NIST's Programmatic Approach to Advanced Communications:
CTL, CAC, and NASTCN

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Outline

Drivers

NIST organizational response

Communications Technology Laboratory: three priority goals

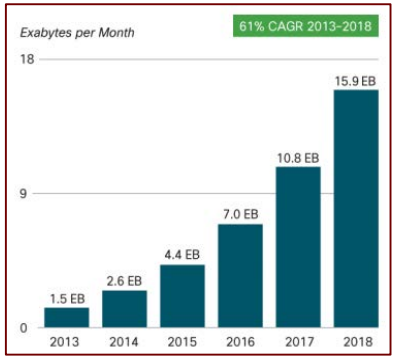
- **background**
- **approach**
- **key activities**

Capability planning priorities

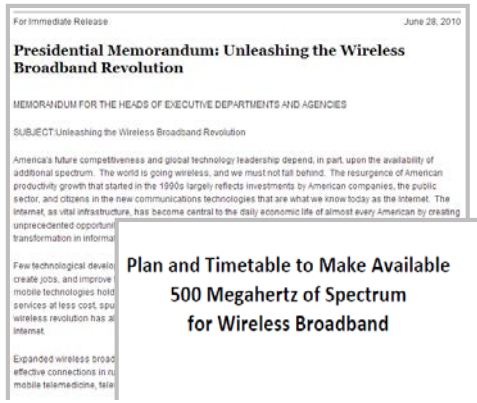
Trends and drivers

Societal demands:

- Insatiable consumption of (mobile) data
- Public safety interoperability



Cisco Visual Networking Index: 2013–2018



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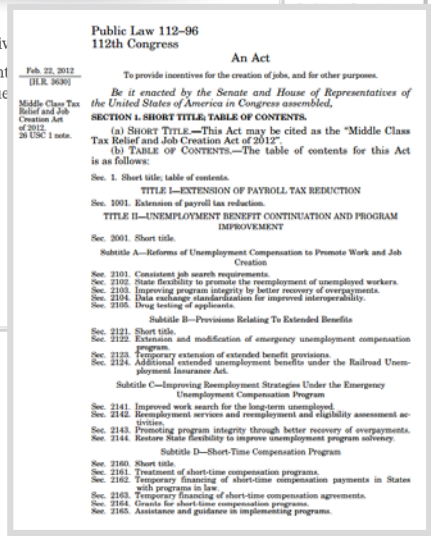


Policy drivers:

2010 National Broadband Plan

- Goals: 300 MHz by 2015; 500 MHz by 2020

2012 PCAST report recommendation

- Share underutilized spectrum to "maximum extent" possible

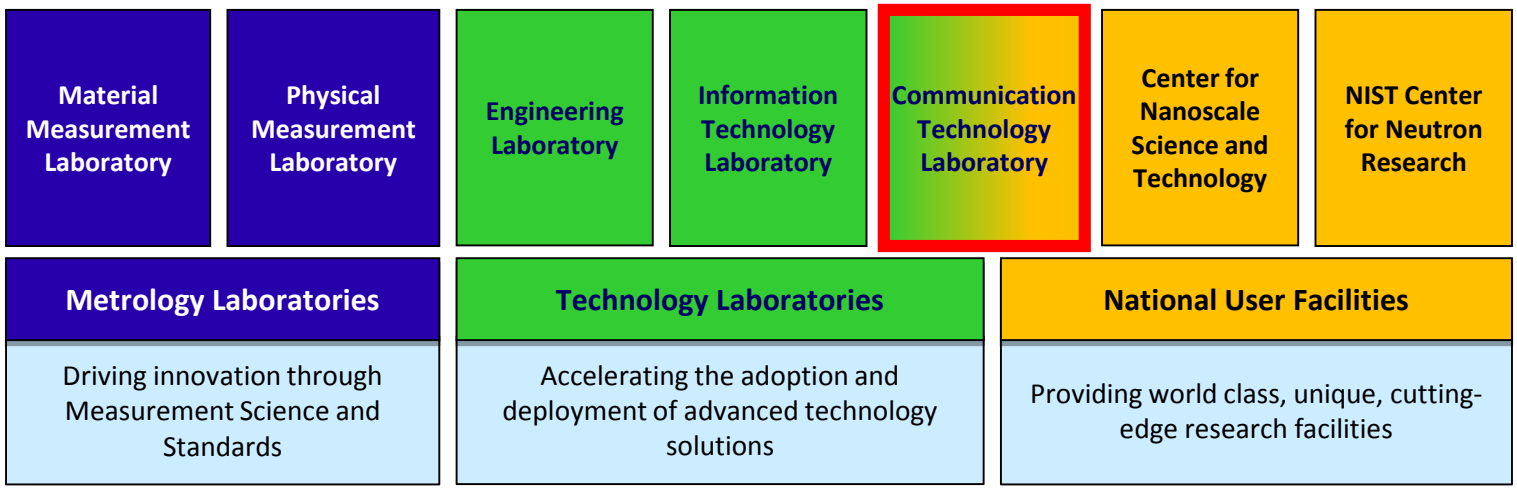
2012 "spectrum act" (Title VI of P.L. 112-96)

- Transfers spectrum from government to commercial use
- Increases unlicensed spectrum
- Authorizes public safety network; provides D block spectrum

2014 FCC

- 3.5 GHz "innovation band" sharing proposal
- "Frontier band" NOI for mm-wave (> 24 GHz)

NIST response: Communications Technology Laboratory



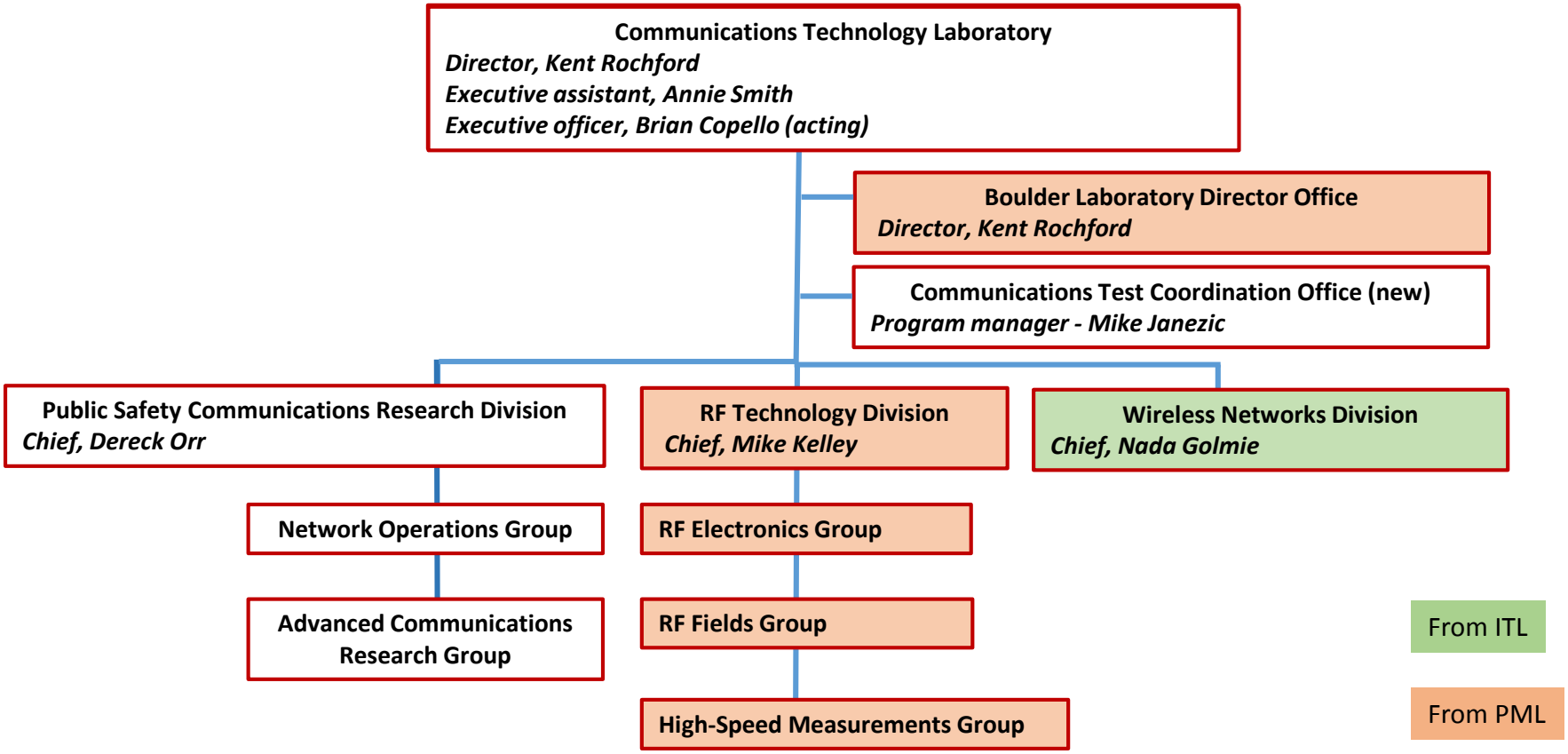
CTL promotes the development and deployment of advanced communications technologies through the conduct of:

- leading edge R&D on both the metrology and understanding of physical phenomena, materials capabilities, complex systems relevant to advanced communications;
- research targeted at supporting testing, including the development of precision instrumentation, validated test-protocols, models, and simulation tools necessary to support the testing and validation of new communications technologies;
- a “Center for Advanced Communications” (with NTIA/ITS) to provide opportunities for collaborative R&D and access to test-bed resources.

Communications Technology Laboratory: organization

Create CTL as a NIST measurement science laboratory to address current and next-generation issues (March 2014)

- Realign to bring communications related programs into CTL (Oct 1)



CTL priority goals

Through the development of appropriate measurements and standards:

1. Enable robust, mission-critical, interoperable **public safety communications**

2. Enable effective and efficient **spectrum use and sharing**
    - Center for Advanced Communications
    - National Advanced Spectrum and Communications Test Network (NASCTN)

3. Enable **advanced communications technologies**

Public safety communications: background

Interoperability among 8000+ public safety jurisdictions is challenging

- Public Safety Communication Research (PSCR) program established by NIST in 2002
  - provides research, development, standards, testing, and evaluation to foster nationwide communications interoperability.

PSCR

- PL 112-96 (2012) created “FirstNet”
  - First Responder Network Authority to provide emergency responders with the first nationwide, high-speed, broadband network dedicated to public safety.

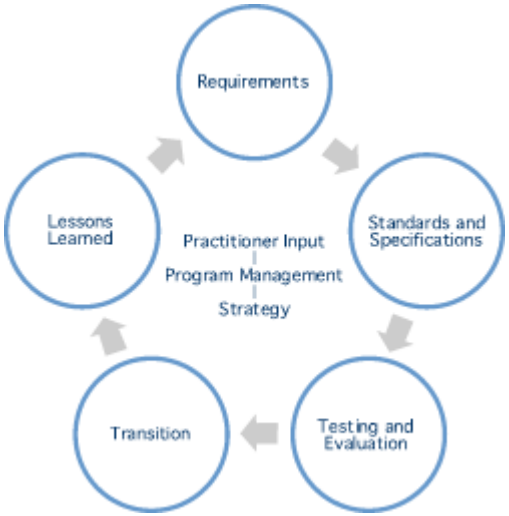
FirstNet™

Public safety communications: approach

The Public Safety Communications Research program has taken a leadership role

- PSCR R&D is driven by practitioner requirements
  - National Public Safety Telecommunications Council
  - Association of Public-Safety Communications Officials
  - DHS-Office of Emergency Communications
  - DHS- Office for Interoperability and Compatibility
  - Public Safety Broadband Stakeholder Conferences
  - PSCR R&D Roadmap Workshop

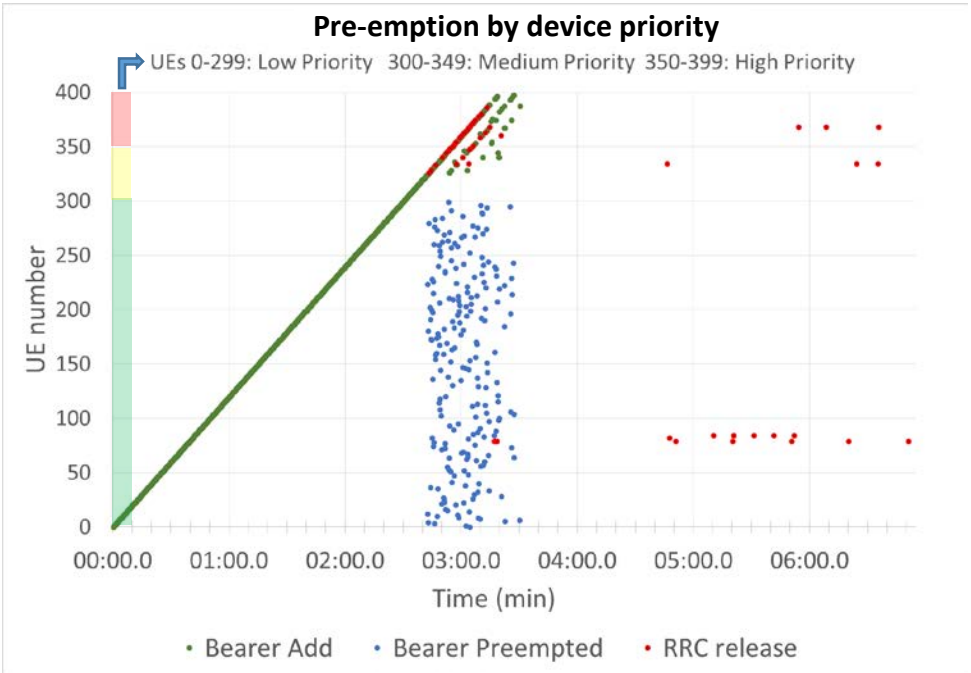
- PSCR transforms practitioner input into real-world results



Public safety communications: key activities

Develop and validate public safety comms requirements

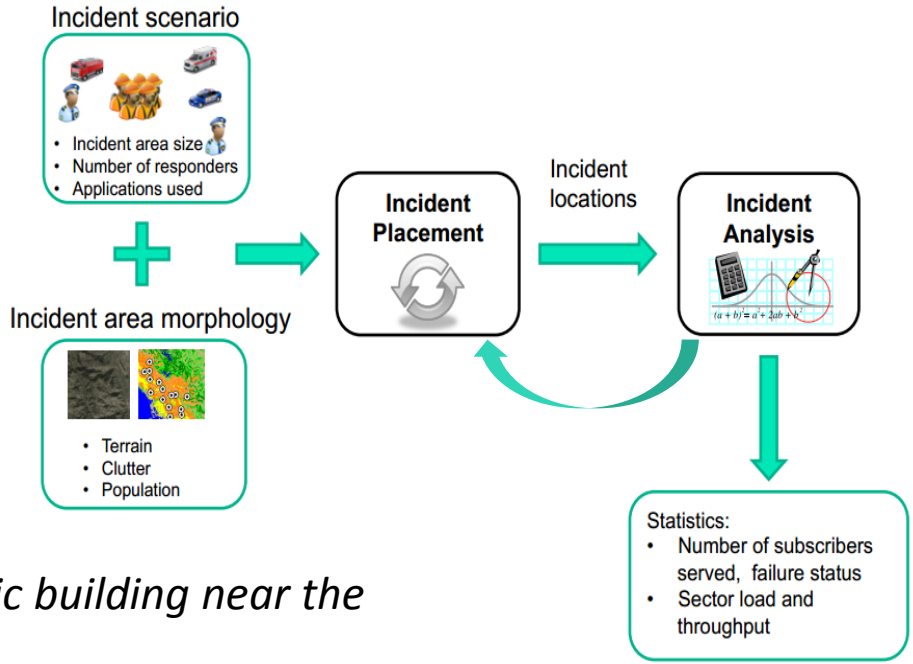
- Gather first responder requirements
- Develop required LTE standards within 3GPP
  - Direct Mode
  - Mission Critical Push-To-Talk
  - Group Communications
- LTE Demonstration network
  - 5 LTE base stations
  - Over 75 CRADAs
- Testing & Evaluation
  - Quality of Service
  - Priority & Pre-emption



Public safety communications: key activities

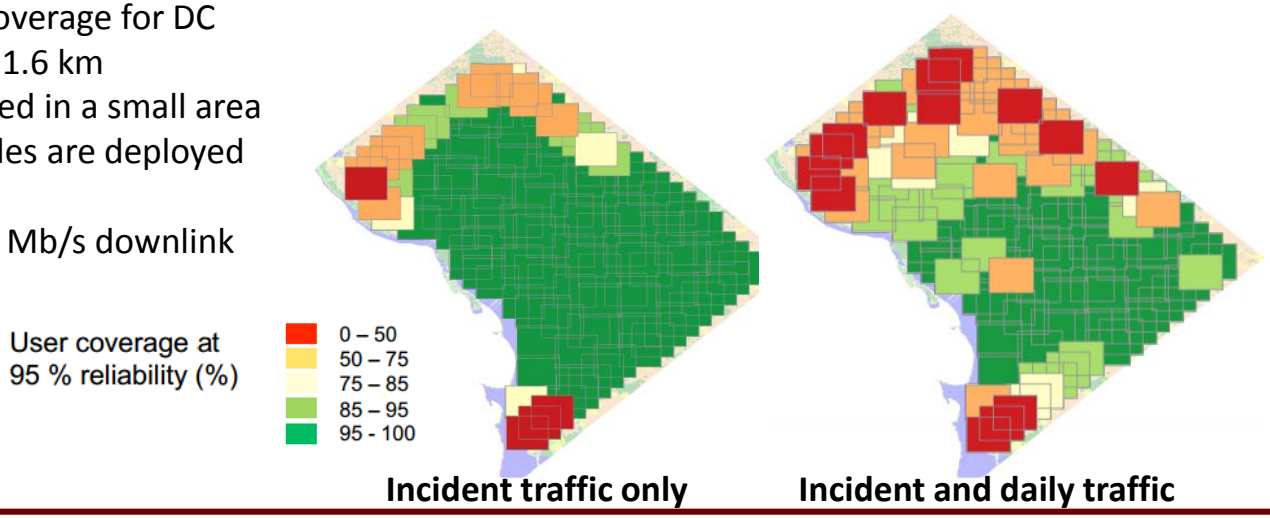
Inform FirstNet requirements

- Modeling & Simulation
  - **Incident Modeling**
  - Site count estimation
  - Excess capacity analysis
  - Resiliency analysis



Scenario: *"toxic gas leak in a large public building near the National Mall in Washington, DC."*

- Use known geodata and cell coverage for DC
- Incident perimeter is 1.6 km x 1.6 km
- Incident command concentrated in a small area
- 327 responders and 127 vehicles are deployed uniformly in the incident area.
- Aggregate 7.4 Mb/s uplink; 11 Mb/s downlink



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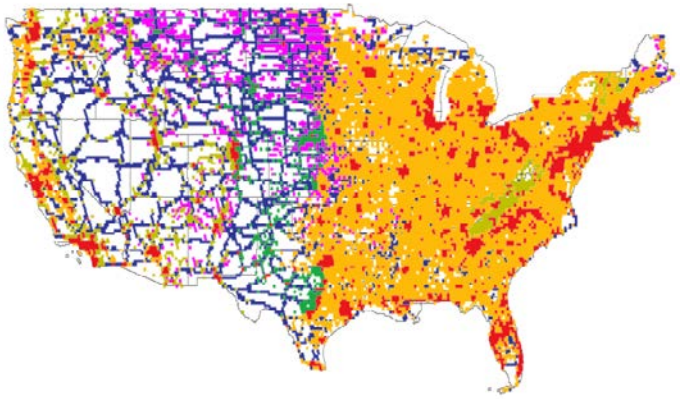
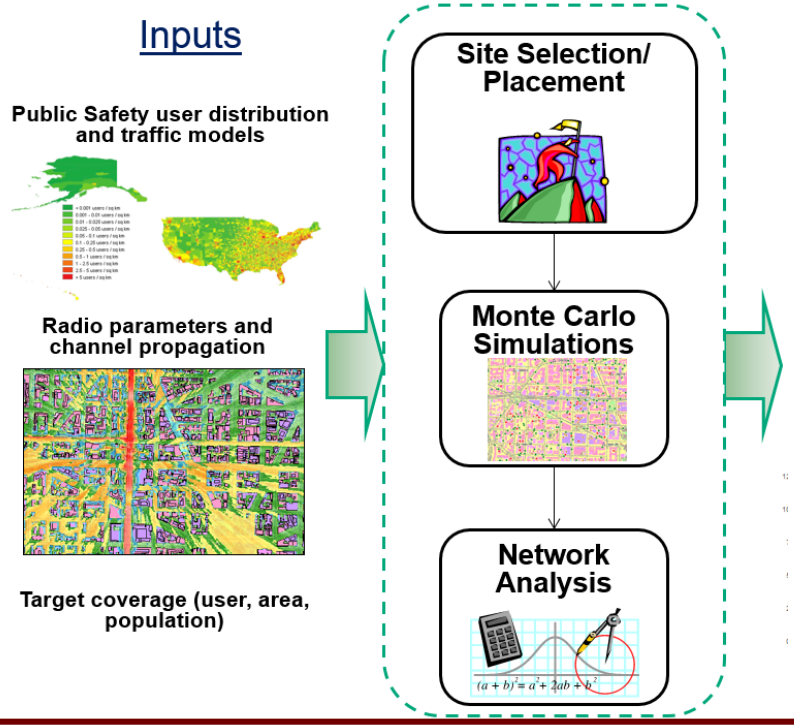
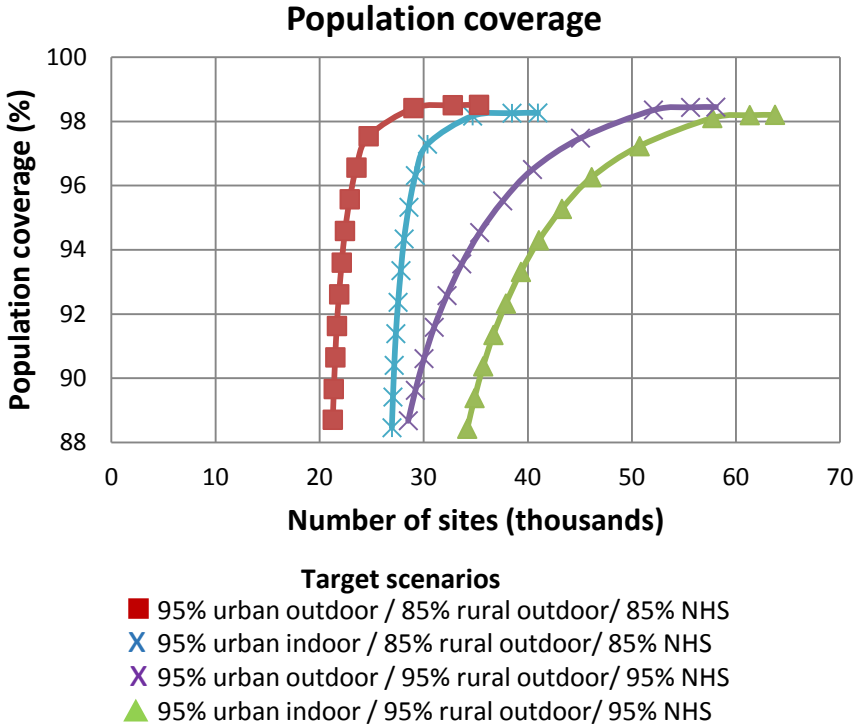






CTL priority goals

Through the development of appropriate measurements and standards:

1. Enable robust, mission-critical, interoperable **public safety communications**

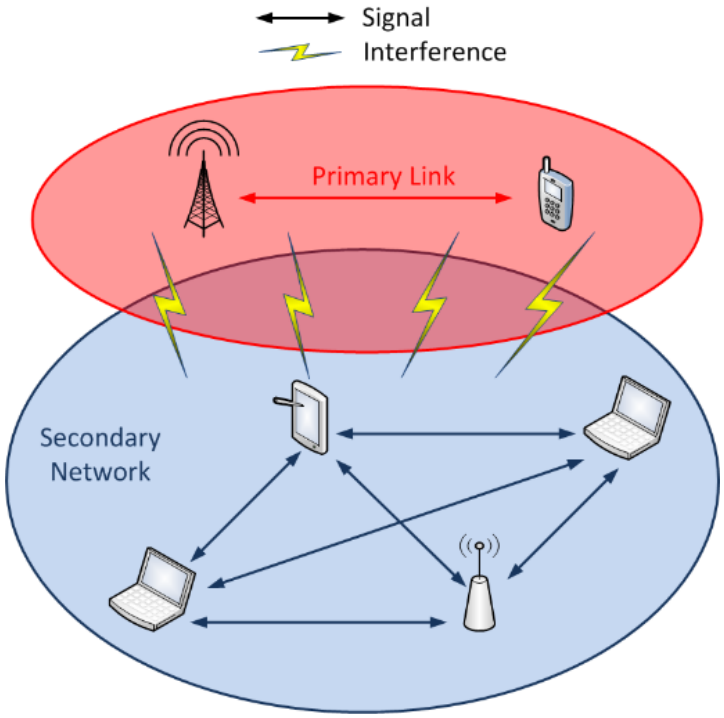
2. **Enable effective and efficient spectrum use and sharing**
    - Center for Advanced Communications
    - National Advanced Spectrum and Communications Test Network (NASCTN)

3. Enable **advanced communications technologies**

Spectrum sharing: background

The Administration has directed the reallocation or sharing of 500 MHz from federal use to commercial use to spur innovation

- National Broadband Plan directs efficient use of federal spectrum
- PL 112-96 (2012) transfers some spectrum and increases unlicensed spectrum
- PCAST report (2012) and FCC's 3.5 GHz "innovation band" proposal (2014) encourages tiered access (Spectrum Access System) and small cells
- DOD and other agencies with target spectrum are seeking ways to analyze trade-offs and understand impacts using less conservative estimates



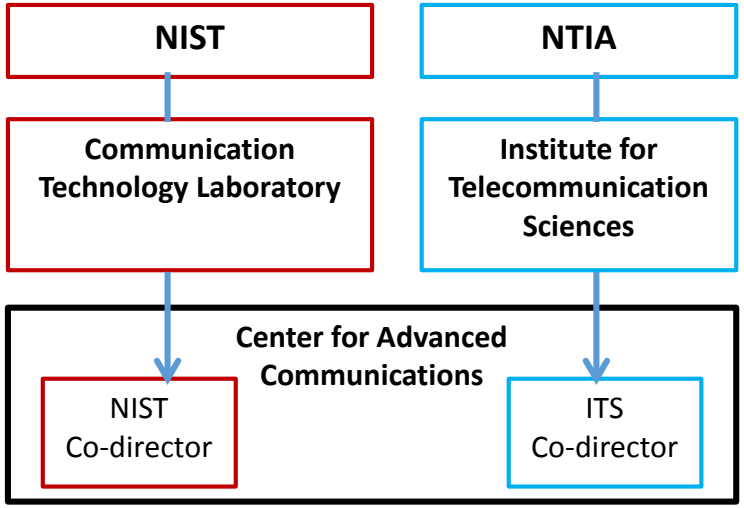
Spectrum sharing: approach

Create the Center for Advanced Communications (CAC)
A joint NIST / NTIA center

CAC is to advance the fundamental understanding of spectrum usage to promote spectrum sharing approaches and innovation.

Key Functions:

- Enhance mission effectiveness of NTIA and NIST by coordinating research, standard development and testing functions
- Promote interdisciplinary research, development, and testing in advanced communications
- Provide a single focal point for engaging both industry and other government agencies on advanced communications technologies



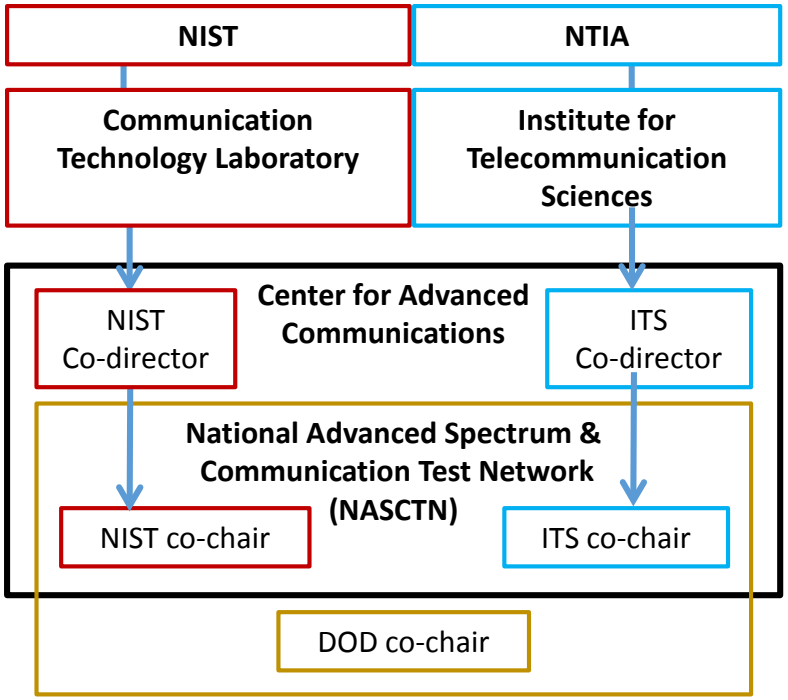
Spectrum sharing: approach

National Advanced Spectrum & Communication Test Network (NASCTN)
A DOC and DOD partnership

NASCTN is a network of government, academic and commercial capabilities able to coordinate the use of intellectual capacity, modeling and simulation, laboratory, and test ranges to meet national spectrum interests and challenges.

<u>Key Functions:</u>

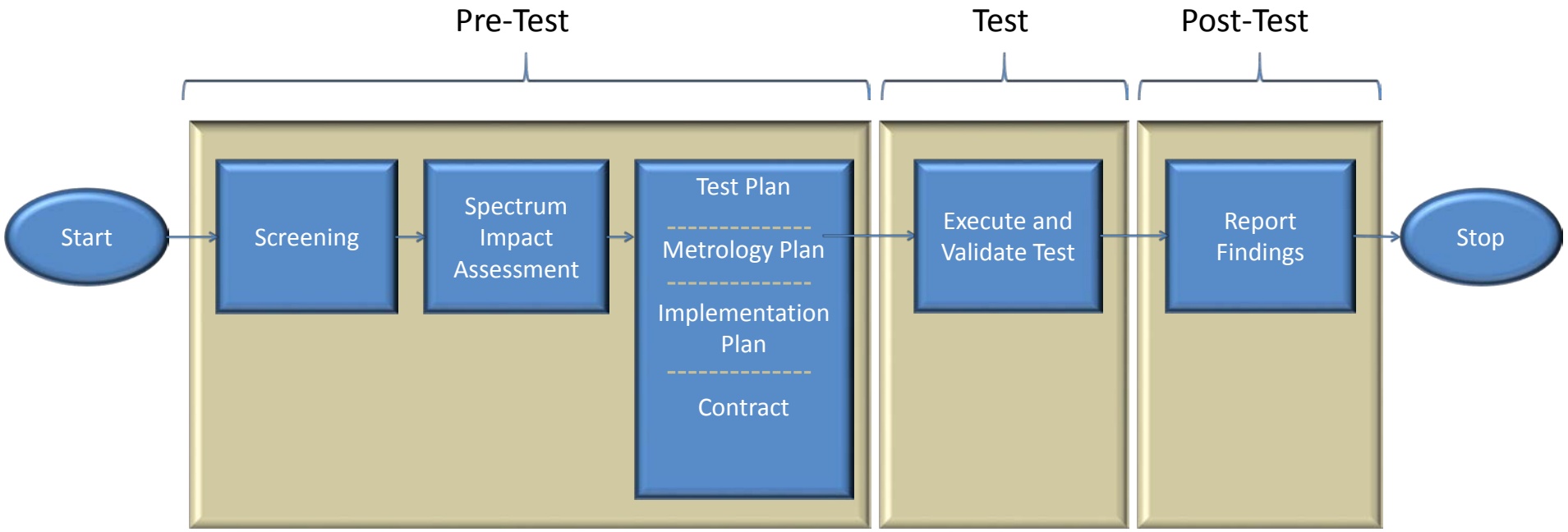
- Facilitate and coordinate spectrum sharing and engineering capabilities
- Create a trusted capability for spectrum sharing evaluations
- Protecting information (proprietary, classified, and sensitive) while facilitating maximum dissemination



Spectrum sharing: key activities

Develop methods for NASCTN engagement

- NASCTN provides a framework for negotiating a measurement science-based test plan, facilitates access to test ranges and laboratories, and methods for validating results.

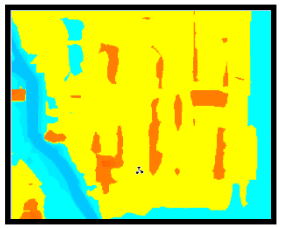


Spectrum sharing: key activities

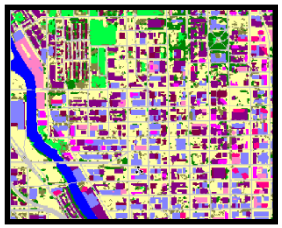
Improve measurements and analyses that enable sharing

Interference metrics determine spectrum re-use

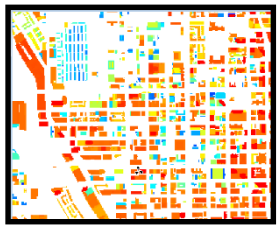
- ITS/CTL clutter measurement campaign
  - 3.5 GHz a hot area for reallocation / sharing
  - Better understanding of 3.5 GHz propagation may improve decision-making
  - ITS to provide field measurements
  - Apply CTL/SED DOE and uncertainty analyses
  - Compare to “state of the art” models



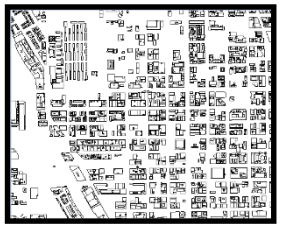
1. TERRAIN HEIGHT



2. LAND USE (CLUTTER)



3. CLUTTER HEIGHT



4. BUILDING MORPHOLOGY

AVERAGE RSS PREDICTION

Spectrum sharing: key activities

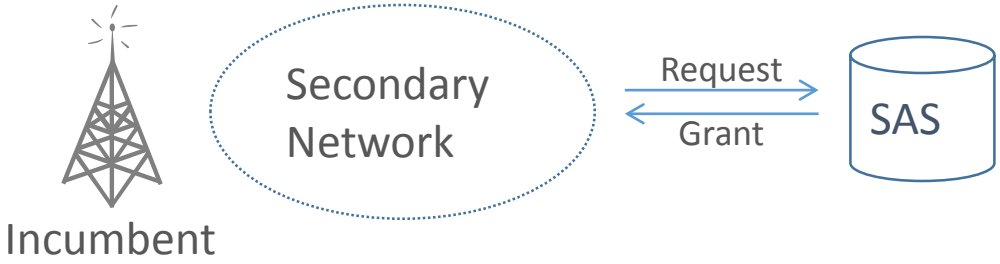
Improve sensing and monitoring techniques

Determine spectrum occupancy for coordination and planning

- Develop a spectrum monitoring pilot program (CTL/ITS collaboration)
- Wideband sensing using sub-Nyquist sampling; Sensing in low S/N environments

Develop sharing technologies

- Evaluate dynamic spectrum access systems



- Develop distributed algorithms for spectrum sharing by secondary systems
- Evaluate control channel alternatives

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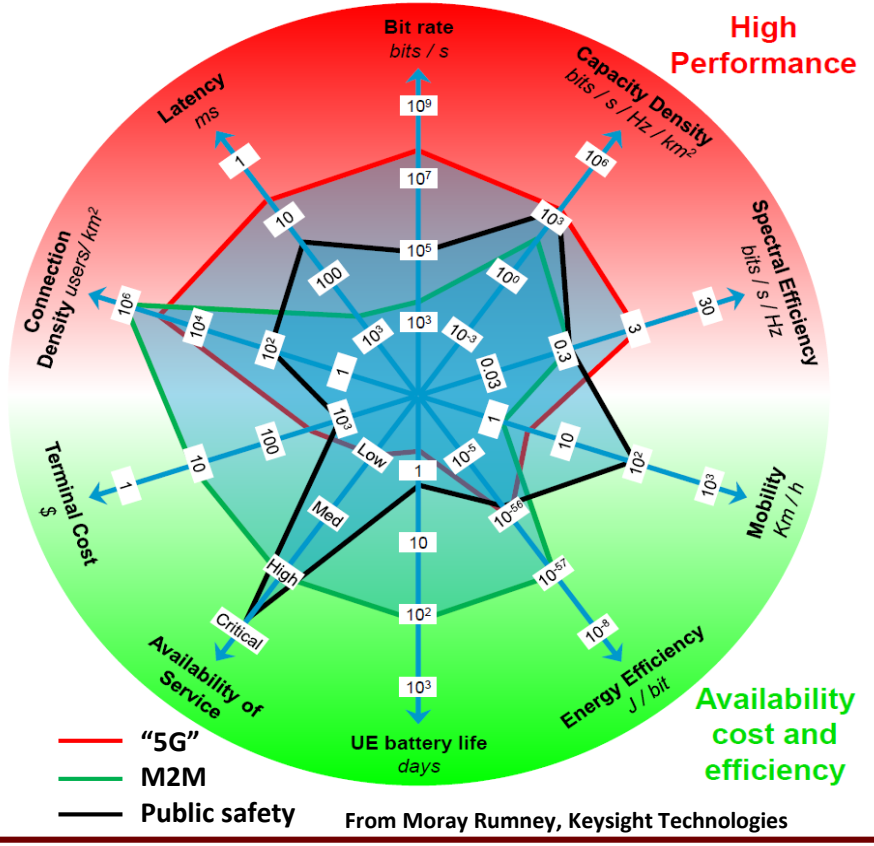
Advanced communications technologies: background

CTL is to perform leading edge R&D on both the metrology and understanding of physical phenomena, materials capabilities, and complex systems relevant to advanced communications

Expert measurement science is required to support CAC/NASCTN, spectrum sharing, and public safety challenges

Forward-looking opportunity

- Trends predict 1000x increase in wireless capacity density demand
- Foresee new and diverse use cases
- Industry participants are now discussing next generation “5G” wireless technology for an aggressive 2020 launch.



From Moray Rumney, Keysight Technologies

Advanced communications technologies: background

Europe and Asia are leading 5G activities

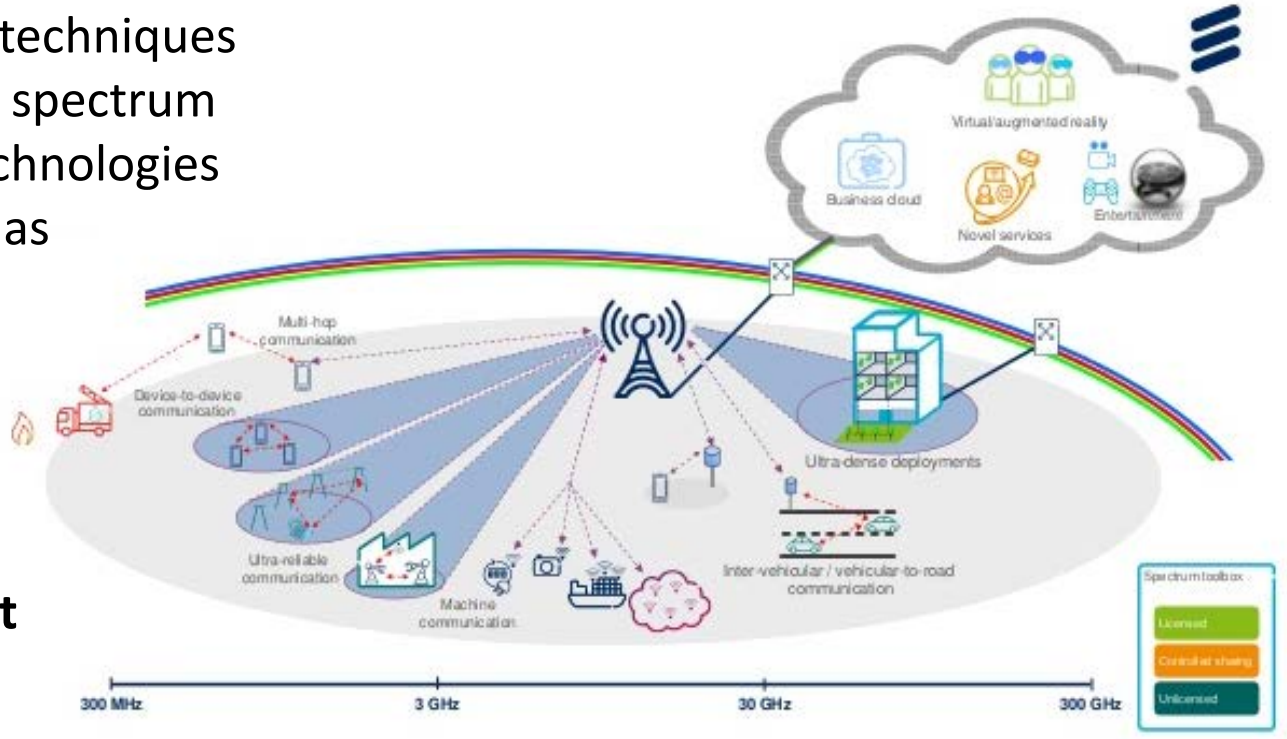
- 5GPPP (EU)
  - Horizon2020 program: €1.4B
  - Framework 7: €125M
- METIS (EU)
  - Funded €29 M (2012-2015)
- Korean 5G forum
  - ROK to expend $1.5B through 2020
  - EU and ROK signed agreement to cooperatively define global 5G standards
- UK 5G Innovation Center / Spectrum Policy Forum
  - €35M university center
- IMT2020 Promotion Group (China)
  - Three Chinese ministries (MIIT, NDRC and MOST)
- "2020 and Beyond Ad Hoc (20B AH)" (Japan)
- Global ICT Standardization Forum for India

Advanced communications technologies: approach

5G is still in the technology development and definition phase

- 5G may include use of
  - Licensed spectrum and shared use of unlicensed spectrum
  - Dense, heterogeneous, and agile networks
  - Device-to-device and multi-hop modes
  - New modulation techniques
  - Higher frequency spectrum
  - Multiple radio technologies
  - Advanced antennas

CTL has a window to develop measurement R&D that enables US technology development and standards



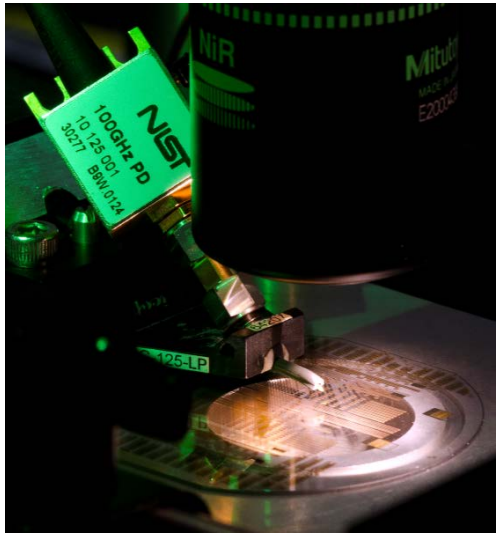
Forbes.com 5/17/2013

Advanced communications technologies: key activities

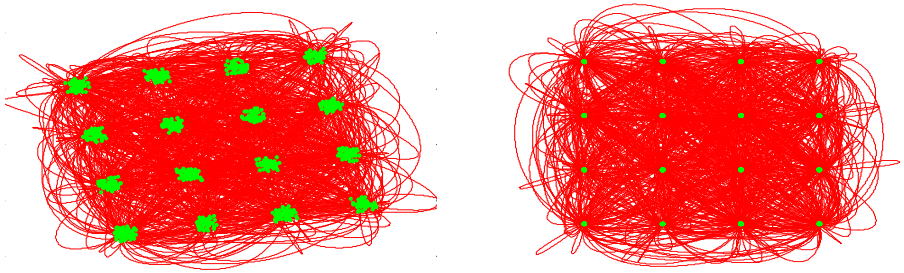
Waveform measurement and traceability

Supports modulated signals characterization

- Electro-optic sampling to provide calibration of waveform instruments to >100 GHz
- Large-signal analysis to 300 GHz
- Precision reference source to 94 GHz for EVM
- Robust point-by-point uncertainty framework
- Calibration services



Electro-optic sampling probe



45GHz 16QAM @ 17% and 0.2% Error Vector Magnitude (EVM)

NIST calibrated photodiode

This work provides a fundamental measurement core to support NASCTN, sharing, next-generation frequencies/bandwidths, and test equipment manufacturers

Advanced communications technologies: key activities

Coexistence measurement science

More wireless in more places demands better interference criteria

- Improve EMC measurements to ensure compatibility of varied wireless applications
- Improve interference criteria to decrease exclusions zones and increase spectrum reuse
- Develop a measurement science approach that includes uncertainties, confidence intervals, and statistical performance.

This work also provides measurement science support to NASCTN and sharing activities

Advanced communications technologies: key activities

"5G wireless" – millimeter waves

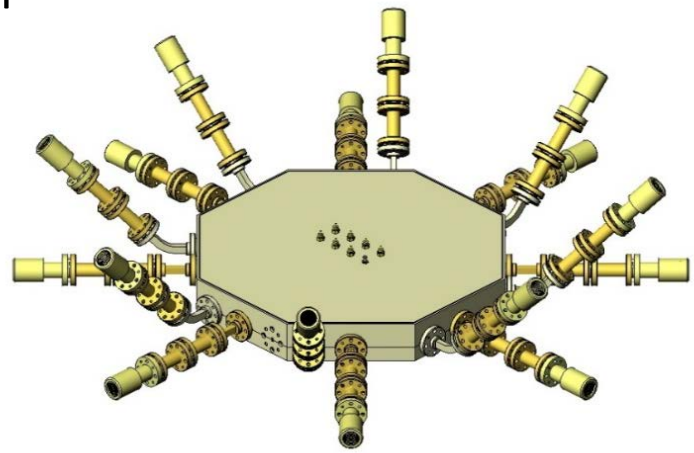
Require 3D channel and propagation models

- Improve measurements in
  - Channel sounding (directional)
  - Large-scale path loss and blocking
  - Small-scale delay characteristics
  - 3D Spatial channel characteristics for MIMO

Small cells within macrocell

- Create measurement-based statistical models of realistic channels

- Use models to identify gaps in current communication protocols

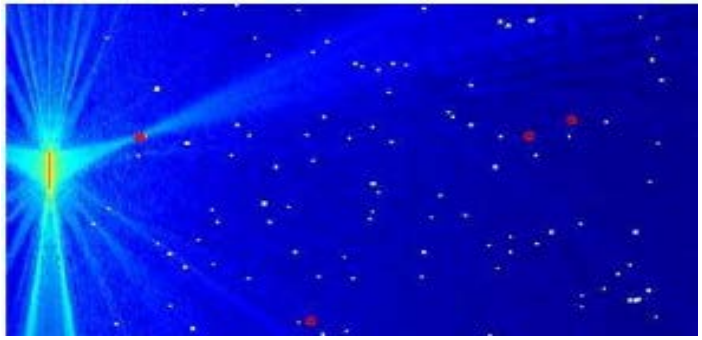


NIST 83 GHz channel sounder

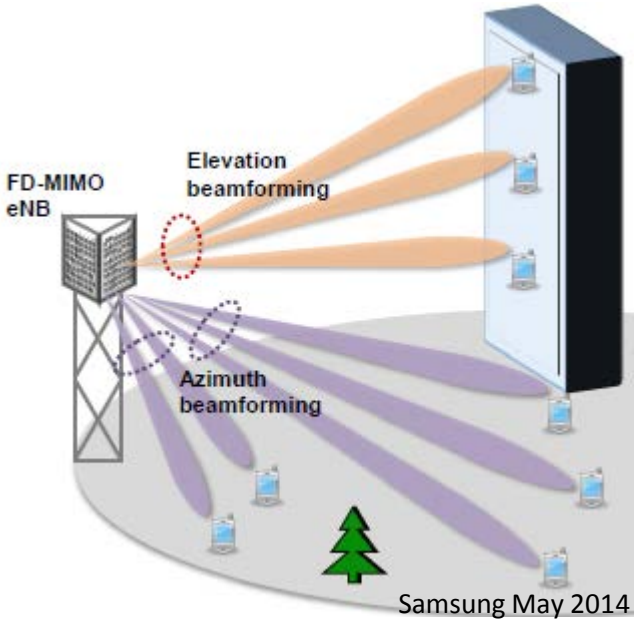
Advanced communications technologies: key activities

Massive MIMO (multiple input multiple output) antennas

A key 5G technology for throughput



200 antenna MIMO simulation



Samsung May 2014

- Requires entirely new antenna characterization methods
- Compare: Current LTE MIMO is 2x2; CTIA OTA test uses 8 transmitter cluster
  - Long calibration and test time (8 channels)
  - Test zone limited to ~0.7λ (small for M2M devices?)
  - Limited "sampling": 8 angles, azimuthal only
  - Uncertainties unknown; Test plan is not final
  - *Not scalable to 20, 50, or more antennas!*

Current collaborations

Federal agencies:

DHS, FirstNet, DOD, DARPA, DOE, FDA

Telecommunication Standard Development Organizations:

IEEE 802, 3GPP, CTIA, ISA, TIA, ATIS, IETF, ETSI, IEC, ISO

Industry Alliances:

WiMAX, WiFi Alliance, Zigbee Alliance, Bluetooth SIG, OneM2M

User's groups:

National Public Safety Telecommunications Council, Association of Public Safety Communications Officials

Manufacturers:

Network equipment, Electronics devices and modules, Test equipment

National Metrology Institutes

NPL (UK), PTB (Germany)

Capability planning priorities

1. National Advanced Spectrum and Communications Test Network (NASCTN)

- Create program infrastructure
- Build competence for technical execution (incl. ITL/SED hires)

2. Situational awareness measurements & analytics for public safety comms

- R&D into applications to drive new standards

3. Metrology for next generation wireless networks

- Strengthen spectrum sharing, coexistence, and channel propagation and modeling expertise
- Develop measurements to support 5G features: massive-MIMO, mm-wave, ultra-dense networks
- Support development of 5G standards and pre-standards activities

4. Optical communications metrology

- Address fiber bottleneck as wireless challenges are solved

Scope decision
Seed key areas anticipating future growth

Current funding

Not funded