NASCTN CBRS Sharing Ecosystem Assessment: Always-On Dynamic Protection Area

Test Plan Community Brief

02/22/2023 – DRAFT – POSTED FOR PUBLIC INPUT

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National Advanced Spectrum and Communications Test Network

National Advanced Spectrum and Communications Test Network (NASCTN)

NIST hosts NASCTN Program Office and a core team to ensure rapid response, access to key skills, consistency, and knowledge management.

NASCTN is a multi-agency, chartered organization that includes DoD, NASA, NIST, NOAA, NSF, and NTIA.

The purpose of NASCTN is to improve opportunities for successful spectrum sharing through accurate, reliable, and unbiased measurements and analyses.

Through its members, NASCTN provides:

- **Robust test processes** and **validated measurement data** necessary to develop, evaluate and deploy spectrum sharing technologies
- Best practices for spectrum sharing **metrology, testing, measurement, and data analysis** to improve quality of information provided to the spectrum community
- **Access** to testing capabilities, spectrum test data, analyses, and reports

National Advanced Spectrum and Communications Test Network (NASCTN)

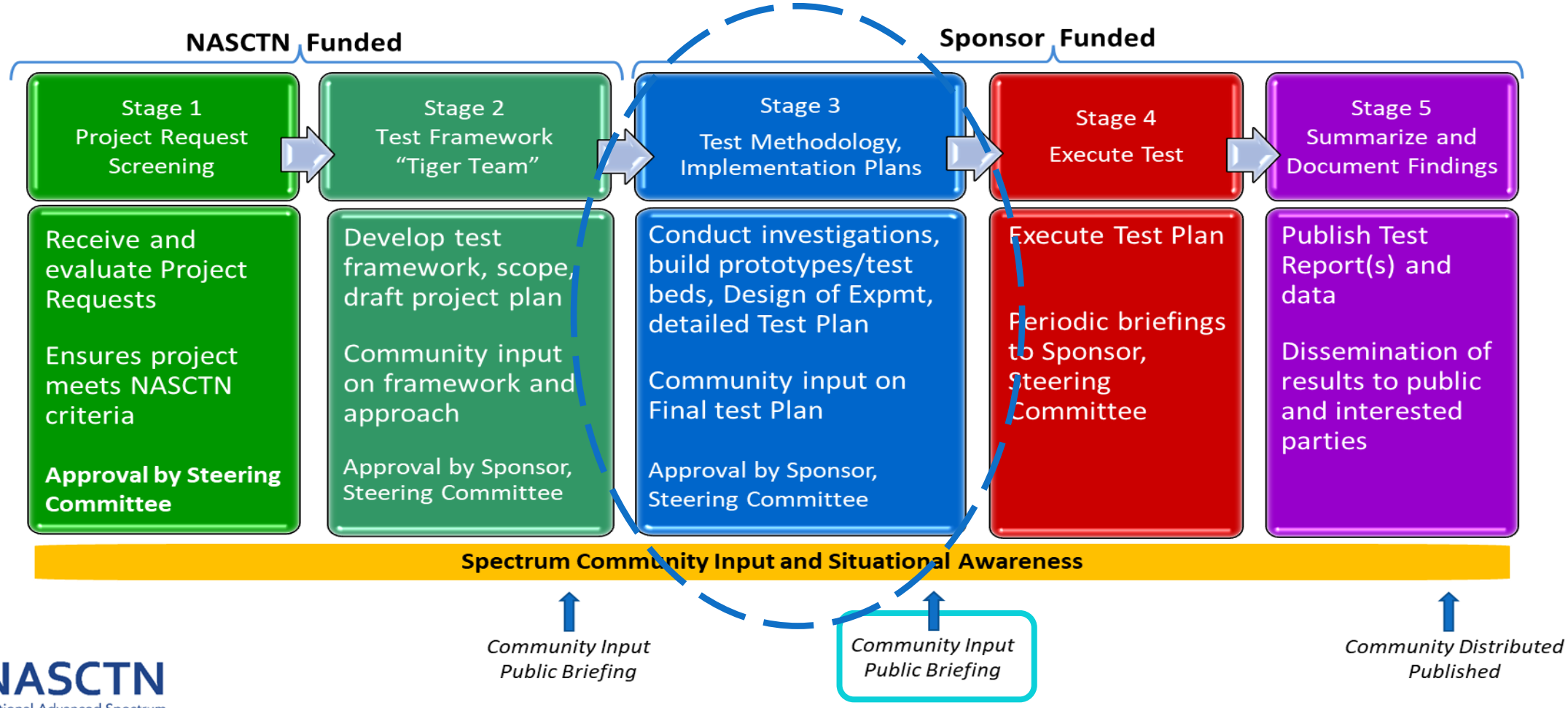
NASCTN:

- Develops Test Plans with independent technical experts
- Identifies and facilitates access to appropriate test facilities
- Executes and validates scientifically rigorous test methodologies
- Delivers detailed test methods and data with transparency, validity, and reproducibility
- Protects all controlled information (proprietary, sensitive, classified)

NASCTN does not make policy recommendations

NASCTN 5-Stage Framework

NASCTN projects follow an open, transparent, comprehensive process for developing and executing *independent*, scientifically based test plans, validating test results, and reporting findings. Serves as a common architecture across all NASCTN projects.



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TEST REQUEST: DoD CBRS Sharing Ecosystem Assessment (SEA) program

Background: DoD 3.5 GHz Transition Plans focus on ecosystem validations, environmental assessments, and continued engagement on refining the CBRS infrastructure. One component was identified for submission to NASCTN, *to evaluate the effectiveness of the CBRS sharing ecosystem to co-exist with DoD radar systems, via independent trusted agent*

Test Request: CBRS Sharing Ecosystem Assessment (SEA)

Collect data required for DISA DSO to ascertain the effectiveness of the sharing ecosystem between CBRS systems as managed by Spectrum Access Systems (SASs), and DoD systems as monitored by Environmental Sensing Capabilities (ESCs). Provide insight into the sharing ecosystem's effectiveness, and track changes in the spectrum environment over time.

4 Key Objectives:

Provide data driven insights into:

1. Efficacy of permanent sharing between CBRS systems as managed by SASs and DoD systems
2. Noise floor measurements through continuous automated observations
3. CBRS emissions within the Always-On Dynamic Protection Areas at Army and Marine sites

Support:

4. The development & management of a measurement data repository

2 Phases:

- Phase 1: Establish the measurement system requirements; develop, build, deploy a metrology system to measure the CBRS ecosystem performance at DoD sites.
- Phase 2: Long-term analysis phase, with continuous noise floor measurements and annual deep dive measurements and analysis.

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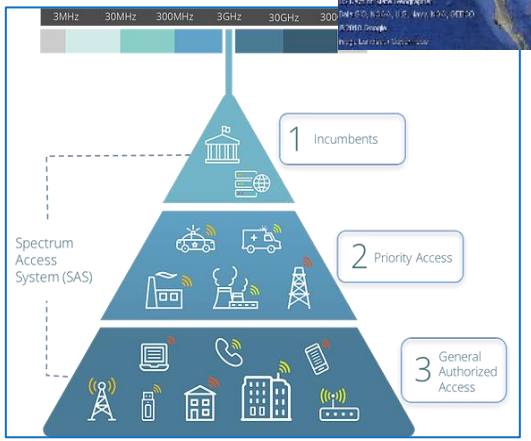
Citizens Broadband Radio Service (CBRS)

The Citizens Broadband Radio Service (CBRS) is the "first of a kind" shared spectrum ecosystem, implemented nationwide.

- **Shared band, 3 tier approach** - Incumbent, Priority Access License, General Authorized Access
- **Sharing stipulations –** FCC part 96
- **Environmental Sensing Capability (ESC)** detects incumbents and **Spectrum Access Systems (SAS)** coordinates spectrum access
- Sharing is coordinated in **Dynamic Protection Areas (DPA)s:** E-DPA (serviced by ESCs), P-DPA (database/portal based), and GB/Always-On DPA (ground base/always on)



Reference: https://ongoalliance.org/the-technology-behind-spectrum-sharing-the-spectrum-access-system/

NASCTN Project: Provide data-driven insight into the CBRS sharing ecosystem's effectiveness between commercial and DoD radar systems, and to track changes in the spectrum environment over time.

NASCTN SEA Project Approach

To achieve the 4 objectives, 5 major technical tasks were identified:

Passive Observation:

Measure Aggregate Emissions in the CBRS Band in Always-On DPAs

- Characterize emission levels in the CBRS band over time in always-on DPAs.
  - Obj 1: Collect data to provide insights into the Always-On Dynamic Protection Areas
  - Obj 2: Measure increase in background emissions due to deployment of wireless systems over time

- **Measure Aggregate Emissions in the CBRS Band in Coastal DPAs**
  - Characterize aggregate CBRS emissions with and without DPA activations.
    - Obj 1: Assess ecosystem performance to timely respond
    - Obj 2: Measure increase in in background emissions due to deployment of wireless systems over time

Active Experimentation:

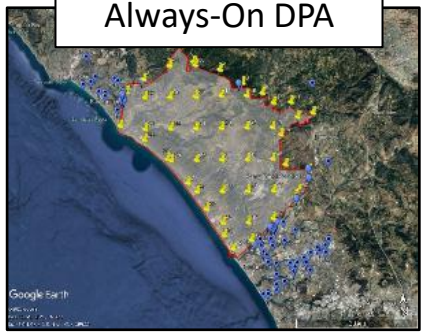
- **Evaluate ESC Performance in the Field (with Navy Ship)**
  - Assess ESC detection performance for a representative set of ESCs in the field.
    - Obj 1: Collect data on ESC site alerting due to Navy transmission. Assess true-positive and false-positive rates and independently verify incident power levels at ESC sensor locations
  - Coordinated investigation with Federal and commercial stakeholders

Long Term Support:

- **Long Term Data Analysis of the measurements**
- **Support DoD Measurement Data repository**

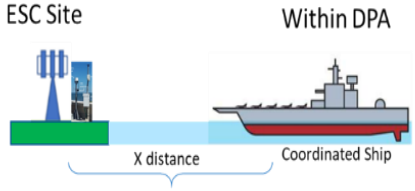
DPA - Dynamic Protection Area

Always-On DPA

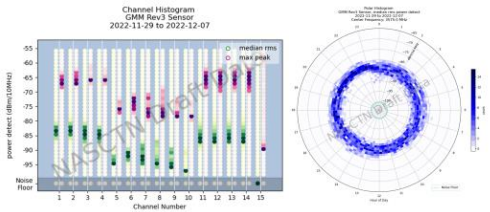


Coastal DPA

ESC Field Performance



LT Data & Analysis



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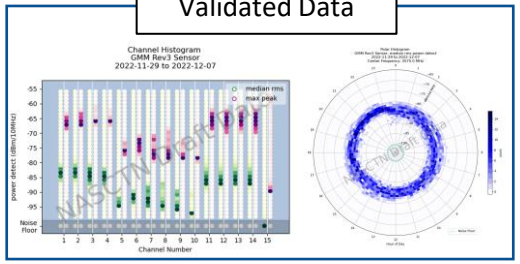
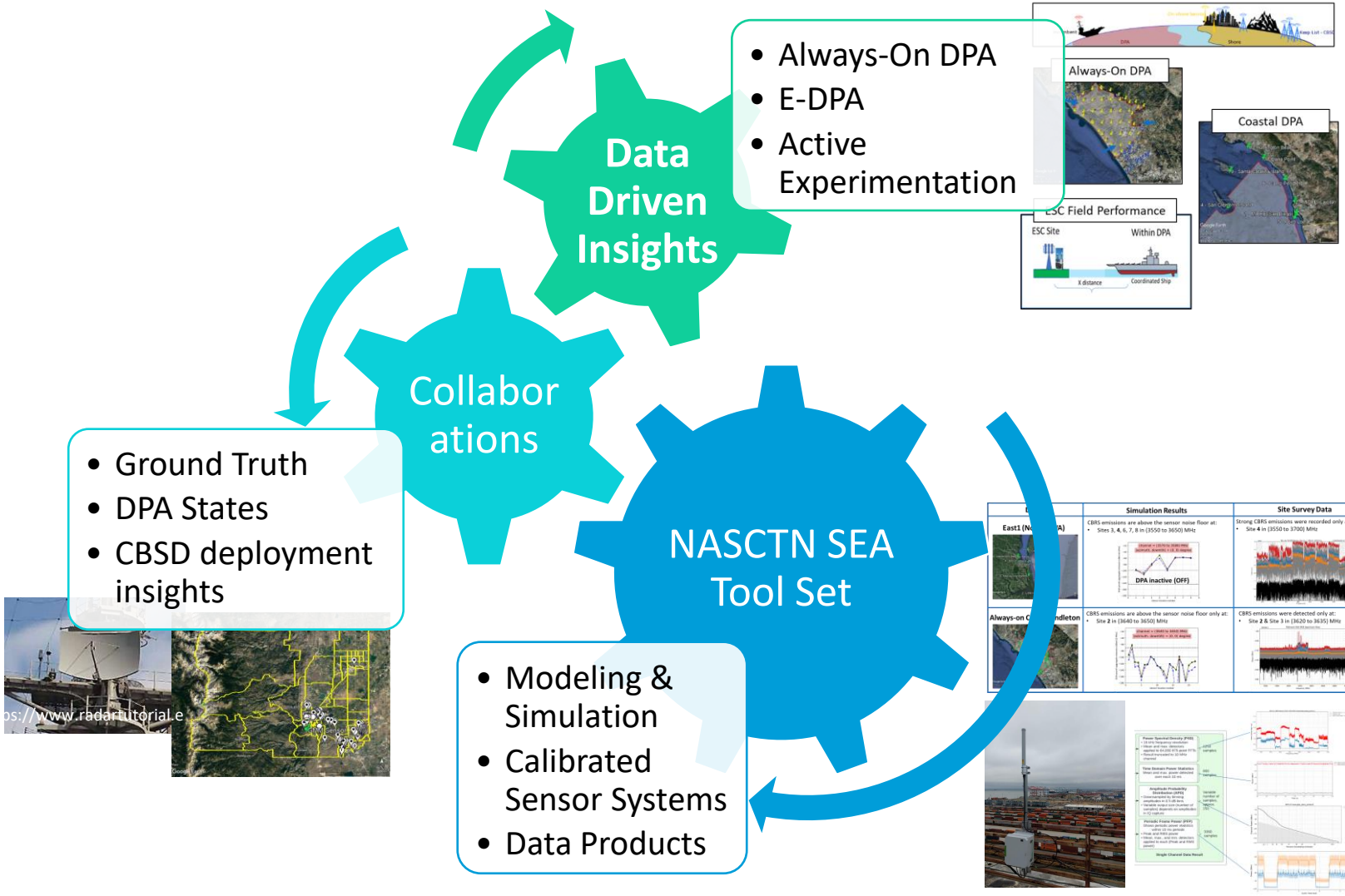
Sharing Ecosystem Assessment – Building Blocks

Provide data-driven insight into the CBRS sharing ecosystem's effectiveness between commercial and DoD radar systems, and to track changes in the spectrum environment over time.

Validated Data



with Statistical and Uncertainty Analysis



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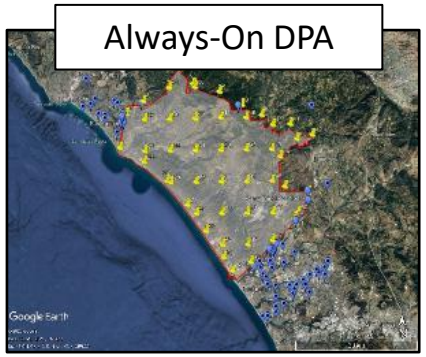
Test Plan Comment Period

- Commentary:
  - Period 02/22/23 – 03/17/23
  - Submission to NASCTN in written form through Comment Review Matrix
  - Will be anonymized & in non-attributing manner
  - All comments to be adjudicated and posted publicly

- A revised Draft Test Plan and adjudicated comments will be posted to the NASCTN website

Passive Observations: Always-on Dynamic Protection Area



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Scope: Always-on Dynamic Protection Area

Characterize emission levels in the CBRS Band over time

- Obj 1: Collect and publish data to provide insights into the always-on Dynamic Protection Area
- Obj 2: Study changes in background emissions as wireless systems continue to deploy

Not Doing:

- Obj 1: Adjudicate or attribute the protection threshold

Location:

- USMC Camp Pendleton, CA

Approach:

- Autonomous, calibrated, leave behind field systems deployed within the always-on DPA
- Modeling and Simulation
  - Identify opportune sensor system siting
  - Evolve understanding of CBRS deployments on SEA sensor measurements

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Outcomes: Always-on Dynamic Protection Area

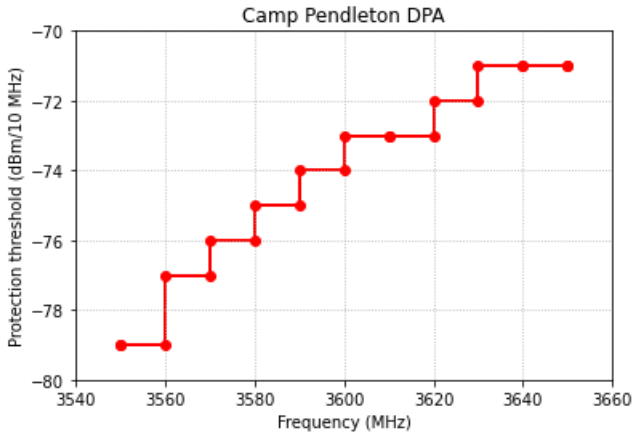
Anticipated Analysis Outcomes:

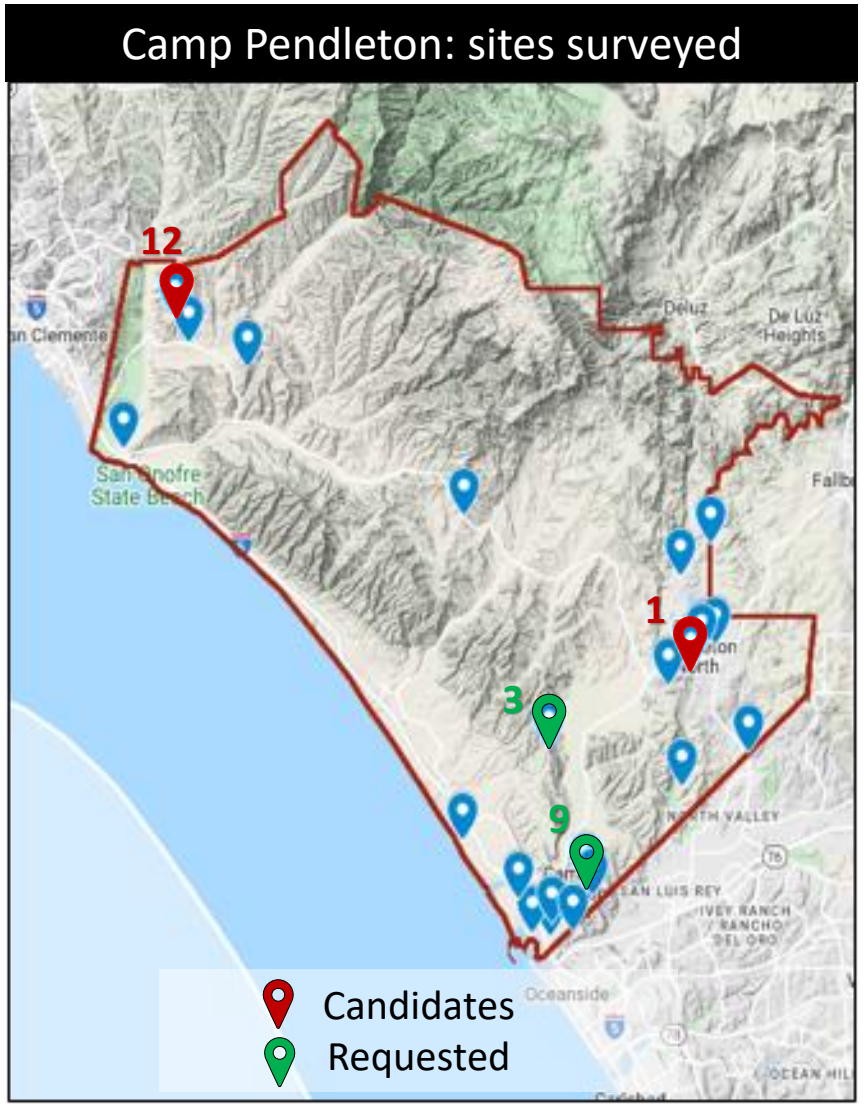
1. Quantified emissions levels at a set of locations
2. Background emissions change over time
3. Publish data to provide for insights into R2-IPM-05:

"SAS's shall manage CBSD aggregate interference levels for inland DPAs"

DPA limits:

- Frequency: 3550 MHz – 3650 MHz
  - Licenses channelized to 10 MHz blocks
- Protection criteria varies by frequency





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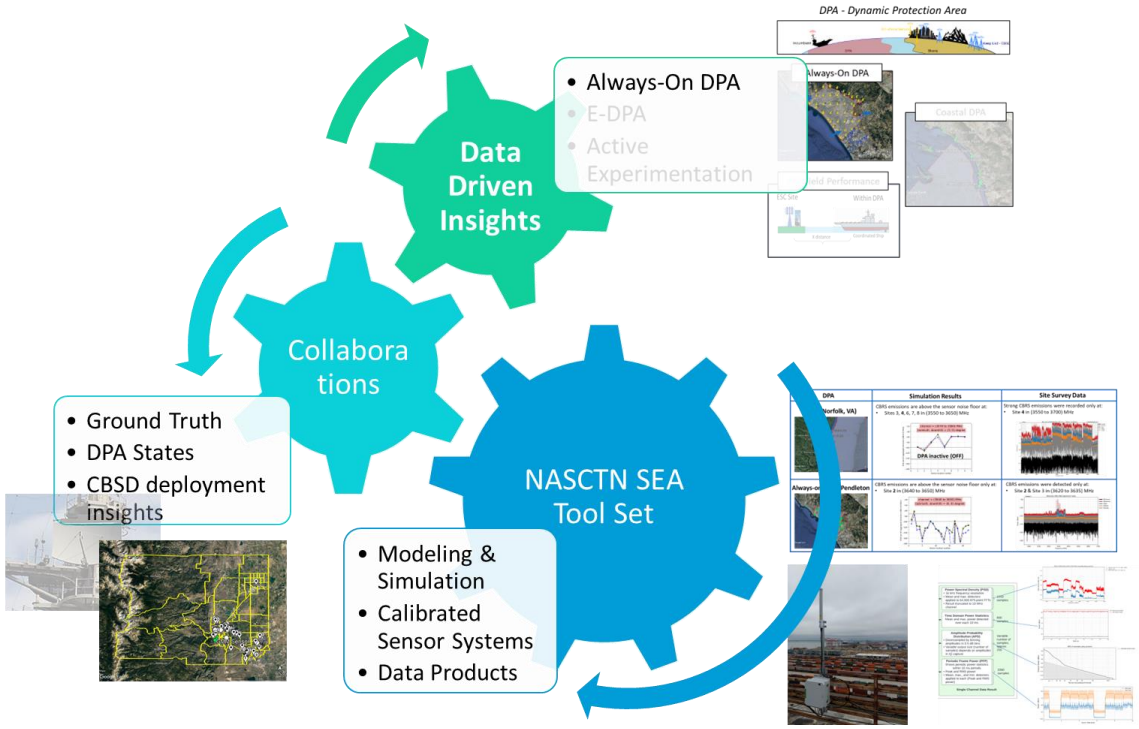
Overview of Technical Section

- **Modeling & Simulation**
  - Informed site selection methodology
- **Calibrated Sensor System**
  - NASCTN SEA Prototype Sensor
    - Architecture
    - Implementation
    - Characterization & Calibration
  - Future evolution/version for Always-On
- **Data Products**
  - Edge Compute Products
  - Insights from Prototype Deployments
- **Deployment plans** (Camp Pendleton)



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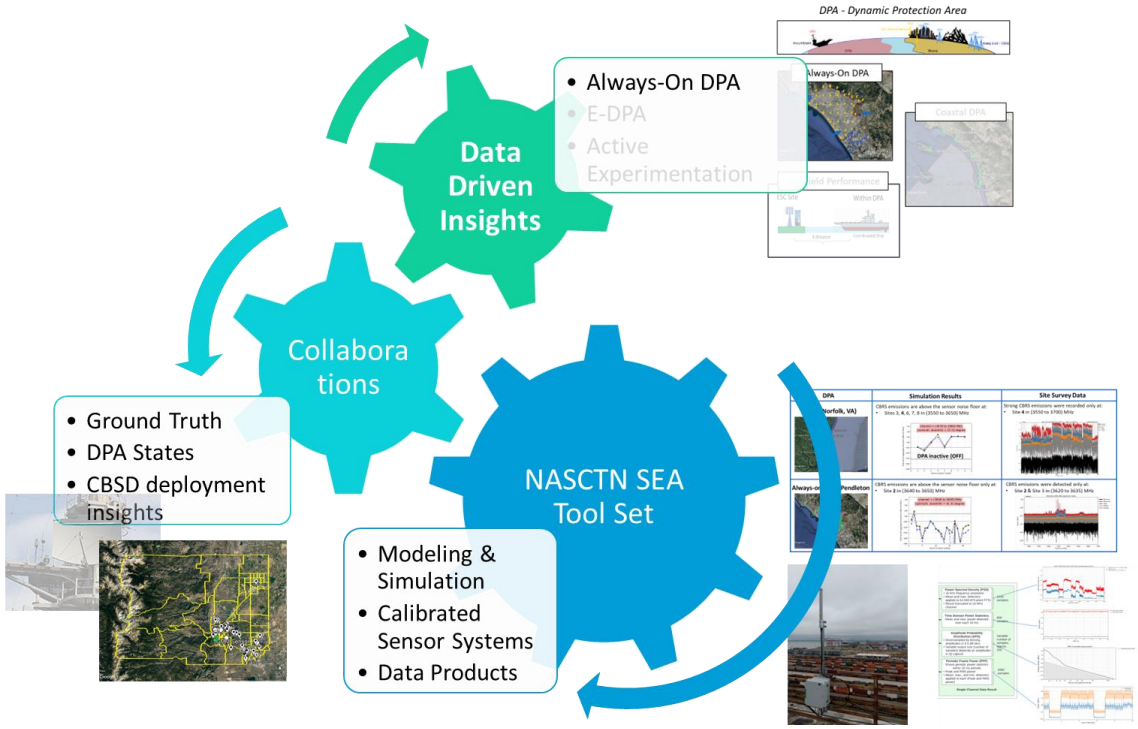

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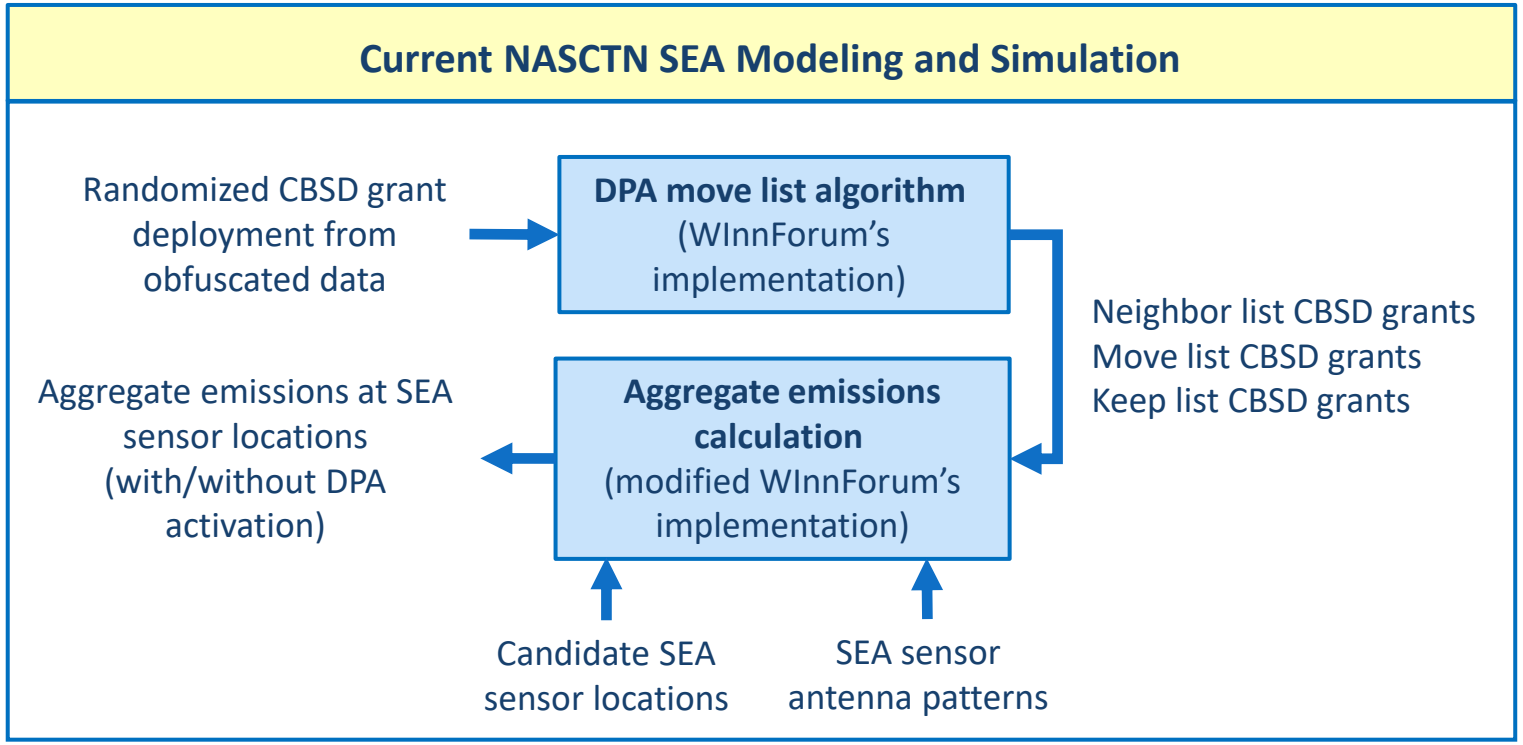
Modeling & Simulation - Informed site selection methodology

Objective: Utilize modeling and simulation as a tool to help inform site selections for SEA sensors

Approach: Estimate aggregate emissions from CBSD grants at candidate SEA sensor locations for each 10 MHz channel in the 3550-3650 MHz band

- Without DPA activation, i.e., emissions from neighbor list CBSD grants
- With DPA activation, i.e., emissions from keep list CBSD grants

*Camp Pendleton is an always-on DPA, only emissions from the keep list CBSD grants are estimated



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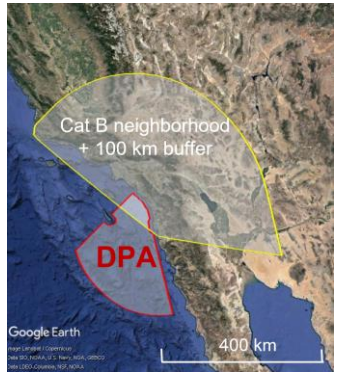
Obfuscated Data on CBRS Deployment for M&S

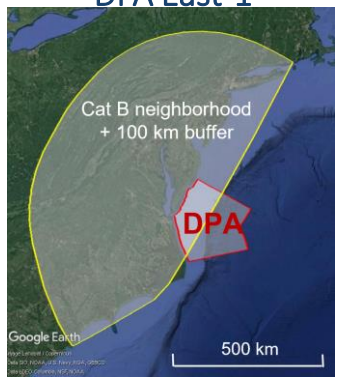
- SAS Administrators provided NTIA obfuscated data on CBRS deployments in support of the NASCTN CBRS SEA project
  - 3 selected areas: DPA West-14, DPA East-1, Boulder & Broomfield counties, CO
- NASCTN utilizes obfuscated data to generate randomized CBSD grant deployments

- Use a modified WInnForum Reference implementation to estimate aggregate emissions from randomized deployments to
  - Candidate sensor locations near DPA West-14 and DPA East-1, and inside Always-on DPA Camp Pendleton
  - Green Mountain Mesa (GMM) sensor in Boulder County, CO

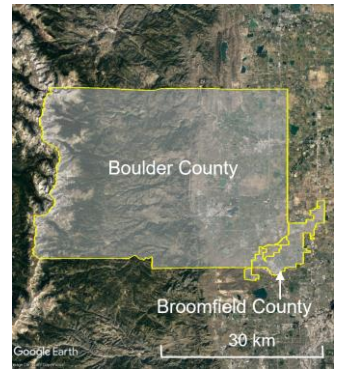
DPA West-14



DPA East-1



Boulder & Broomfield Counties



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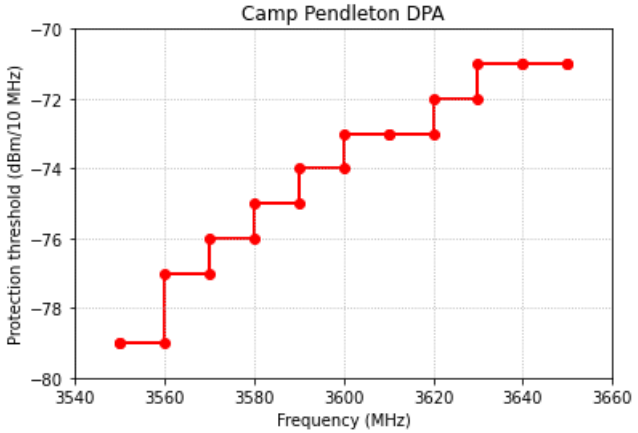
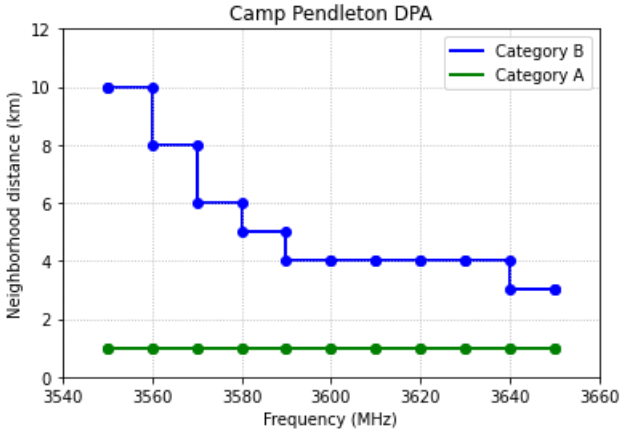
Simulation Results for Always-On DPA Camp Pendleton

Always-on DPA Camp Pendleton overview:

- Frequency range: 3550 MHz – 3650 MHz
  - Channelized to 10 MHz blocks
- Protection criteria vary by 10 MHz channels





Examples of computed neighbor list, move list, keep list CBSD grants per 10 MHz channel

Protection points within DPA

Neighbor list CBSD grants

Move list CBSD grants

Keep list CBSD grants

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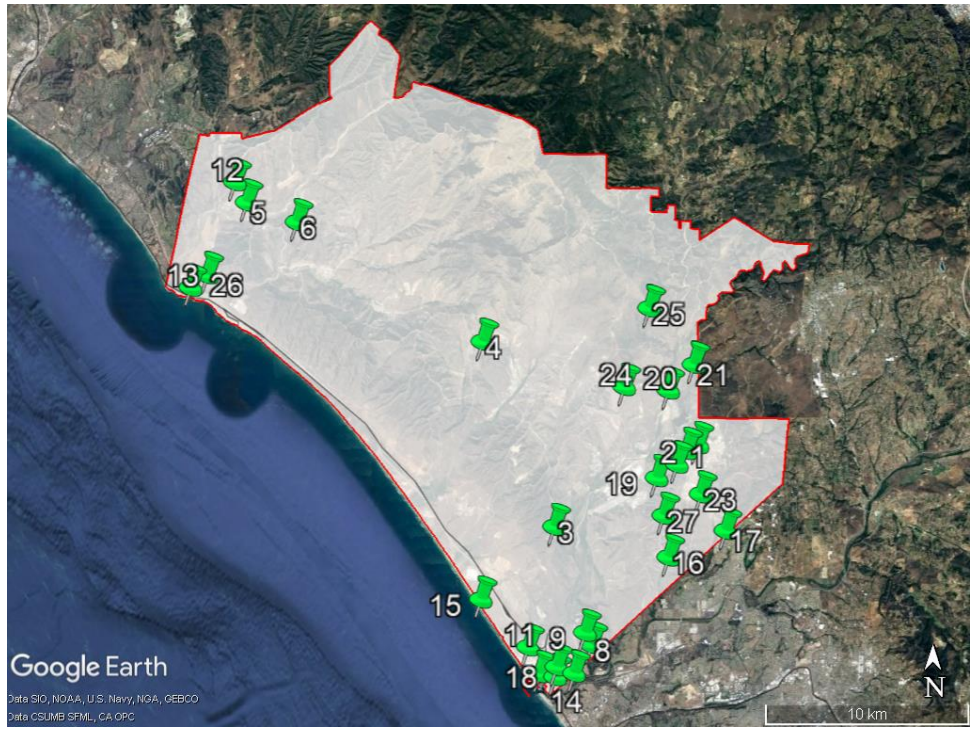
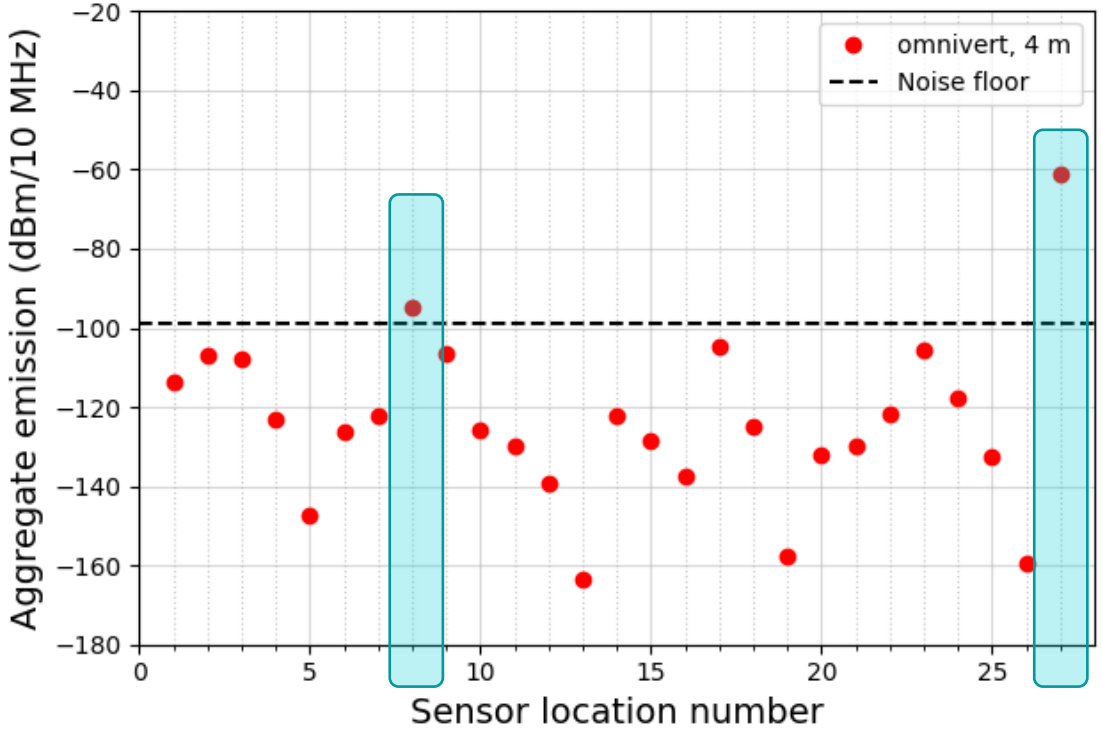
Simulation Results for Always-On DPA Camp Pendleton

Candidate SEA sensor locations under investigation for simulation and field evaluation



Aggregate emission estimates from keep list CBSD grants to candidate sites in 3630-3640 MHz channel



Areas of high interest for sensor placement

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Key Technical Challenges with Current Modeling

- Use randomized CBSD deployments from obfuscated FAD data instead of real CBSD deployments
- Use maximum requested EIRP values of the grants
  - Grants may operate at lower maximum allowable EIRP values
  - Some CBSDs with approved grants do not transmit
- Have not considered the effects of activation of adjacent DPAs or other protection entities nearby
- Have not taken clutter into account in the propagation model

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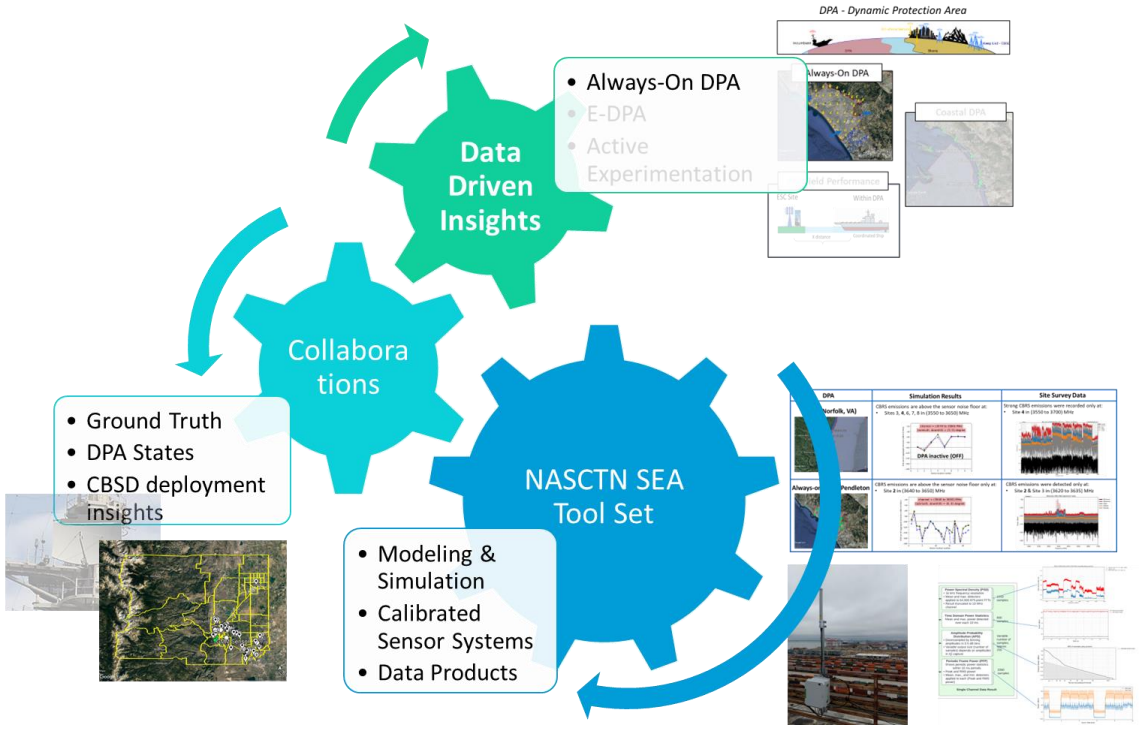

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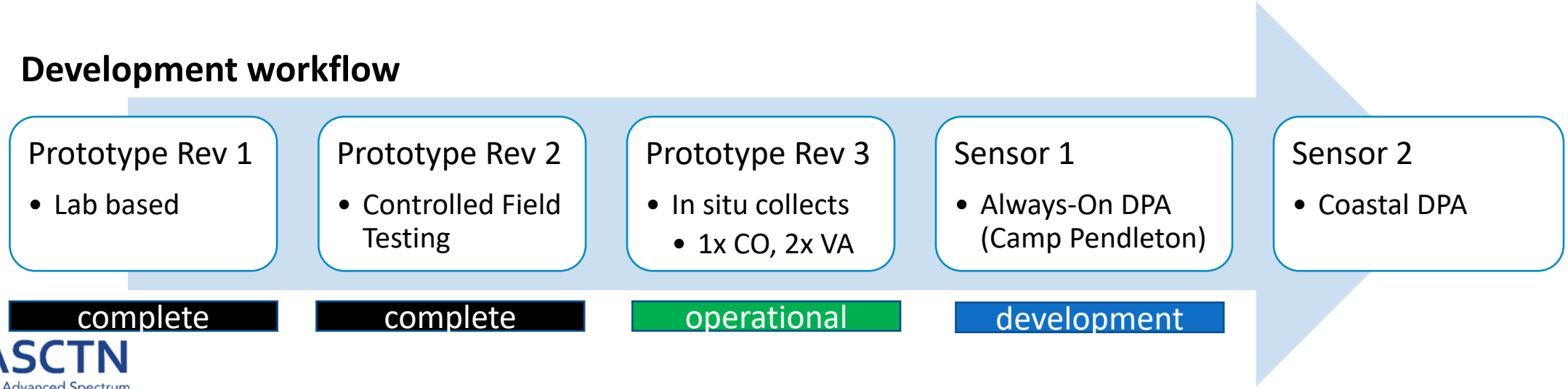
Calibrated Sensor System - SEA Prototype Sensor

Motivation:

1. Insights into the CBRS ecosystem behavior at a representative location to inform Test Plans,
2. Demonstrate the operating of remote sensing nodes that perform autonomous, calibrated, measurements with quantified levels of uncertainty over time,
3. Trial edge compute data products on real world signals, and
4. Evolve CBRS ecosystem understanding with simulation and measured data.

Development workflow



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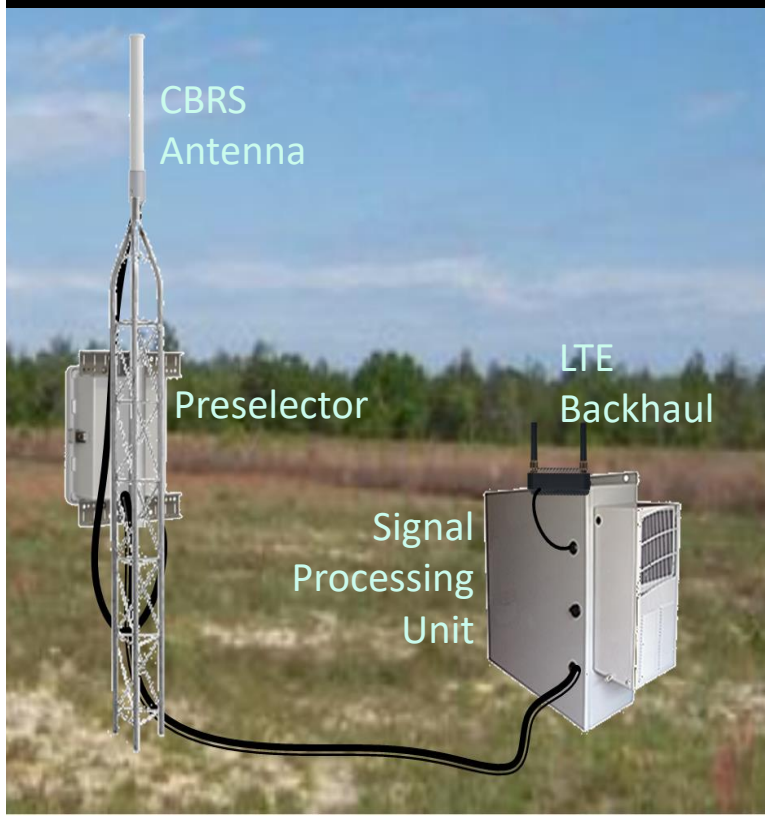
Technical Highlights

- *Professional design and integration* through MITRE – Bedford Laboratories
- *Traceable to NIST* Calibrated and referenced to NIST's thermal noise radiometer (https://www.nist.gov/programs-projects/thermal-noise-metrology)
- *Authority To Operate network* through NTIA / ITS
- *Leverages NTIA's reference implementation* of the Spectrum Characterization and Occupancy Sensing (SCOS) sensor standard. (IEEE 802.15.22.3)
- *On-the-fly calibration* through NIST traceable on-board RF thermal noise reference
- *Portable lab to field uncertainty characterization methodology* demonstrated and in preparation for publication
- *Deployed sensor investigation and monitoring* through NASA Langley

SEA Prototype Sensor Rev3 System – at a Glance

Modular Sensor System



	Parameter	Typical Value	Conditions	Note
RF System	Frequency Range	3550 – 3700 MHz		3540 – 3710 MHz expanded collects recommended
	Gain	31.5 dB	**Channel 8** (3620 – 3630 MHz) **RSA Settings:** Preamp: Enabled Reference level: -25 dBm Input attenuator: 0 dB	
	Input-Referred Noise Power	-98 dBm/10 MHz		
	Input 1 dB Compression Point (w/ CW Stimulus)	-48 dBm		
	Adjacent Channel Rejection	*in development*		Highly dependent on ADC overrange condition See Section 4.4.4
Antenna	Type	Omni (360°)		*GMM sensor variation* 90° Sector Gain: 17 dBi Pol: +,- **45°** Slant Pol Vert: 6°
	Gain	9 dBi		
	Polarization	Vertical		
	Vertical 3 dB Beamwidth	11°		

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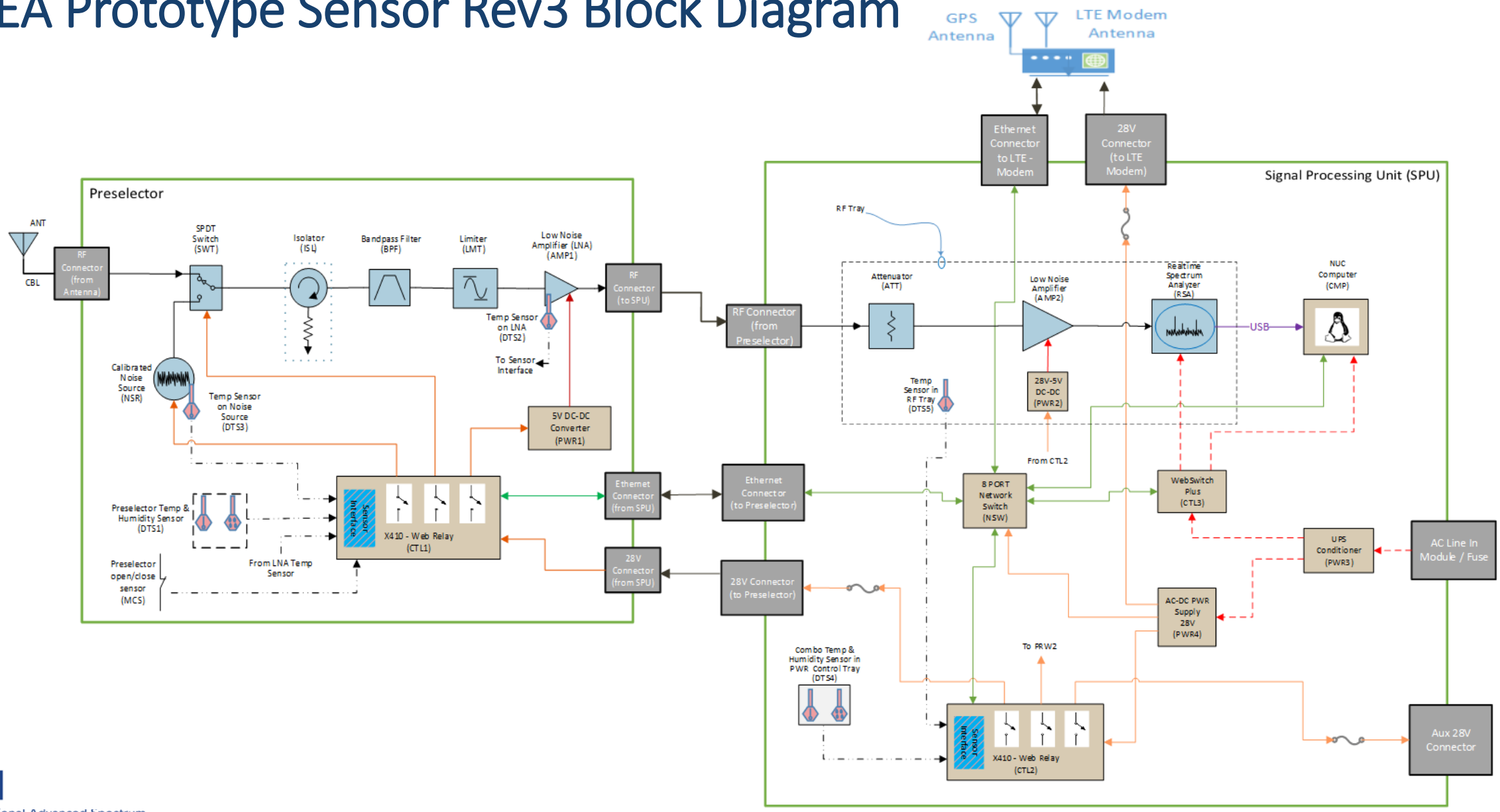
SEA Prototype Sensor Rev3 Block Diagram



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Green Mountain Mesa Sensor


Green Mountain Mesa Site

GMM Sensor, Installation	
Latitude	39.99180 deg
Longitude	-105.2745 deg
Azimuth	12 deg +,- 5 deg*
Elevation	0 deg +,- 1 deg
AGL	4.09 m +,- 0.05 m
AMSL (WGS-84)	1783.4 m +, - 1.5 m

*Azimuth to be further refined

KP Performance Antennas KP-3SX4-90	
Gain	17.0 dBi +,- 0.3 dB
Slant Pol	+,- **45 deg**
Horizontal HPBW	90 deg +,- 5 deg
Vertical HPBW	6 deg +,- 0.3 deg

https://www.kpperformance.com/Content/Images/Downloadables/Datasheets/KP-3SX4-90_datasheets_US.pdf

Sensor Specs - System Gain

- System Gain (Independent of Antenna): ~31.5 dB +,-unc* dB

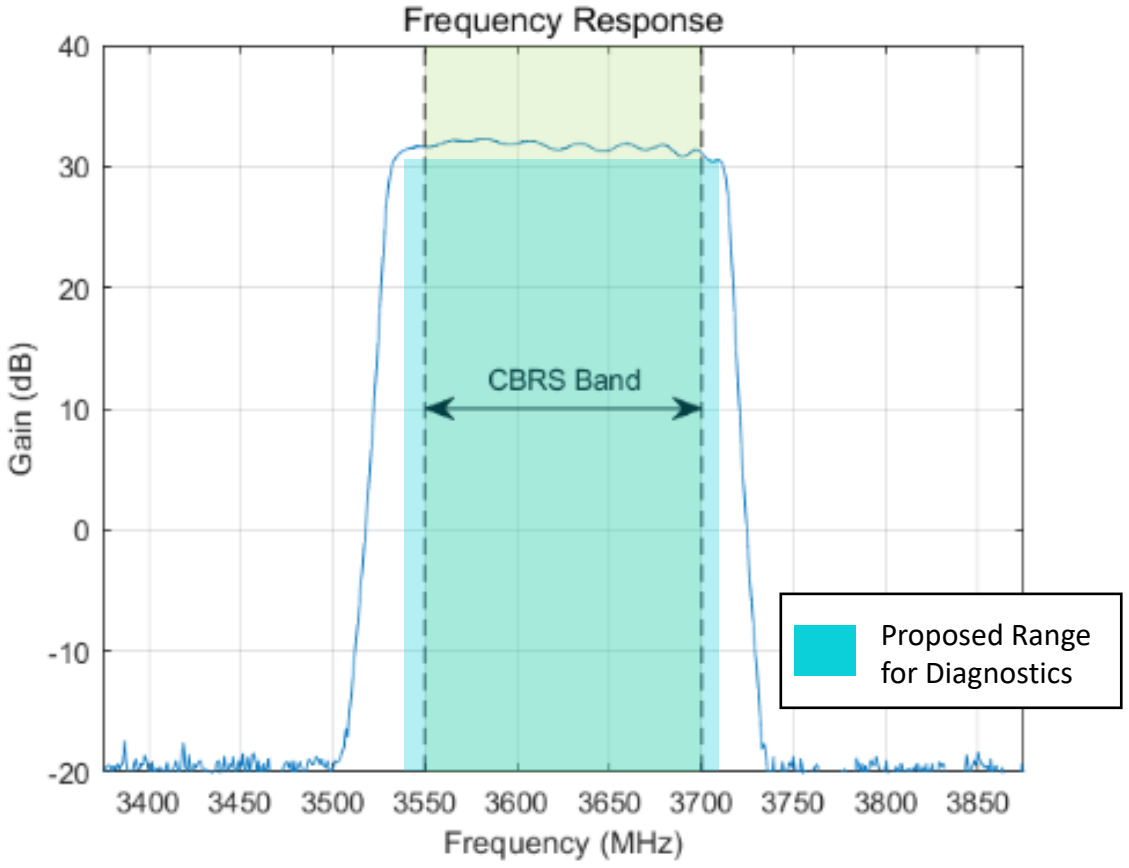

Figure 4.31: Full System Frequency Response

*Estimate of uncertainty for a known fixed power and any time and temperature variations unaccounted for is +,-0.3 dB

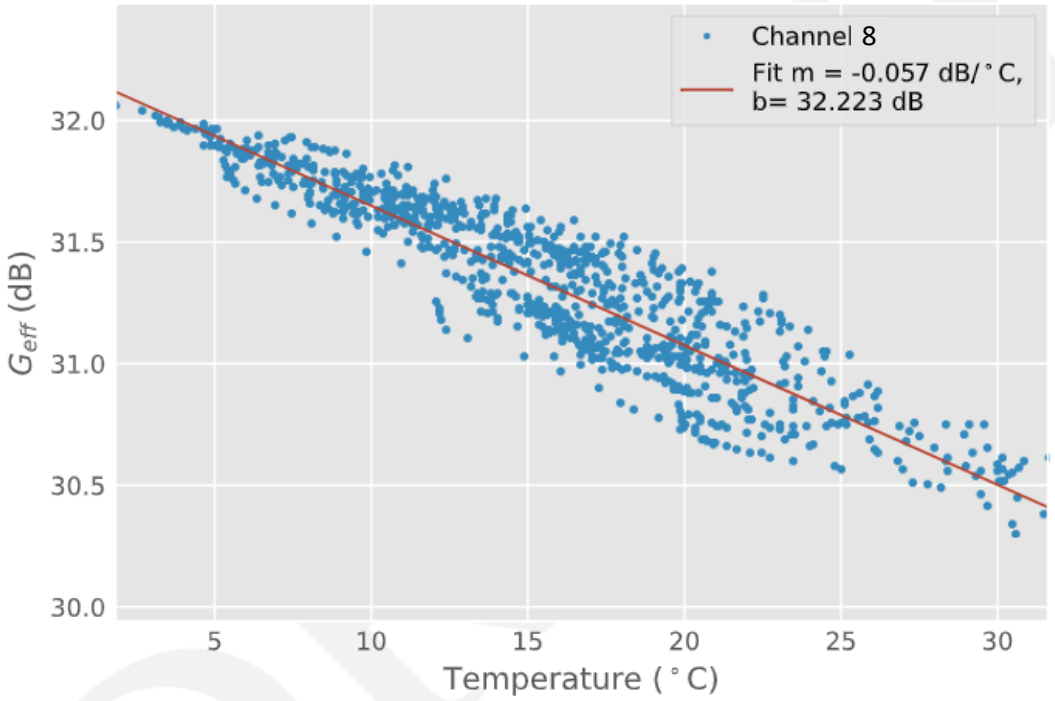

Figure 7.3: Gain (logarithmic units) versus temperature of channel 8 (center f = 3625 MHz) shows a clear linear trend, this is repeated for all channels

Sensor Specs - System Noise Figure

- Full System Noise Figure: 4.2 dB < NF < 6 dB*

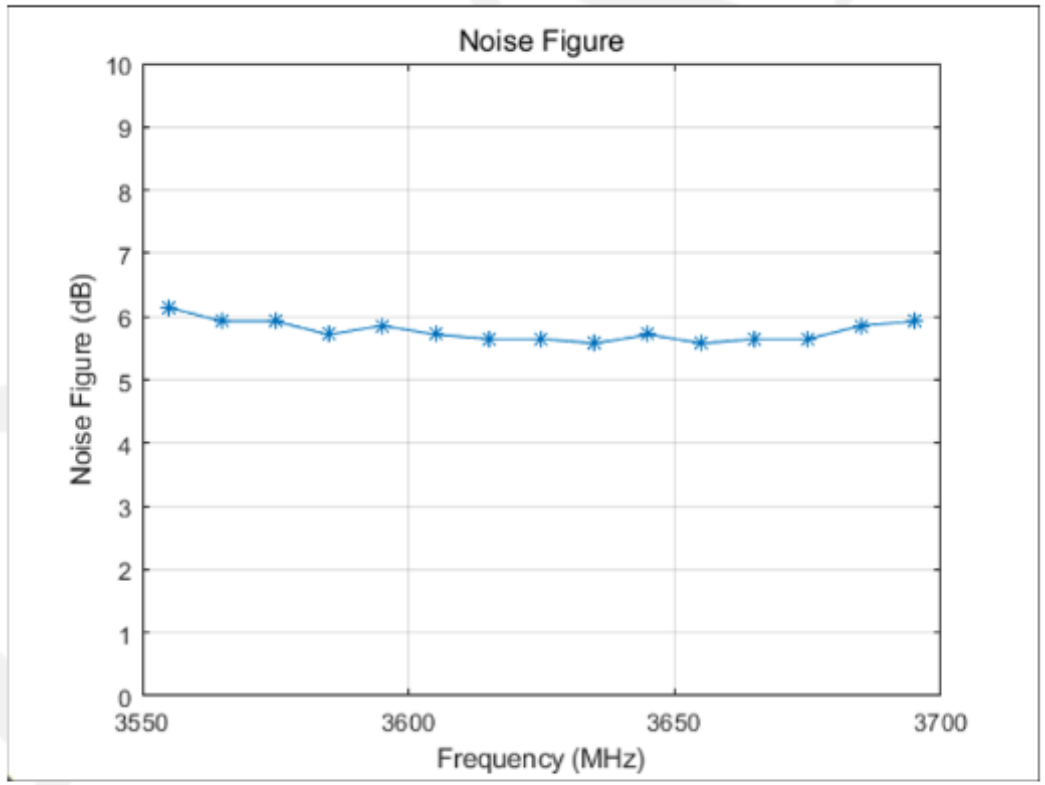

Figure 4.32: Full System Noise Figure

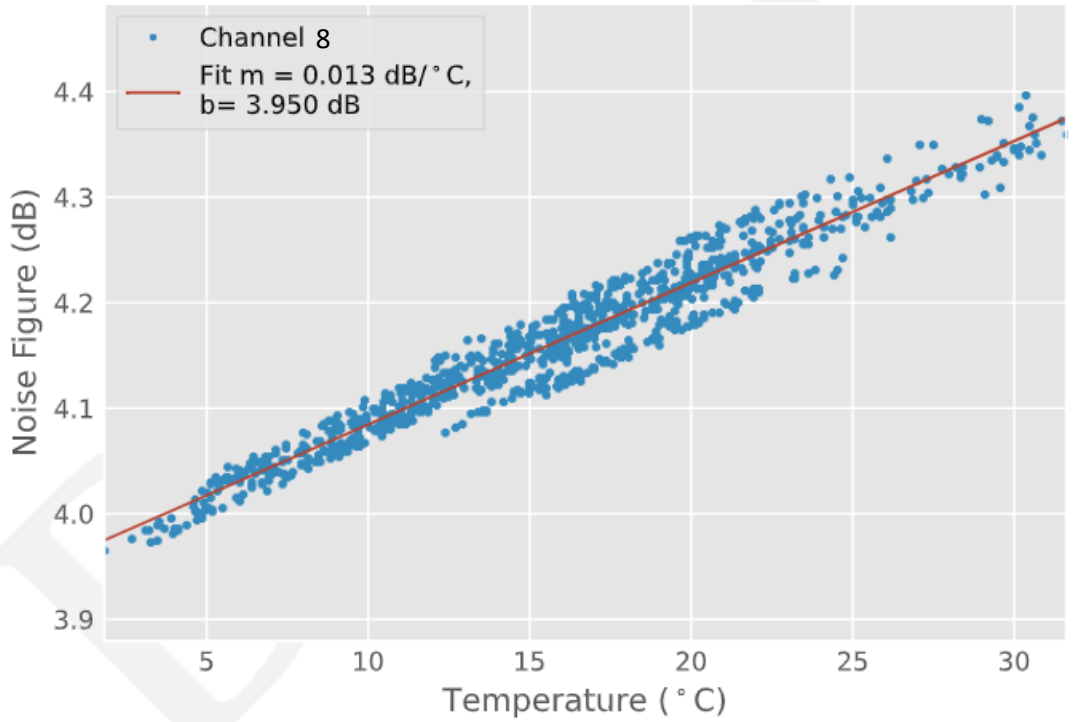

Figure 7.6: Temperature Dependence of Noise Figure Channel 8, Hampton University Sensor.

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* The range accounts for loss mechanism between the antenna element port and on-board calibration reference planes. We estimate the revised sensor noise figure to be closer to 4.5 dB.

Sensor Command and Control Software

Leverages NTIA's reference implementation of the Spectrum Characterization and Occupancy Sensing (SCOS) sensor standard.

Standard: IEEE 802.15.22.3 defines the architecture, abstraction layers, interfaces, and metadata requirements

Open-source software repositories: https://github.com/NTIA/scos-sensor

- *scos-sensor* - control software residing on the host processor
  - Controls preselector and signal analyzer
  - Runs actions to collect and process data
  - Notifies manager when data is available
- *scos-manager* - tasking software residing on a server at ITS
  - Task the sensors and manage their schedules
  - Retrieve sensor data
  - Remove retrieved data from sensors
- *Back-end orchestration* using Ansible and puppet
  - Install OS and updates
  - Install or rebuild scos-sensor

SCOS Manager Demo with deployed SCOS Sensors around Boulder
*a prior NTIA ITS effort

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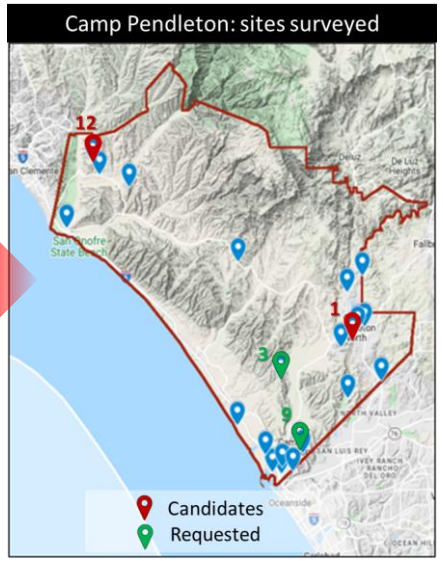
Sensor 1: Design Iteration towards Field Deployment at Camp Pendleton

- **Software**
  - Evolved on-board calibration methodology
  - Reduced overhead in metadata
  - Higher sensor stability and reliability
- **Hardware**
  - Revised VAC/VDC power control
  - Refined antenna selection
- **Data Pipeline**
  - Automated translation from SigMF to database repository
- **Data Analysis**
  - Formalized timeseries analysis



Development workflow

Prototype Rev 1	Prototype Rev 2	Prototype Rev 3	Sensor 1	Sensor 2
• Lab based	• Controlled Field Testing	• In situ collects • 1x CO, 2x VA	• Always-On DPA (Camp Pendleton)	• Coastal DPA
complete	complete	operational	development	

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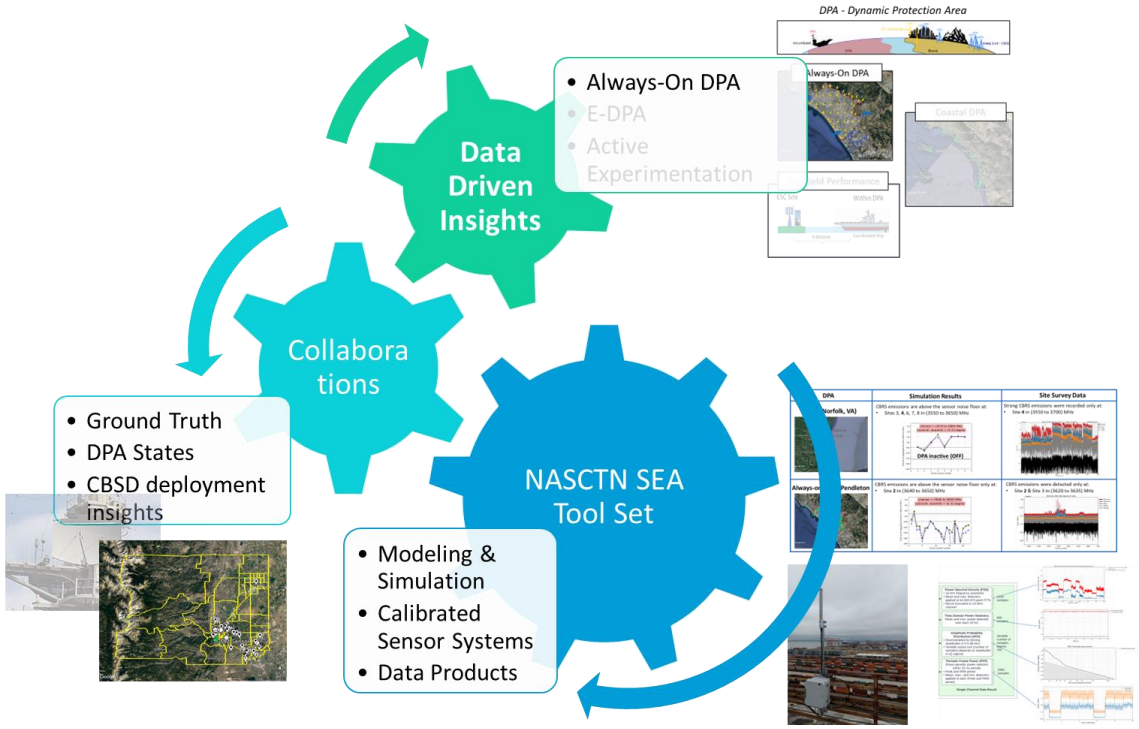
- **Modeling & Simulation**
  - Informed site selection methodology
- **Calibrated Sensor System**
  - NASCTN SEA Prototype Sensor
    - Architecture
    - Implementation
    - Characterization & Calibration
  - Future evolution/version for Always-On
- **Data Products**
  - Edge Compute Products
  - Insights from Prototype Deployments
- **Deployment plans** (Camp Pendleton)



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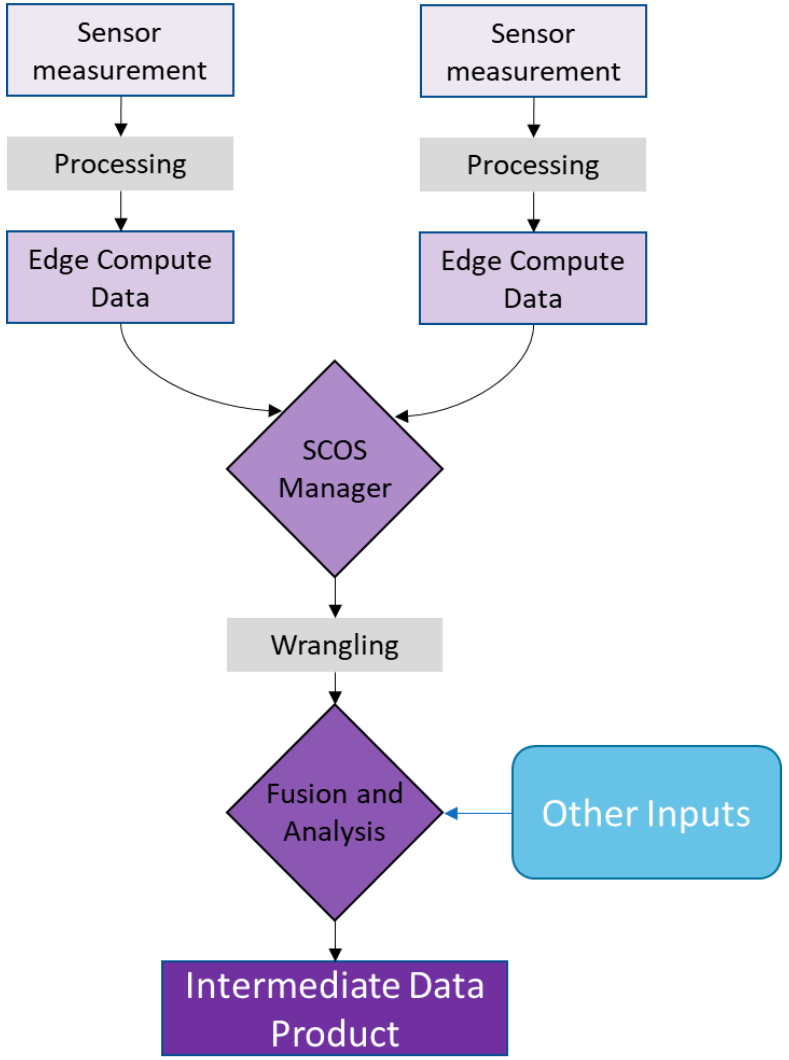
Data Products: Data at the Edge

Goal: Compute a compressed stream of key measurements from field waveforms in real time

- Summary power statistics
- Structure/distributions in time/frequency

These are “building blocks” - downstream aggregation and analysis will digest into intermediate data products for each of the major tasks



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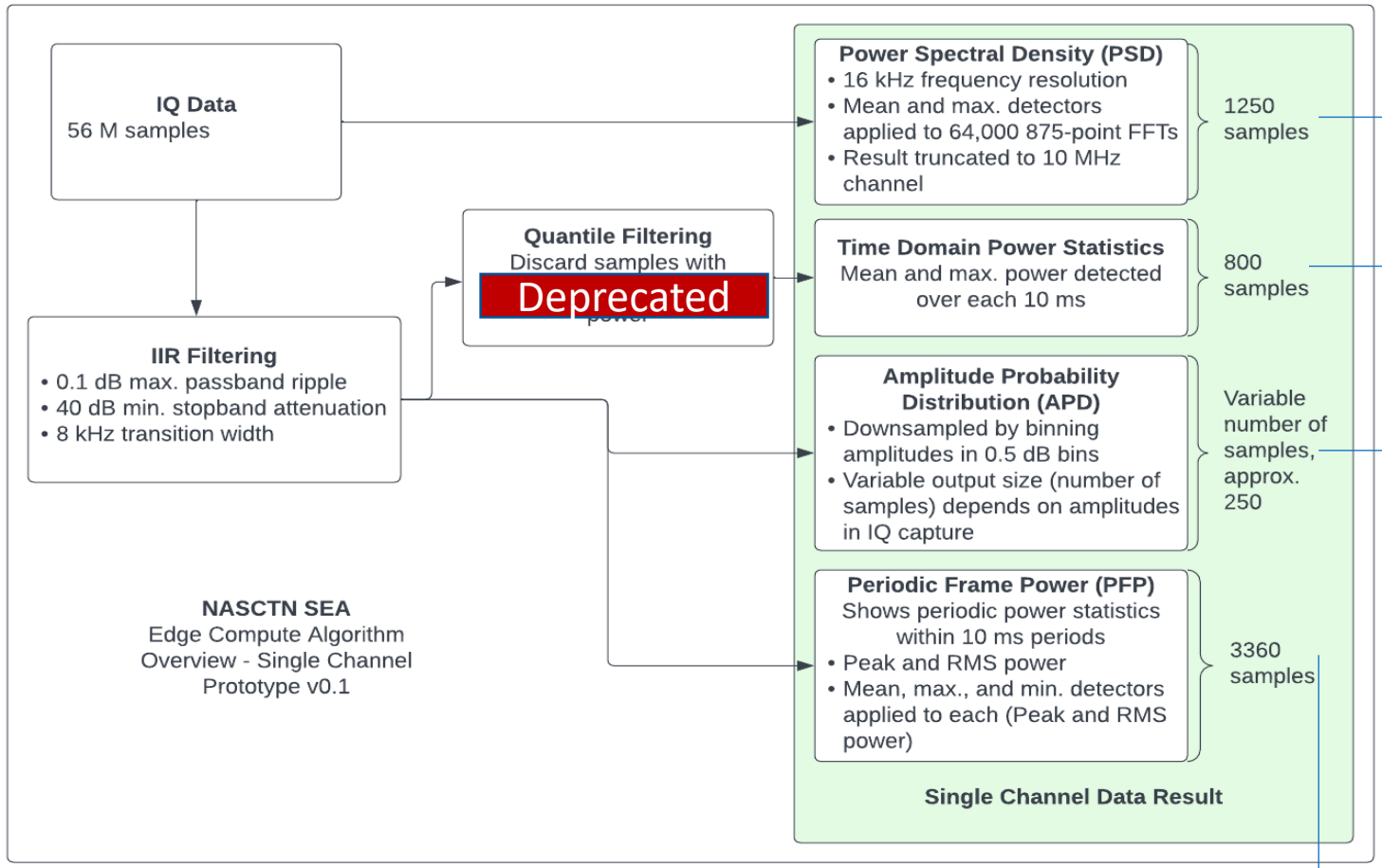
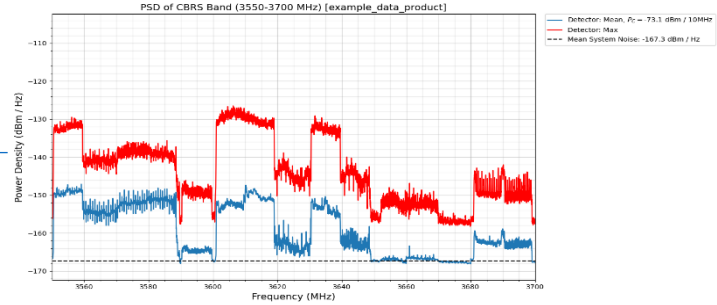
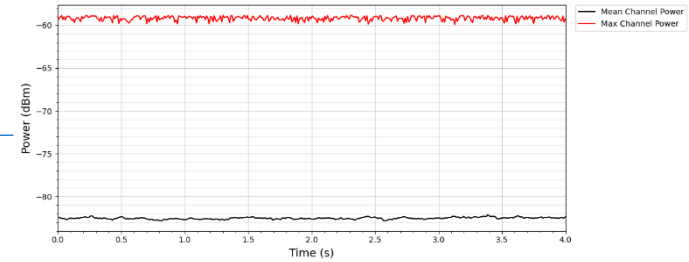
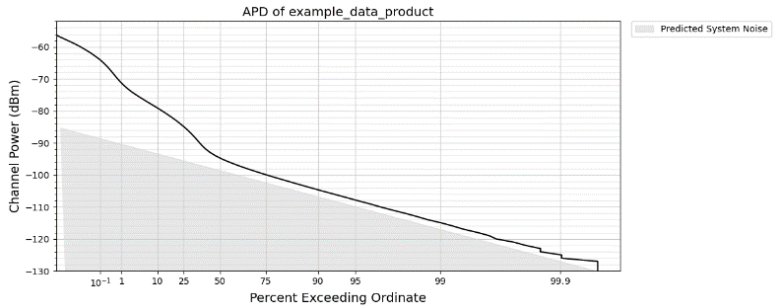
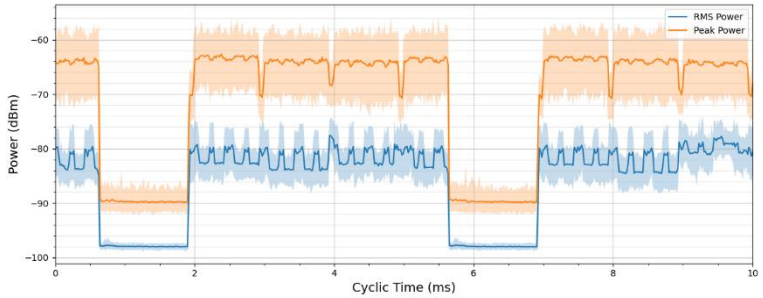
Candidate Edge Compute Products – at a Glance







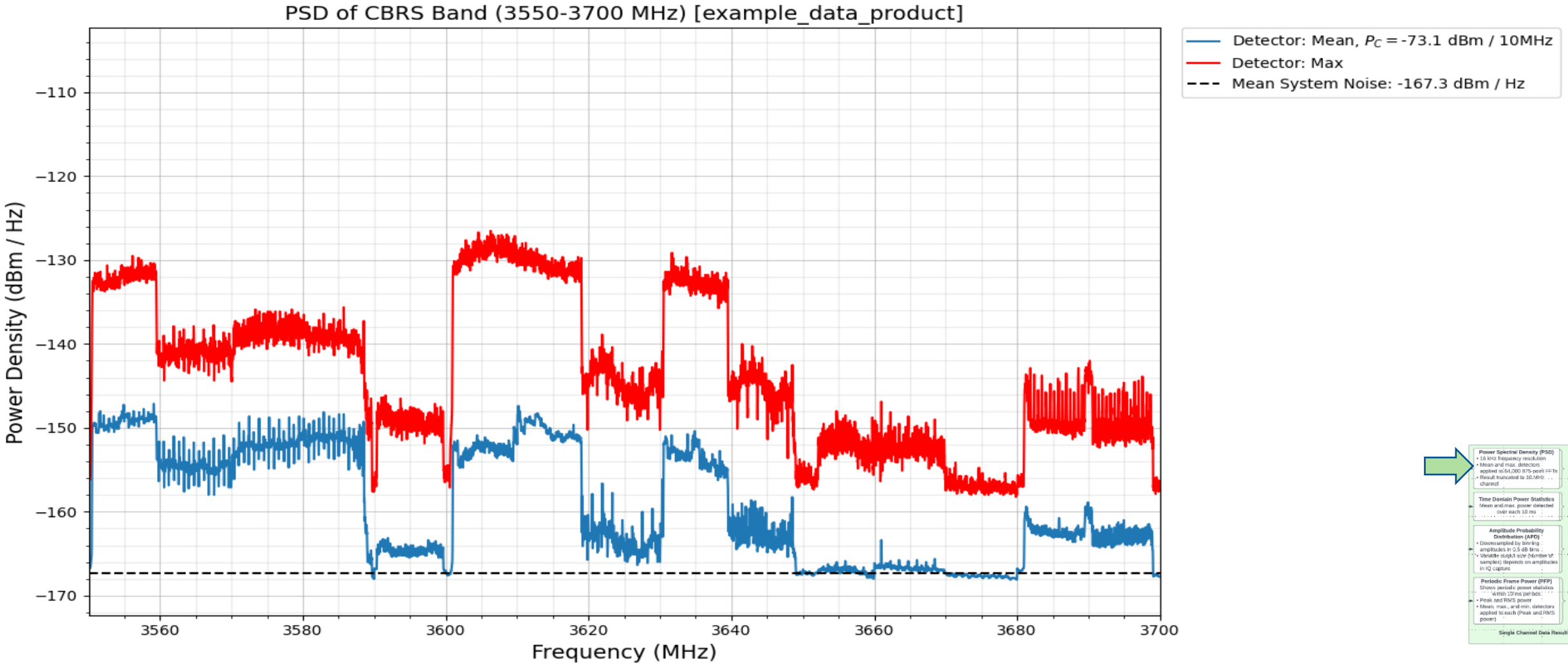




Edge compute products are candidate edge compute data, other data derived from IQ are feasible, though need to be evaluated for their utility to longitudinal studies.

Example data product: Power Spectrum

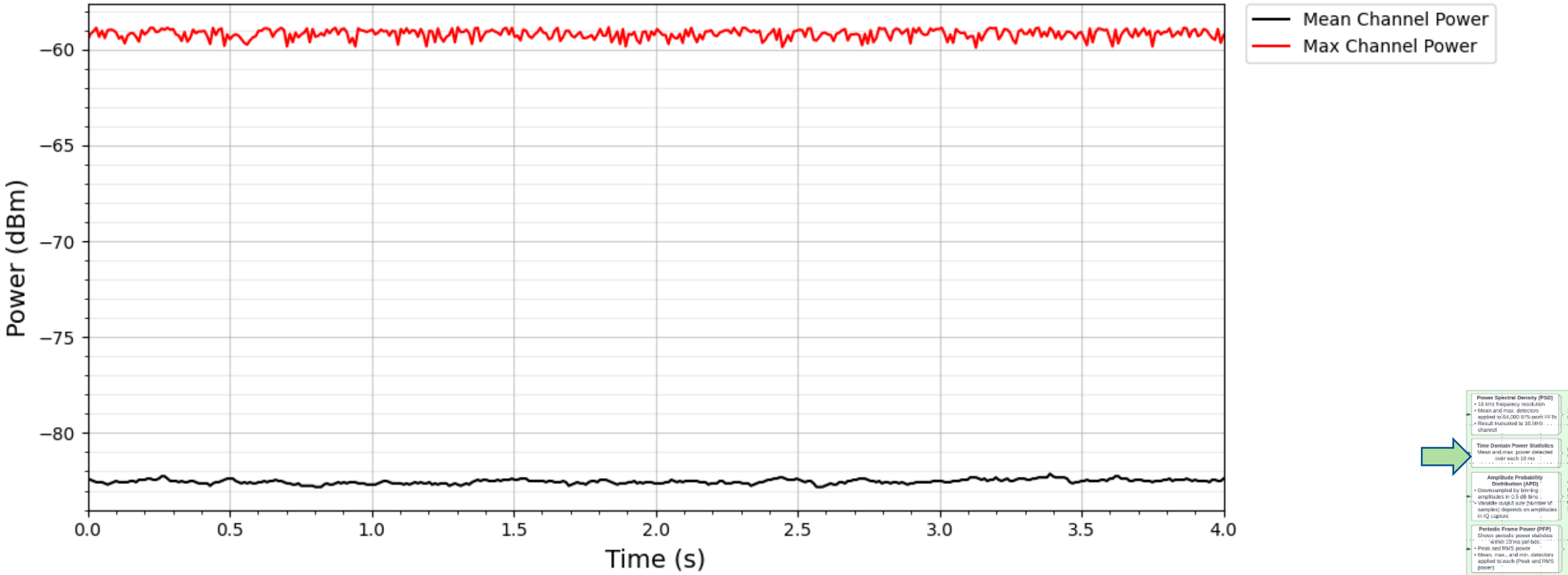
(4 s capture in each channel, concatenated across band)



Example data product: Channel Power vs Time

3600-3610 MHz, Green Mountain Mesa, Boulder, CO

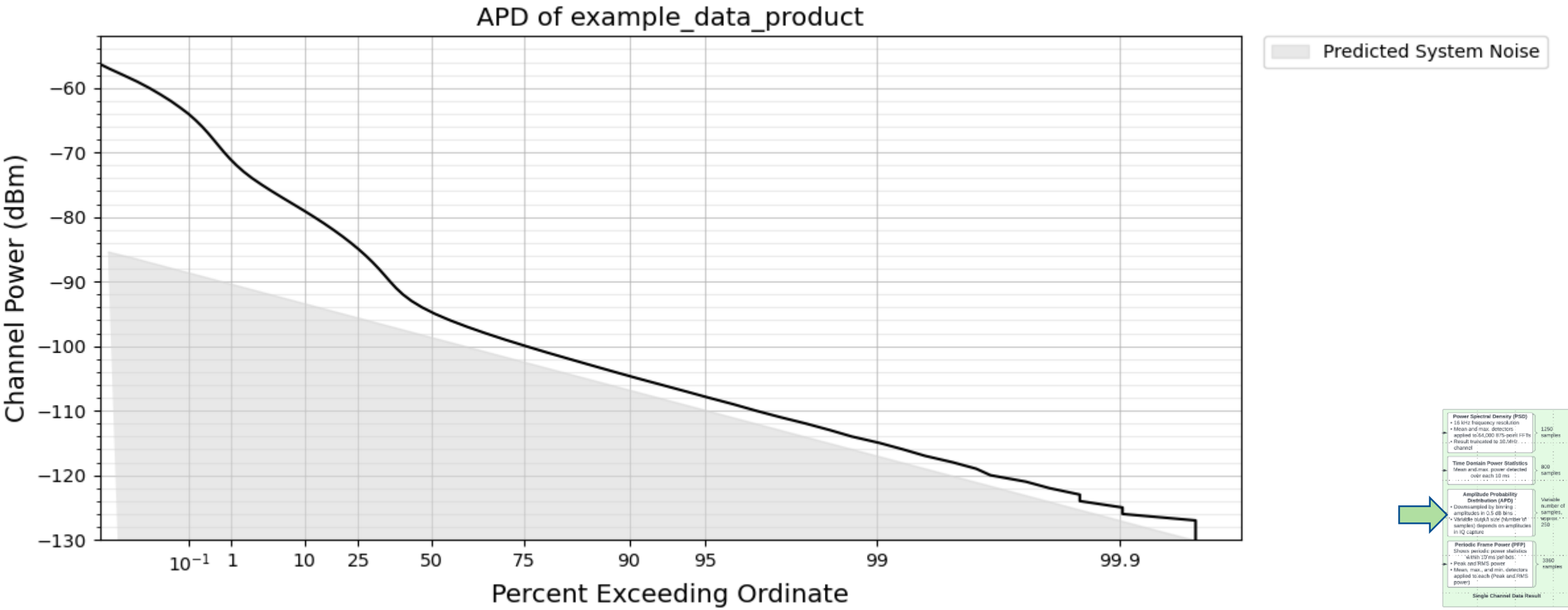
(Δt = 10 ms, 4 second capture)



Example data product: Amplitude Power Distribution

3600-3610 MHz, Green Mountain Mesa, Boulder, CO

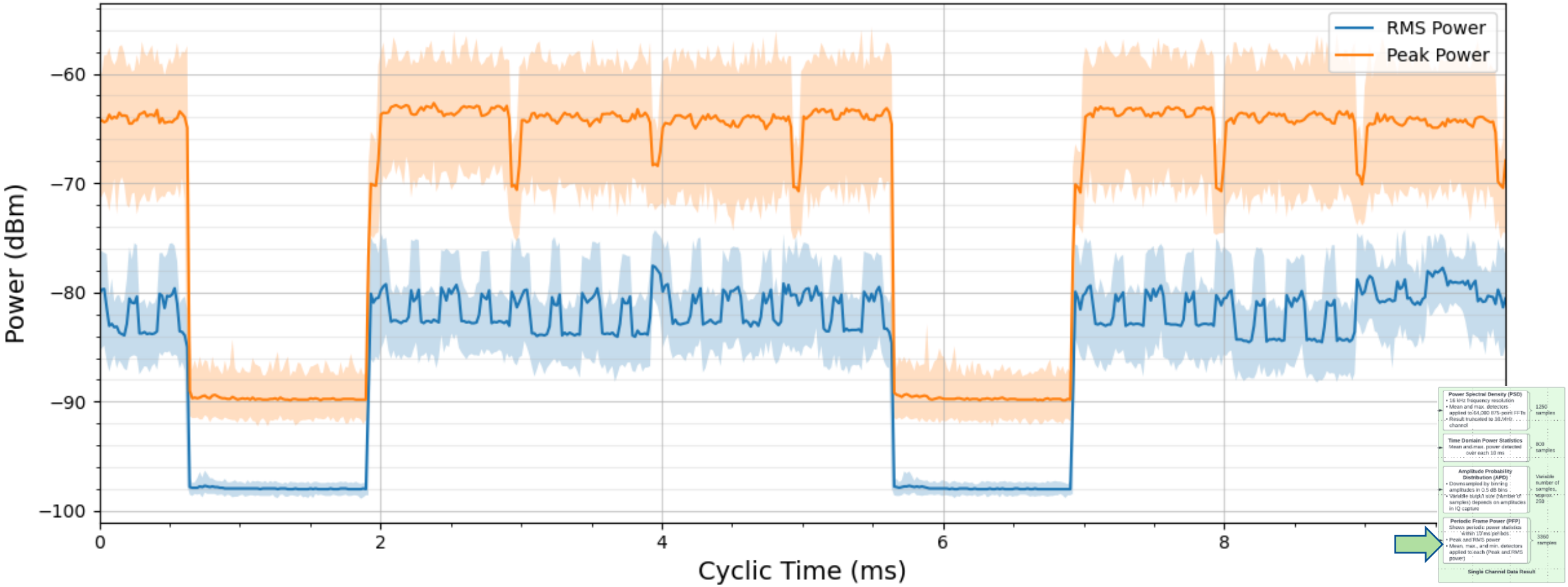
(4 second capture)



Example data product: Frame Power

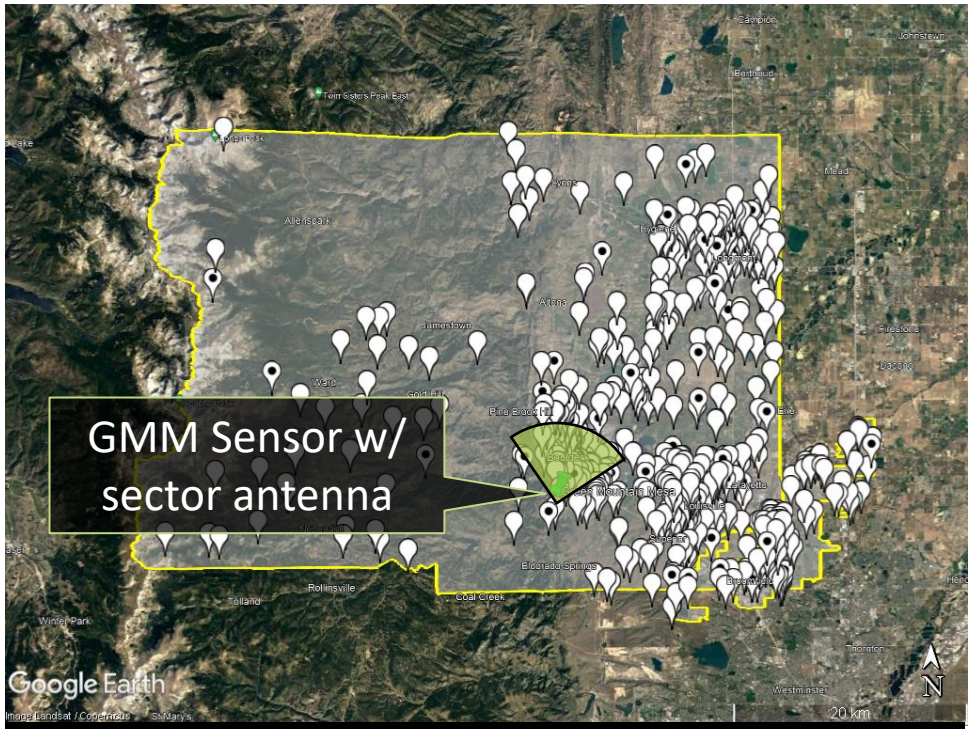
3600-3610 MHz, Green Mountain Mesa, Boulder, CO

(Δt = ~71.4 µs, 4 second capture)



Green Mountain Mesa - a stand in location

- Stand off distance & overlook to population center and CBSD deployments within Boulder
- Data collected as Revision 2 and Revision 3 sensor:
  - Development of Edge Data Products and Sensor refinements with hardline backhaul to avoid data limits
- Allows team to exercise insights into day-to-day CBRS activity as well as trends on the week scale
- Data Products of note here:
  - Channelized time domain Summary Statistics w/ Sensor Overload KPI
  - Spot checks with Periodic Frame Power to glean insights into emitter types



GMM sensor in Boulder with example CBSD deployment within Boulder county

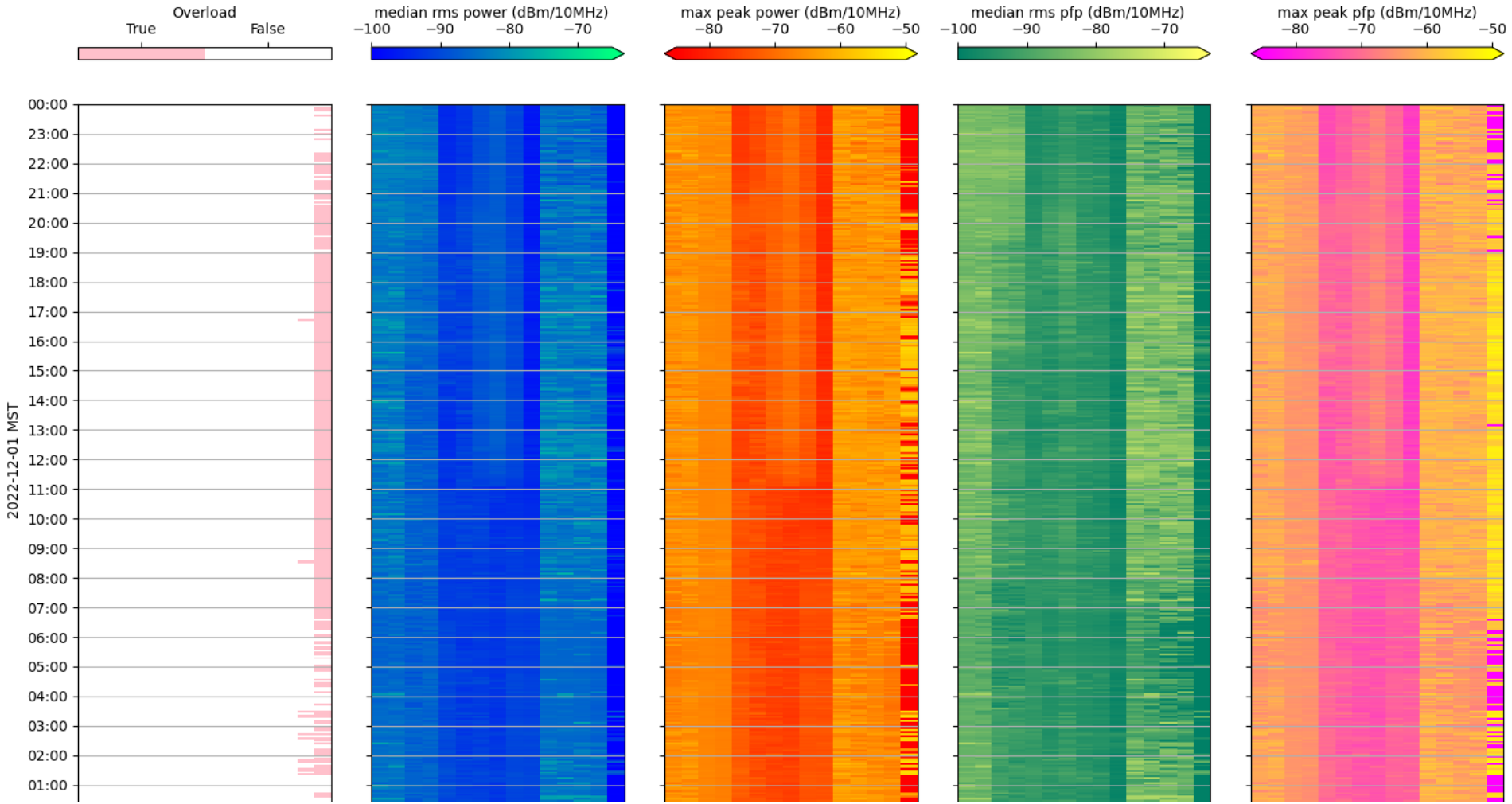
Exploratory Visualizations - A Day at a Glance

GMM Rev3
2022-12-01

Overload

Time Series Edge Data:

- Median RMS Power
- Max Peak Power
- Median RMS PFP
- Max Peak PFP



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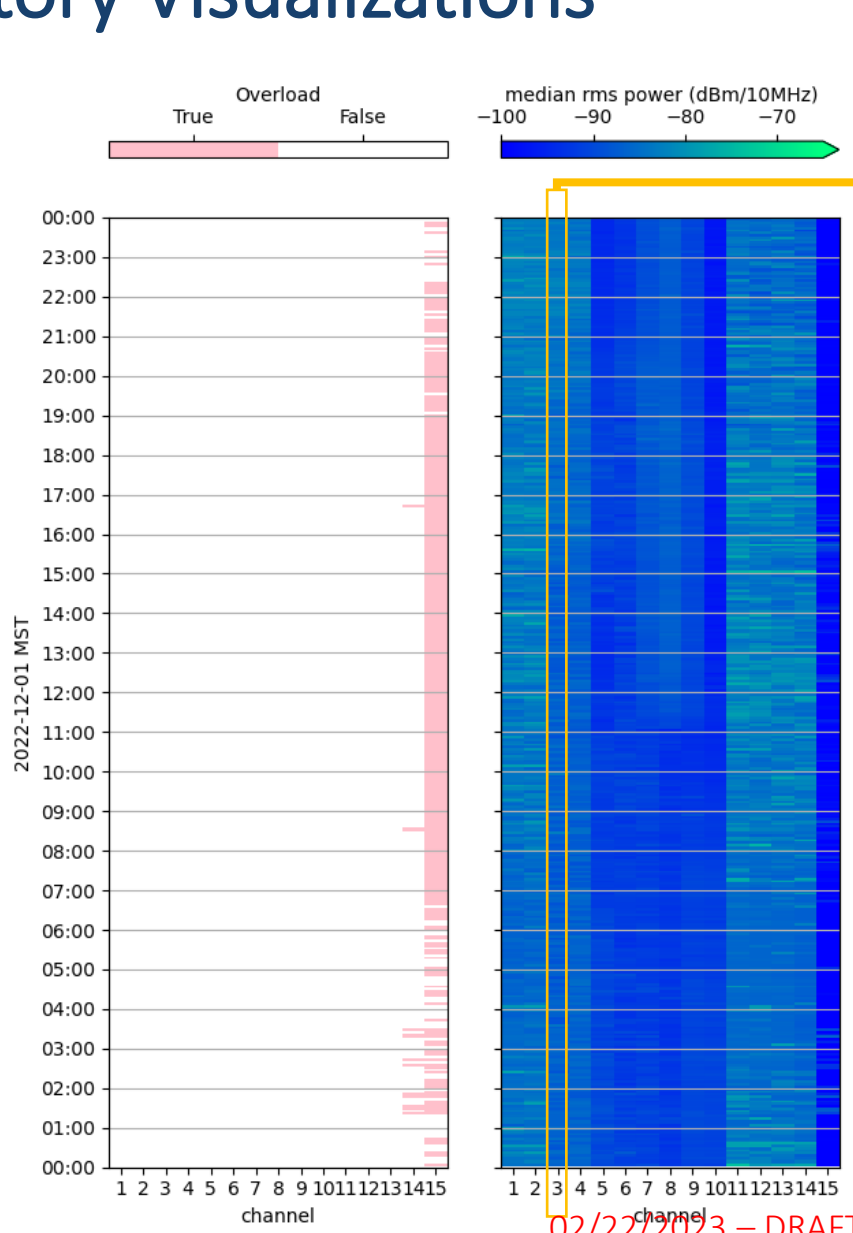
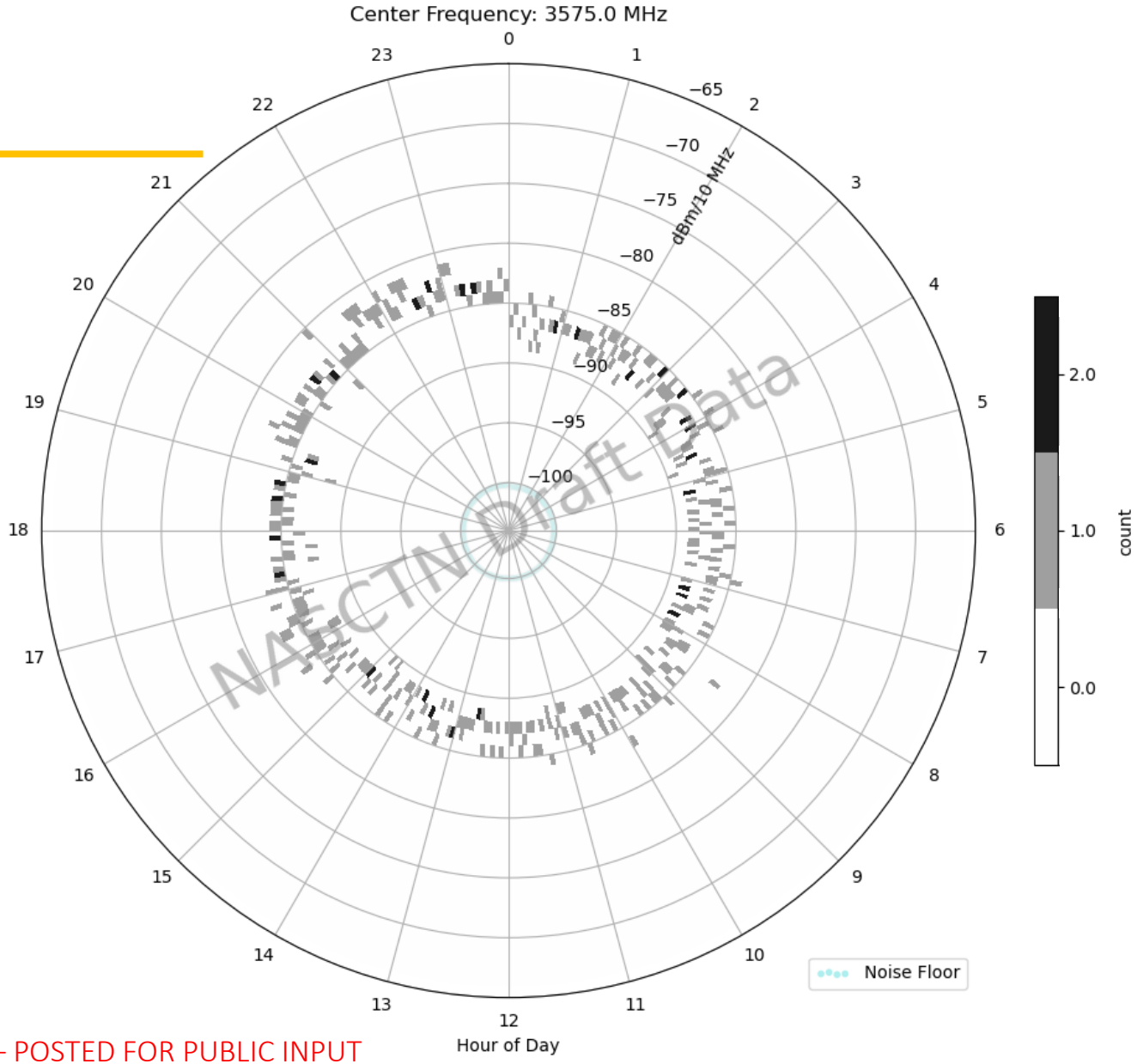
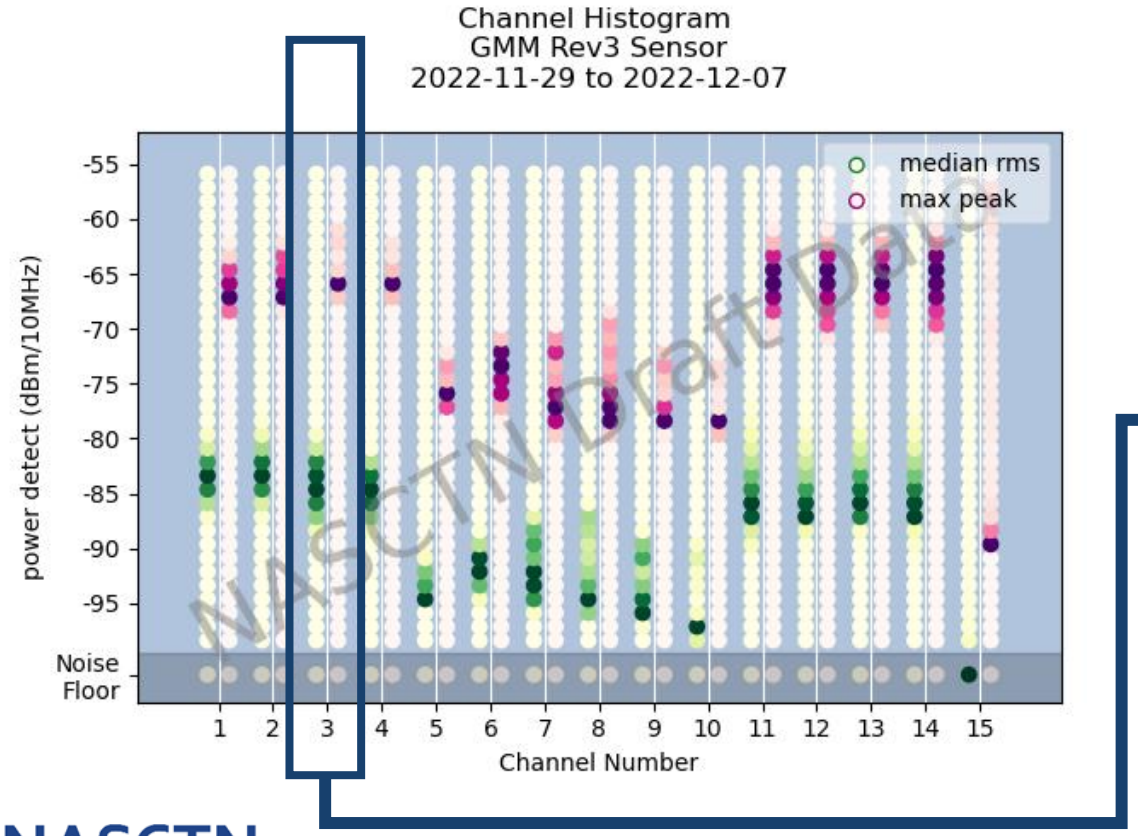
Exploratory Visualizations

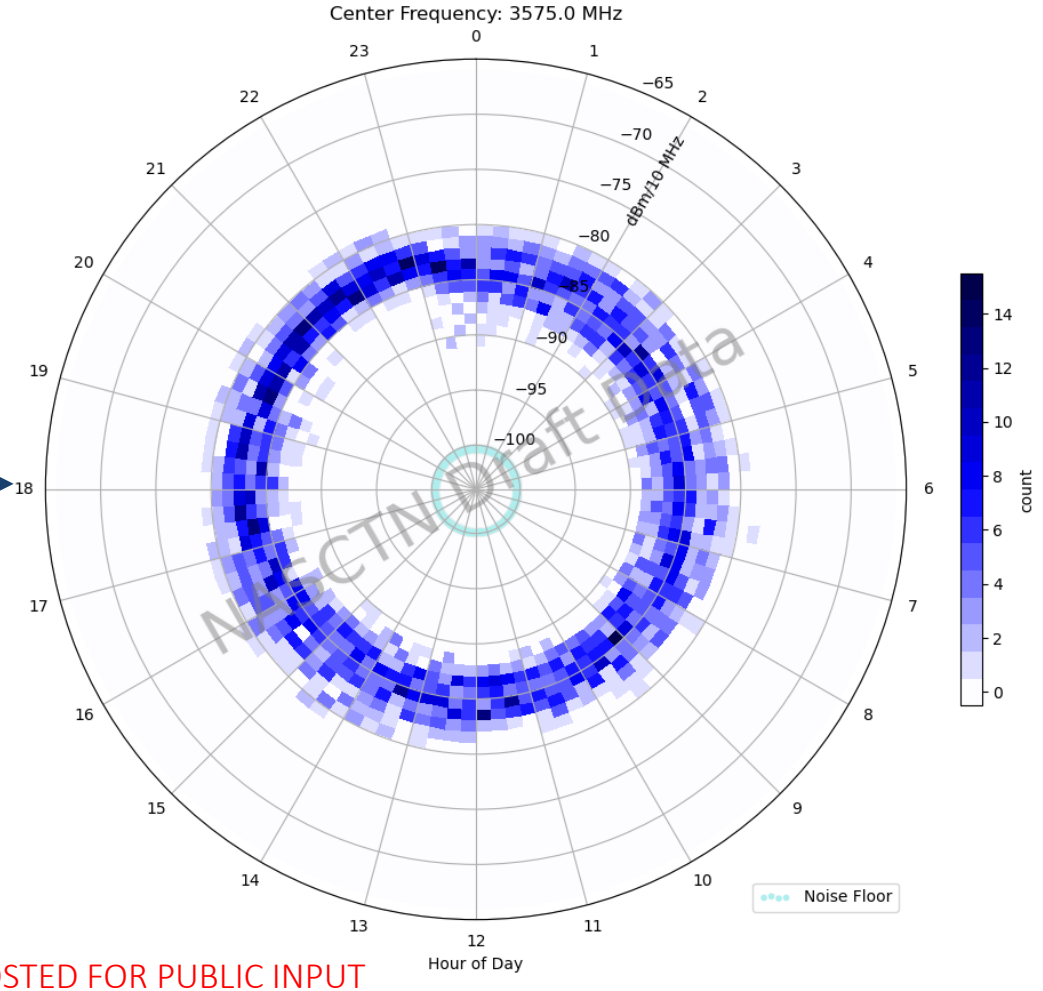




Exploratory Visualizations

- Long term trend maps
  - Histograms Traditional and Polar Projections





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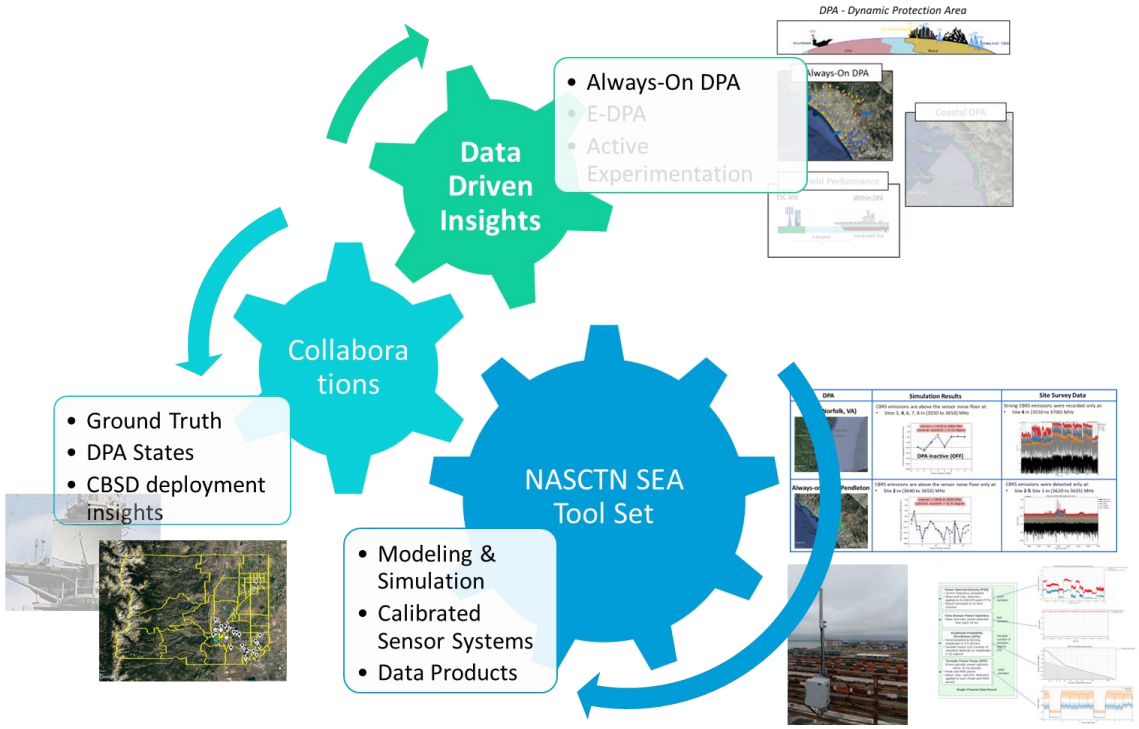
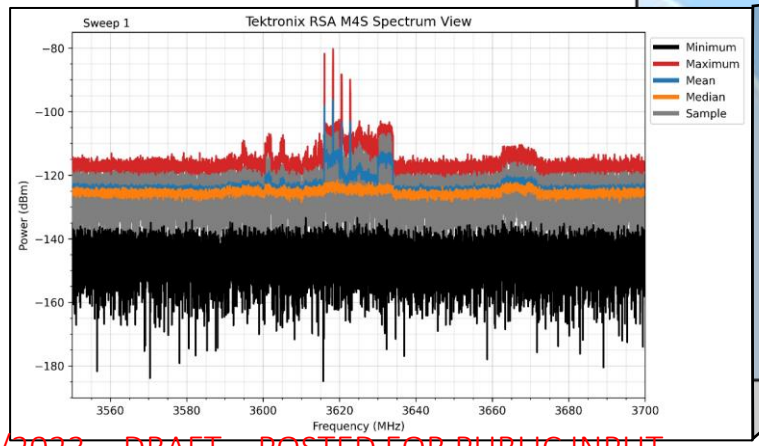
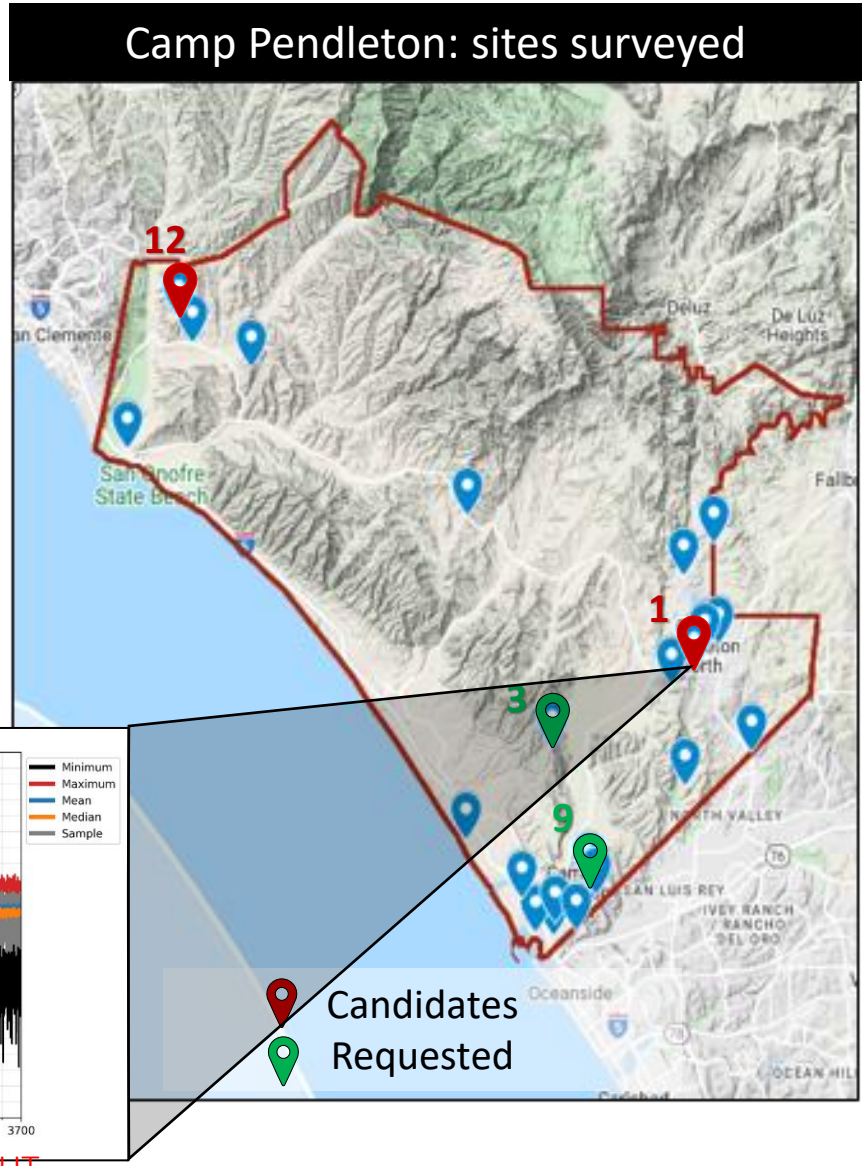


Site Survey

- Site surveys conducted to identify areas for sensor deployment during March 2022
  - 23 sites surveyed that covered available areas at Camp Pendleton
- Goal: Identify sites that support our sensor requirements
  - Power, antenna and mounting friendly, and good RF vantage to adjacent area from DPA
- The following data was collected at each site:
  - Spectrum and I/Q data around CBRS band 48
  - Observations of any signals indicating incumbents nearby
  - Active LTE signal levels for backhaul use (outside band 48)
  - AC power and shelter availability
  - Altitude measurements
- 4 sites were initially down selected from the original 23 with the highest potential





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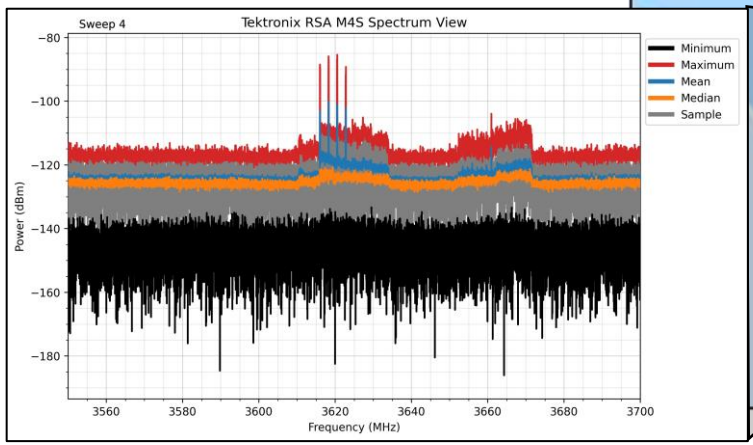
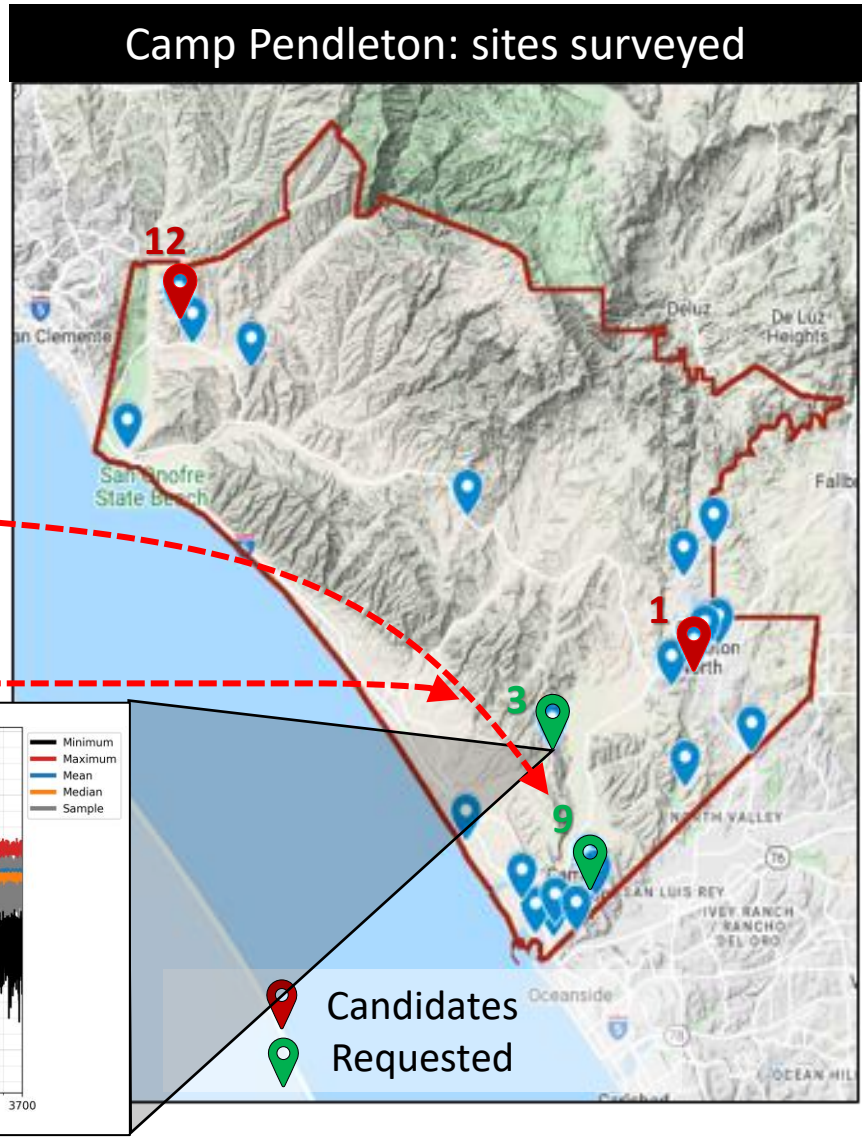
Camp Pendleton DPA Sensor Sites

- Selection Criteria Summary / Initial Sites Requested
  - Criteria for Site Selection
    - Located adjacent to a structure with power and room to deploy
    - CBRS Signals detected in band 48
    - Good correlation with CBRS modeling data
    - Sufficient LTE reception for backhaul
- Initial Pendleton Site Request for 2 sites:
  - Submitted to Pendleton POC on January 12, 2023
  - **Site ID 9** (~300ft altitude)
    - Structure with power nearby
    - Several options for mounting sensor system
    - Limited CBRS signal level measured at 3m AGL but good exposure to north San Diego County
  - **Site ID 3** (~570ft altitude)
    - Co-located near Navy sensor
    - High probability of securing site
    - Power available
    - Strong CBRS signal level measured at 3m AGL.





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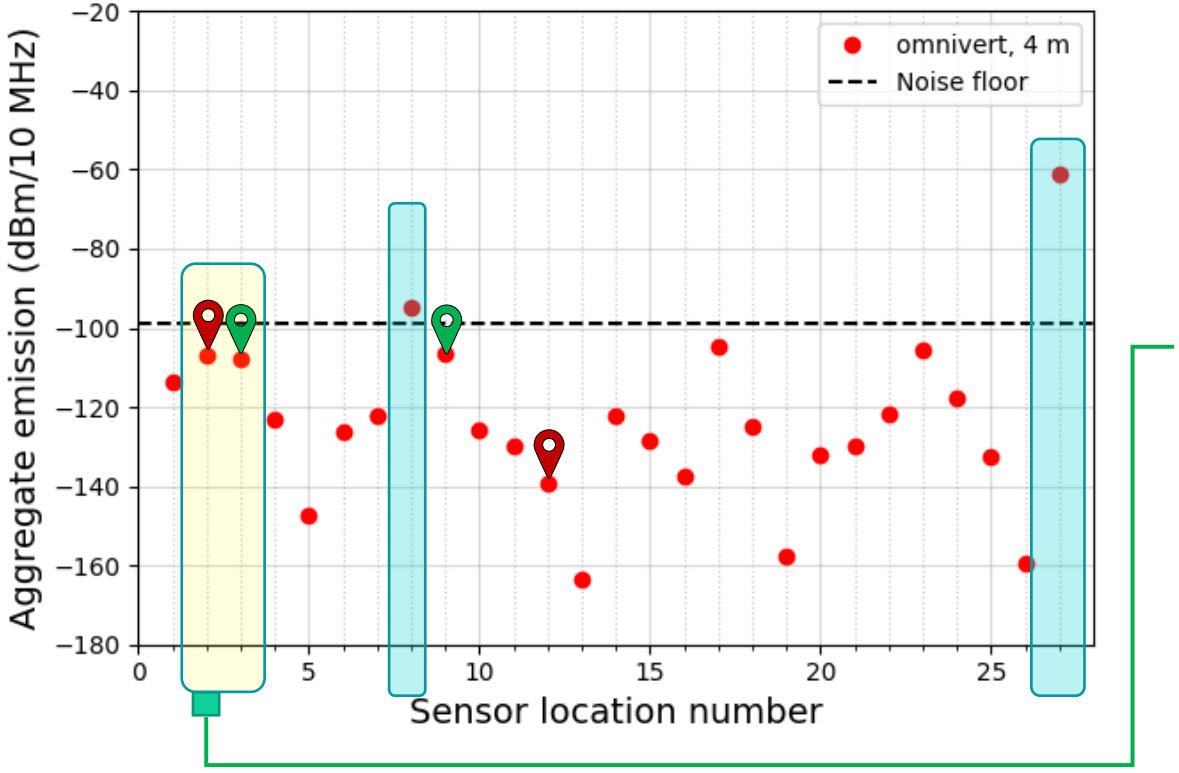
A Quick Comparison between Simulation Results and Site Survey Data

Simulation Results (seeded from 1/2023)

Aggregate emission estimates from CBSD grants to candidate sites in 3630-3640 MHz channel



Areas of high interest for sensor placement

Areas worthy of investigation from site survey

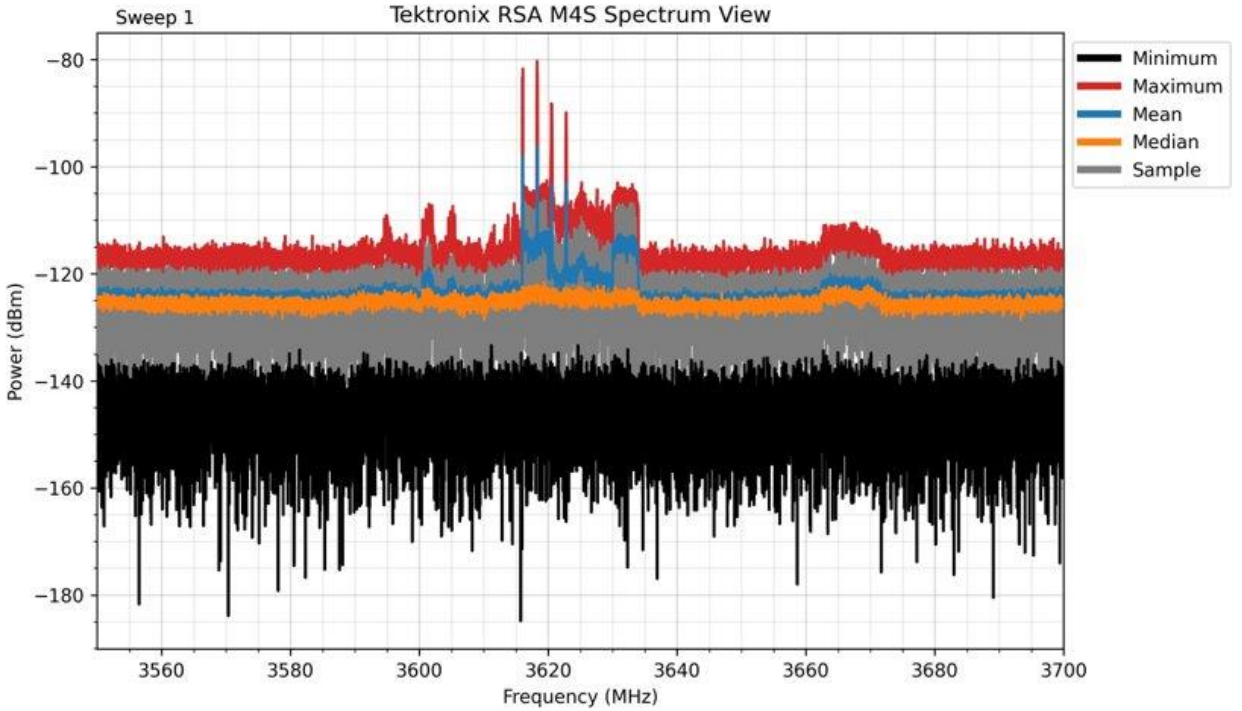
Candidates

Requested

Site Survey (March 2022)

CBRS emissions were detected only at:

- Site **2** & Site 3 in 3620-3635 MHz



State of Current Efforts

A. Prototype Systems

- Deployed in-situ to inform NASCTN Test Plan development and provide for initial insights into the CBRS band. (GMM, NIT, HU)
  - Data has shown interest from stakeholders
- *Software - on going revisions to:*
  - Evolve on-board calibration methodology
  - Reduce overhead in metadata
  - Improved sensor stability and reliability
    (latest round of updates points to >95%)
- *Hardware - on going revisions to* :
  - Exclusively outdoor fielded system
  - VAC/VDC power control
  - Antenna selection
- *System verification checks*
  - Additional test identified and under investigation

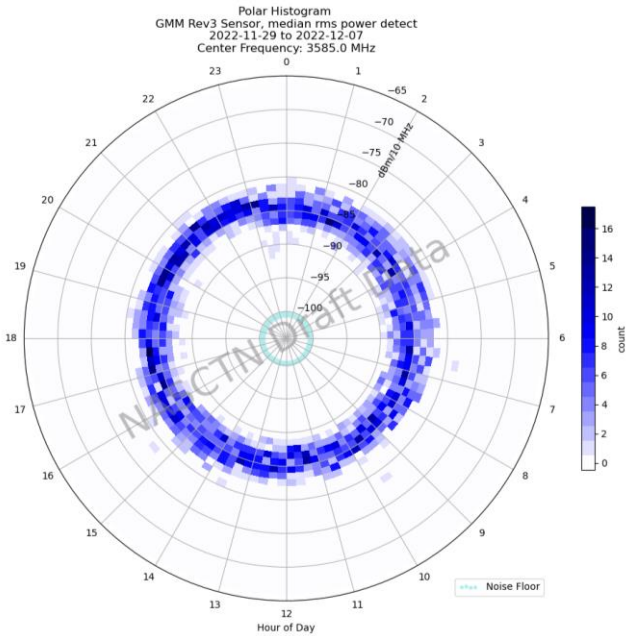
B. Data Ingestion & Analysis

- Work towards automated translation from SigMF to database repository
- Establish methods in formalized timeseries analysis

C. Data Publication Plan

- Need to investigate and formalize processes through with NASCTN will publish at a cadence relevant to stakeholders

Green Mountain Mesa	Norfolk International Terminal	Hampton University Tower
		
39.99180 N, 105.27452 W, 5851 ft +,- 5 ft ASL	36.91552 N, 76.32245 W, 159 ft +,- 5 ft ASL	37.02578 N, -76.34120 W, 231 ft +,- 5 ft ASL



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State of Current Technical Efforts: Stage 3

D. Sensor site selections

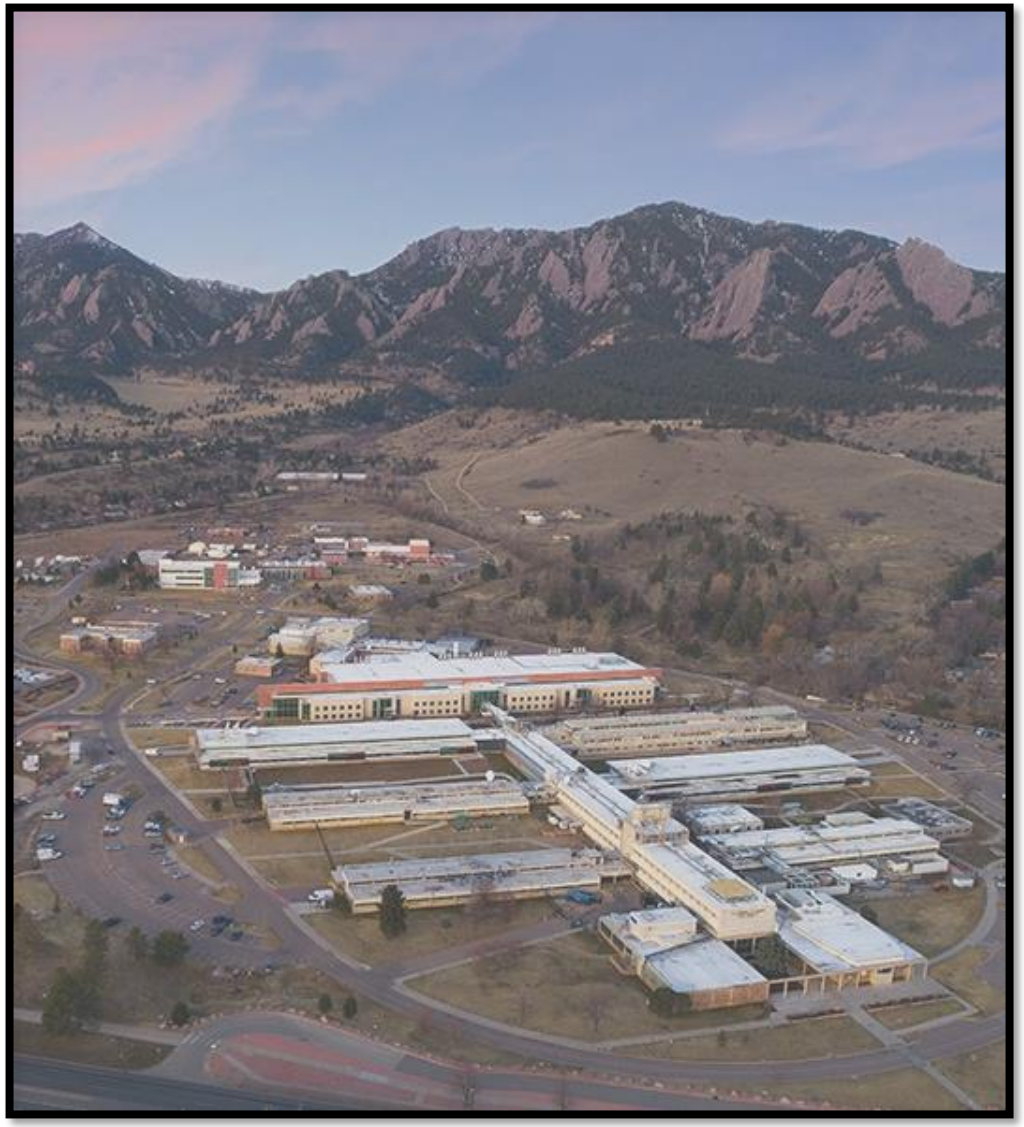
- Task 2 (Always On DPA) – Camp Pendleton. Initial site survey completed, site access requested & coordination in progress
- Task 1 (Coastal DPAs) – East 1: initial surveys conducted and West 14 upcoming focus.

E. Modeling

- Incorporating methods and industry provided data to better inform site selections.

F. Test Plan development

- Task 1- Fundamentals to test plan to be informed by Workshop input
- Task 3 - (Active Experimentation with Navy Ship) – Initial signal of opportunity events encouraging, looking to inform further through Workshop input



Contact Us

nasctn@nist.gov

NASCTN Program:

- https://www.nist.gov/ctl/nasctn

Updates on the Project:

- https://www.nist.gov/programs-projects/cbrs-sharing-ecosystem-assessment

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END of Deck

Comments Matrix for NASCTN Test Plan

UNCLASSIFIED

COMMENTS MATRIX FOR NASCTN TEST PLAN, "**LTE Impacts on AMT**"								
Commenter Area							NASCTN Adjudication Area	
#	ORGANIZATION & POC Name, Phone, and E-mail	Line Number	Page	Para	Comment Type	Comments and Justification	Resolution	A/R/P

HOW TO USE THE NASCTN COMMENT MATRIX if you are the coordinating organization:

Use this form to provide comments to NASCTN. Complete the header and footer, columns 2-7:

Column 1	Number the comments sequentially as they are added by each contributor.
Column 2	Enter the Organization, name, phone number, and email address for each contributor
Columns 3, 4, & 5	Enter the appropriate information for each comment. Leave columns 4 & 5 blank for general comments that apply to the entire document.
Column 6	Enter comment type (C, S, or A). (C) Critical: Critical comments apply to situations where the document violates established policy, guidance, or directives. The justification for critical comments MUST identify violations of law or contradictions of Executive Branch or Federal Agency policy; unnecessary risks to safety, life, limb, or materiel; waste or abuse of appropriations; or imposition of an unreasonable burden on an organization's resources. (S) Substantive: Make a substantive comment if a part of the document seems unnecessary, incorrect, misleading, confusing, or inconsistent with other sections, or if you disagree with the proposed responsibilities, requirements, or procedures. (A) Administrative: An administrative comment concerns non-substantive aspects of an issuance, such as dates of reference, organizational symbols, format, and grammar.
Column 7	Place only one comment per row. Enter your comment, recommended changes, and justification in the area provided. If any material is sensitive, proprietary, or requires special handing, contact the NASCTN Program Manager for guidance on marking and handling the comment matrix.

NASCTN Adjudication

Consolidate comments from all contributors and adjudicate them. Remove column 2 to maintain anonymity of contributors prior to posting to the NASCTN portal page (**https://www.nist.gov/ctl/national-advanced-spectrum-and-communications-test-network-nasctn**). Set header and footer as appropriate. Complete information in column 8 & 9:

Column 8	Enter your resolution and/or justification. Include any related communications with the contributing organization. You MUST provide convincing support for rejecting critical comments.
Column 9	Enter whether you accepted (A), rejected (R), or partially accepted (P) the comment. Your justification in column 8 must be consistent with this entry.

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Norfolk International Terminal Sensor

South Tower, Site

NIT Sensor, Installation	
Latitude	36.91552 deg
Longitude	-76.32245 deg
Azimuth	N/A
Elevation	0 deg +,- 3 deg
AGL estimate	45 m
AMSL (WGS-84)	48.5 m +, - 1.5 m
Omni-Directional: HG3509U-PRO	
Gain	9.0 dBi
Slant Pol	Vertical
Horizontal	360 deg
Vertical HPBW	11 deg

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https://www.l-com.com/Images/Downloadables/Datasheets/ds_HG3509U-PRO.pdf

Hampton University Tower Sensor

Hampton University Tower

HU Sensor, Installation	
Latitude	37.02578 deg
Longitude	-76.34120 deg
Azimuth	N/A
Elevation	0 deg +,- 3 deg
AGL estimate	65.5 m
AMSL (WGS-84)	70.4 m +, - 1.5 m
Omni-Directional: HG3509U-PRO	
Gain	9.0 dBi
Slant Pol	Vertical
Horizontal	360 deg
Vertical HPBW	11 deg

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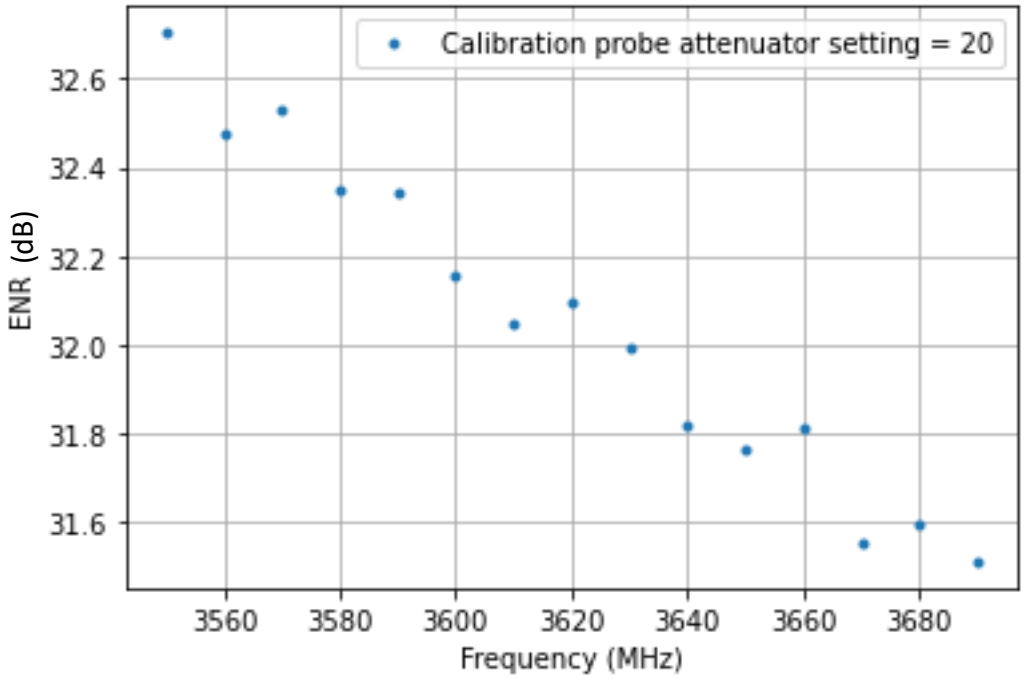
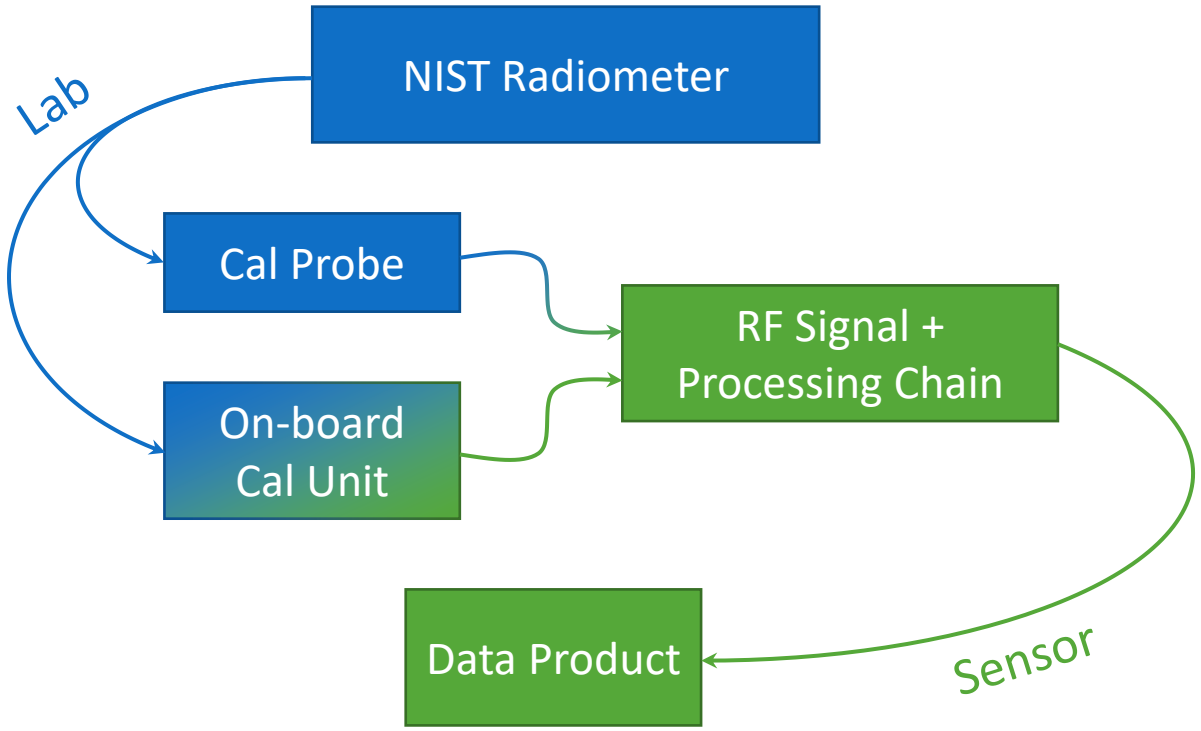
https://www.l-com.com/Images/Downloadables/Datasheets/ds_HG3509U-PRO.pdf

Verification, Bench Calibration, and Acceptance

NIST Traceable Calibration Probe, Reference ENR





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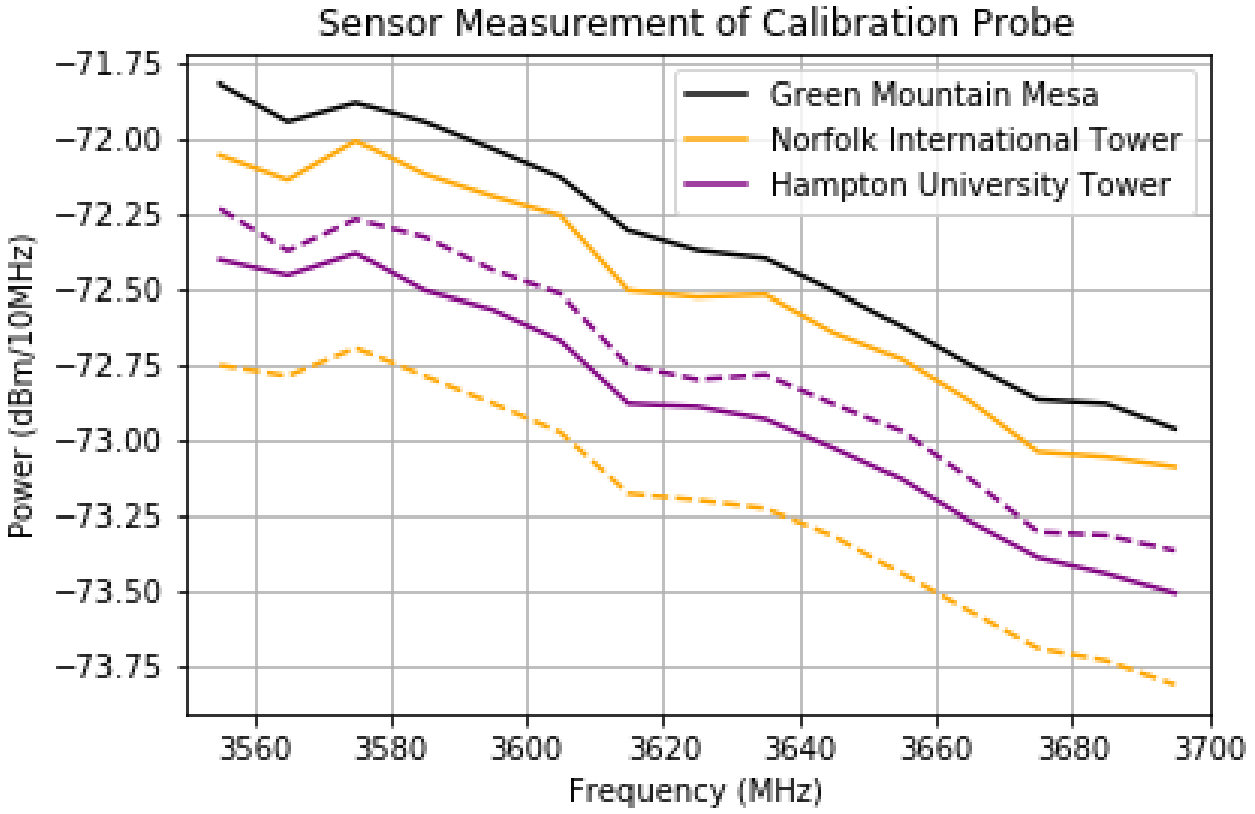
On-site Calibration Verification



- Calibration was verified at the antenna port post install (--) with the Calibration Probe
- Systems are within 1 dB of Lab Verification
- Collected S_{11} of as-installed Antennas for cascaded uncertainty analysis

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Proposed Install Zone options:

- Good vantage, permanent structures and possible shore AC power.
- There are several possibilities for mounting
- CBRS reception was limited but anticipated to improve with elevated antenna

- Good vantage, CBRS reception, and power infrastructure
- Recent approval for a NSWC Dahlgren effort, co-location may prove insightful for longitudinal studies and comparisons

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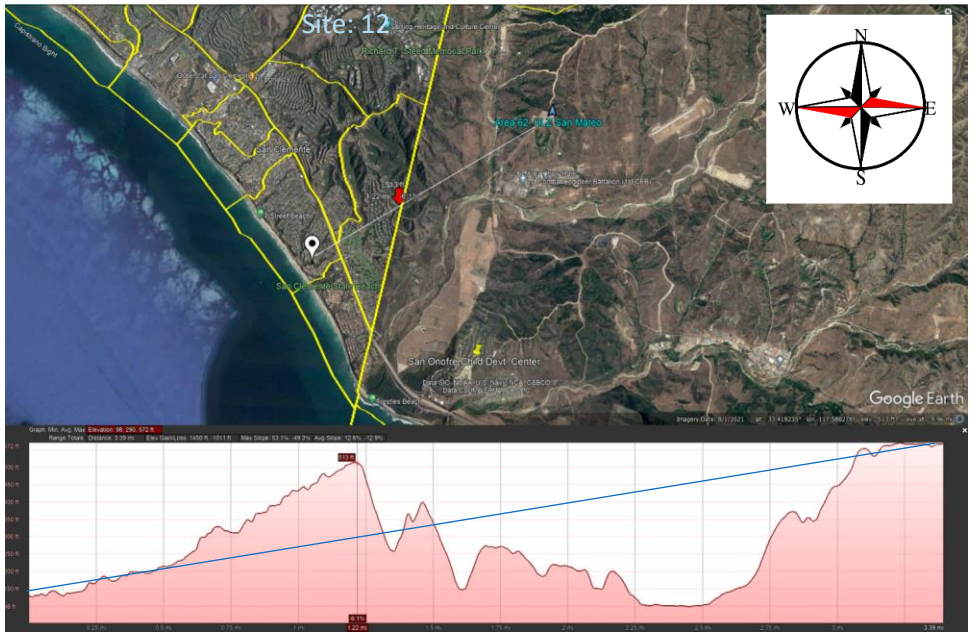
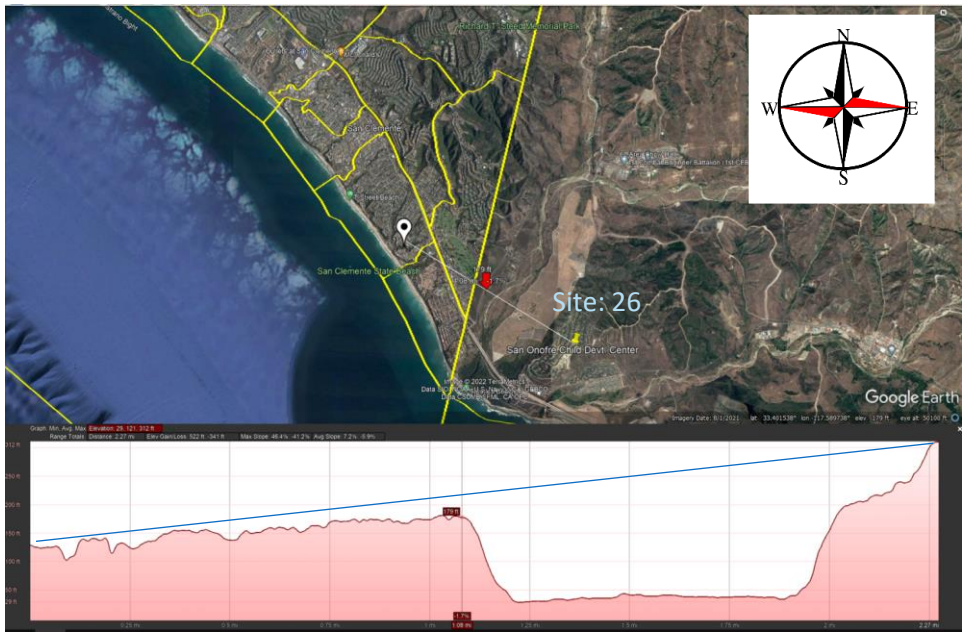
Backup Example using "Line of Sight (LOS)" terrain analysis for site refinement

Example Backup Site Comparison: New Site compared to HLZ San Mateo, Site #12:

- Alternate Site Benefits:
  - Improved / clearer LOS to CBSD(s) in San Clemente area, therefore better vantage to potential CBRS signals
  - However, modeling does not show improvement in signal levels – most likely due to low # of CBRS devices?
  - Suggest using location for long term CBRS monitoring and raising antenna to 20-25 ft to get better signal reception





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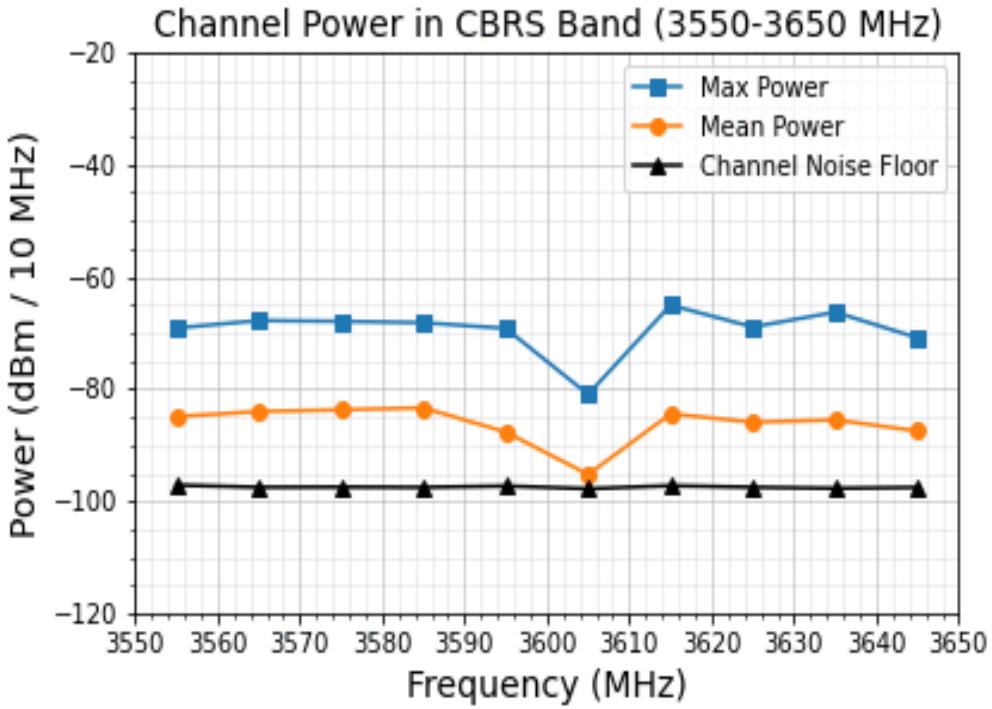
Measured vs. Calculated Aggregate Emissions

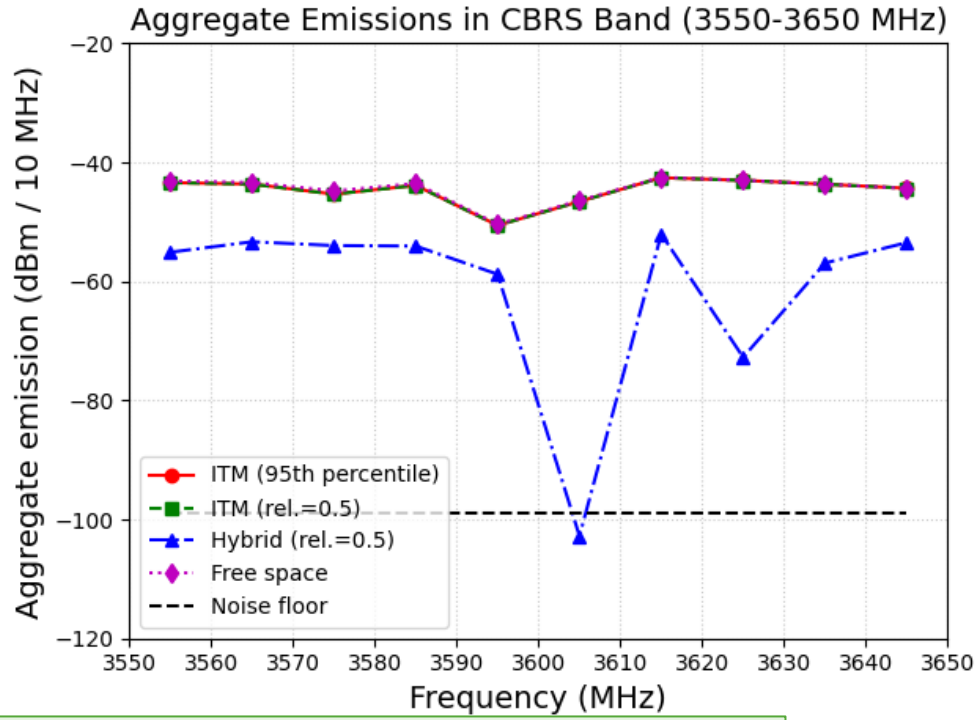
Measured max/mean powers in each 10 MHz at GMM sensor:

- CBSD activities found in many channels in (3550 to 3650) MHz
- ~20 dB difference between max and mean values

Estimated aggregate emissions in each 10 MHz at GMM sensor using different propagation models/configurations:

- ITM (95th percentile) and ITM (reliability = 0.5)
- ITM/eHata hybrid (reliability = 0.5) and free space





Findings:

- ITM model overestimates the aggregate emissions for all channels
- eHata/ITM hybrid model provides estimates closer to the measured max powers
  - Note, hybrid model adjusts the Tx-er/Rx-er heights (i.e., height_tx >=20 m, height_rx = 1.5 m), and it depends on the Tx-er region type (‘URBAN’, ‘SUBURBAN’, ‘RURAL’)

02/22/2023 – DRAFT – POSTED FOR PUBLIC INPUT

Backup – Data Transfer Estimates (Monthly)

- The table below is total data transfer from 20 sensors for one month
  - 20 sensors uploading data
  - ITS hub downloading data from 20 sensors
  - "Data size" refers to data product file size for measurement of entire CBRS band

		Seconds per Acquisition			
		10	**60**	**90**	**300**
Data Size	**406 kB**	4.35 TB	725 GB	483 GB	145 GB
	88.5 kB	948 GB	158 GB	105 GB	31.6 GB
	14.3 kB	153 GB	25.5 GB	17.0 GB	5.11 GB
	6.15 kB	65.9 GB	11.0 GB	7.32 GB	2.20 GB

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