 2-6 GHz frequency bands
- Data bandwidths of up to 50Mbps
- Cell Radius of 1 to 3 miles
- Flexible RF channel BW between 1.25 MHz to 20 MHz
- Orthogonal Frequency Division Multiple Access (OFDMA) with variable power, spreading and reuse
- Supports a full range of smart antenna technologies: Beamforming, Space-Time Code (STC), Spatial Multiplexing (SM)
- Supports Handoff and Roaming
- Hard Handoff (HHO), Fast Base Station Switching (FBSS) and Macro Diversity Handover (MDHO)
- Supports Multicast and Broadcast Service (MBS)

IEEE 802.16e Adaptive Modulation and Coding

- Support for QPSK, 16QAM and 64QAM are mandatory in the DL, but In the UL, 64QAM is optional.
- Both Convolutional Code (CC) and Convolutional Turbo Code (CTC) with variable code rate and repetition coding are supported.
- Block Turbo Code and Low Density Parity Check Code (LDPC) are supported as optional features.

		DL	UL
Modulation		QPSK, 16QAM, 64QAM	QPSK,16QAM, *64QAM*
Code Rate	CC	1/2, 2/3, 3/4, 5/6	1/2, 2/3, *5/6*
	CTC	1/2, 2/3, 3/4, 5/6	1/2, 2/3, *5/6*
	Repetition	x2, x4, x6	x2, x4, x6

IEEE 802.16e Security Features

- Mutual device/user authentication, flexible key management protocol, strong traffic encryption, control and management plane message protection and security protocol optimizations for fast handovers.

Research Results

Key Results to Date:

- ✈Airport surface communications requirements analysis (NASA Glenn - Trios/SAIC, 2005)
- ✈Airport surface communications spectrum requirements (Mitre, 2006)
  - ✈Concluded that 60 to 100 MHZ of spectrum is required
- ✈Compatibility study of 5091-5150 MHz airport surface LAN and FSS feeder links (Mitre, 2005)
  - ✈Concluded that compatibility is achievable
- ✈Channel sounding campaign to characterize the airport surface channel at 5091-5150 MHz (NASA Glenn, FAA, Ohio University – 2006-06)
  - ✈Gathered data at CLE, MIA, JFK and several smaller airports
- ✈Development of 5019-5150 MHz channel model (Ohio University)
- ✈Modeling of IEEE 802.16e and performance simulation in airport channel using Ohio University model (NASA Glenn – ITT Inc., 2005-06)
  - ✈Concluded that 802.16e is suitable for the airport surface at 5091-5150 MHz
- ✈Research/testing of IP mobility mechanisms (NASA Glenn, on-going)
  - ✈Contributing to development of IP mobility standards through IETF & ICAO

C-Band Channel Model – Ohio U. Measurements

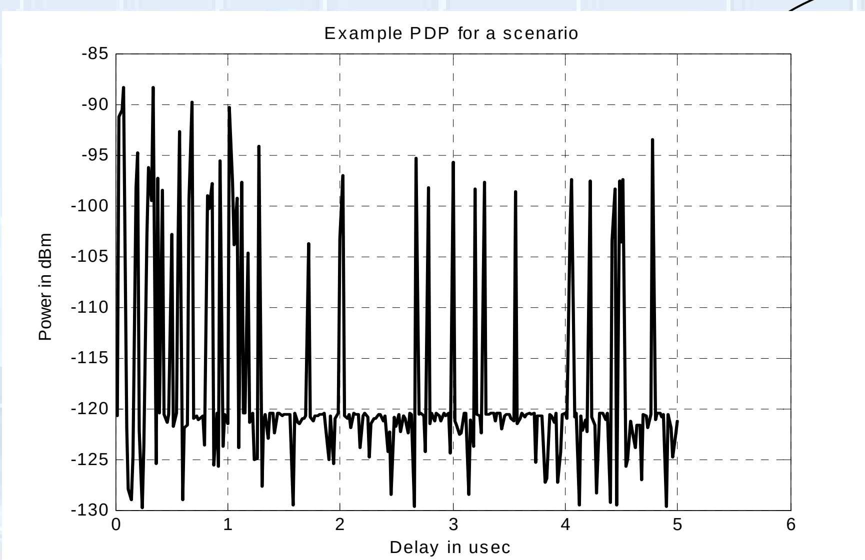
- Ohio University conducted wireless channel characterization of the MLS Extension band (5.091 – 5.150 GHz) for NASA Glenn
- At three large airports (Cleveland, Miami & JFK) and three small airports (Ohio University, Burke & Tamiami)
- Channel sounding has characterized
  - Type of channel (LOS, NLOS and NLOS Specular)
  - Type of airport (small, medium, large)
- Measurements included
  - Mobile and Point-to-point
  - Emulation of communication relay (both Tx & Rx on airport surface)
- Measurements included statistics on
  - Delay Spread, Coherence Bandwidth, Path loss
  - Tap amplitudes, # of taps and correlation between taps

C-Band Channel Model – Ohio U. Measurements

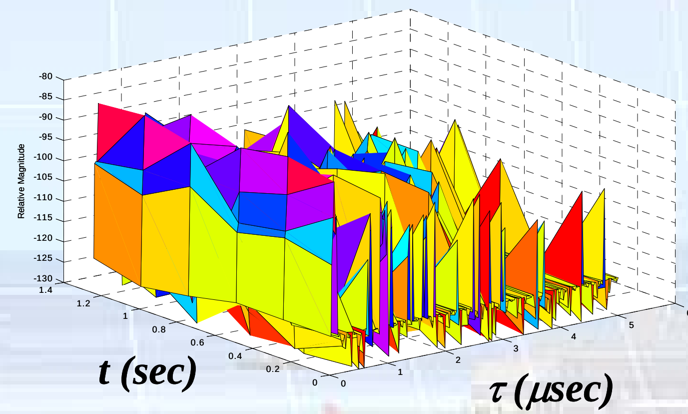
Results enable large scale (for determining coverage and creating link budgets) and small scale channel models (tapped delay lines for waveform simulations).

Major findings include:

- Mobile channel is non-stationary (statistical sense); shows evidence of persistent, long-delay multipath, scattering is non-isotropic, and there is correlation between channel taps
- Point-to-point channel exhibits smaller channel dispersion and much larger coherence bandwidth than mobile channel



Measurements over time



Snapshot of channel showing multiple delayed paths

Time variation of channel