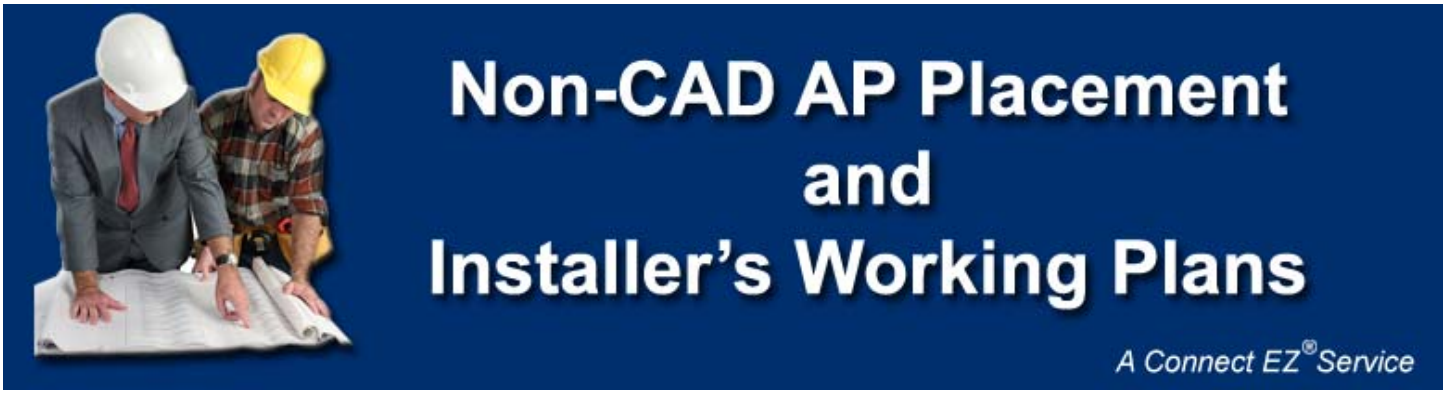



PERRIS UNION
HIGH SCHOOL DISTRICT

# Installer's Plans
# Perris Union High School District
# Riverside County, California
## January 19, 2016

**Connect802 Corporation**
111 Deerwood Road, Suite 200
San Ramon, CA 94583
(925) 552-0802 sales@Connect802.com
www.Connect802.com

# CONNECT EZ™ NON-CAD RF DESIGN

The present report presents a design plan for 802.11 WiFi access points and/or antennas that is based on a visual assessment of site plans by a team of experienced RF engineers. Tools such as predictive RF CAD modeling and simulation software were not applied to this design, hence the term “Non-CAD design”.

## Disclaimer and Perspective on RF Analysis

Every effort has been made to assure the accuracy of the design presented in this report however it may be the case that unanticipated construction characteristics, placement of interior obstructions (furniture, shelving, etc.), or other factors could cause a weak coverage area or “dead spot” to be discovered after installation. In this case one or more additional access points may be necessary to remediate the design. If this situation were to occur, additional RF engineering services to remediate the problem would be provided at no additional labor cost as part of this project. Equipment, installation or other expenses would be billed as per the terms of the original price quotation.

Any radio system may experience problems related to unpredictable or unanticipated RF interference, noise, or other spectral events. Producer does not warranty or guarantee any work, or equipment usability, when such situations arise. **In all cases,** Producer**'s liability will be limited to a refund of all monies paid by the customer.**

Producer will perform all RF consulting work in a professional manner and will attempt to correct, at no cost to the end-customer, oversights that may arise in conjunction with a project. This assurance does not extend to problems resulting from unexpected, or unnoticed characteristics of the RF environment at the customer's site. Producer will work towards solving problems that may arise out of RF spectral events but these services (or products) may be quoted and billed as additional work on a project, subject to the customer's approval. Customer's may opt to include a full Faraday Cycle Analysis as part of their pre-installation design work.

Every effort has been made to provide accurate, reliable information and to draw valid conclusions. If you base any decisions on the information in this document, or on any other discussions with the RF engineering, sales or management team, you accept all liability for consequences arising from those decisions. You must consider the following points when applying the contents of this document to anything:

- Component data are extracted from catalogs, brochures, and web page material provided by various vendors. Component specifications may change without notice and individual manufacturing tolerances, equipment damage, or incorrect installation may result in variations from published equipment specifications.
- The RF environment is subject to influences that may not be anticipated. Findings presented in this report reflect the state of the RF environment at the time the measurements were taken. Every effort has been made to confirm that the measurements are representative of the typical state of the environment but that environment may change without any obvious visible indication.
- Information obtained from subject matter experts and other authoritative sources may be used without independent validation and may be inaccurate.
- The electromagnetic characteristics of any space are affected by a variety of complex interactions ranging from the 11-year sun spot cycle to microwave ovens and cordless phones. It is impossible to anticipate or evaluate all of the possible environmental influences that may cause the conclusions in this document to be invalid.

If you base any decisions on the information contained in this document you acknowledge that you have carefully considered the potential for error and you accept that risk. The data in this report is provided on an as-is basis with no warranty or guaranty for accuracy. No warranty, express or implied, is made concerning consistency with any standard of merchantability, or that the information provided will meet your requirements for any particular application.

**The information in this report must not be relied upon for implementing a transmission system whose incorrect design, installation, or use could result in injury to a person or loss or damage to property, including but not limited to intellectual property or computer data.**

Any liability shall be limited to a refund of all monies paid to obtain this report and there shall be no liability for loss or injury caused by its actions, omissions, or for contingencies beyond its control nor for decisions made or action taken or not taken in reliance upon the information furnished in this document.

# TABLE OF CONTENTS

# IMPORTANT INSTALLATION GUIDELINES

**PLEASE READ CAREFULLY BEFORE YOU BEGIN INSTALLING EQUIPMENT:**

Our experience has been that post-installation validation of designs based on RF CAD modeling and simulation confirm that actual signal strength is highly consistent with predicted values. Nonetheless, **field validation of the present design must be performed at the time of installation to avoid potentially costly and time consuming problems** after end-users begin to access the system. Those responsible for the installation of the system must assure that the assumptions made in this design, and the equipment specifications used in creating the models, are correct. The confirmation process includes the following steps that must be performed as equipment is installed:

**Upon installing the FIRST radio on each building floor:**

1. Use a measuring tool that reports dBm or mW signal strength and confirm that actual coverage is consistent with predicted coverage. The tool could be as simple as NetStumbler or as sophisticated as AirMagnet (or an actual RF spectrum analyzer.) If measured signal strength is below the Design Signal Strength for the present project (discussed on in the Design Signal Strength section of this report) you should **STOP THE INSTALLATION PROCESS** and call to discuss the discrepancy. Not only is this type of validation considered standard practice, it is also the most effective way to avoid future problems.
2. Connect to the SSID of the access point and use the MS-DOS PING command to confirm data transfer capability across the wireless link. This may require that you manually configure the IP address of your notebook computer to match the subnet of the access point's management interface. Use the "-t" option with PING to continuously send ping packets. Walk around the intended coverage area for the access point and confirm that ping responds properly. 802.11 wireless networks typically have error rates that can approach 10% so expect an occasional lost PING packet. If you experience greater than 10% lost PING packets, **STOP THE INSTALLATION PROCESS** and call to discuss the problem. This may require that an RF engineer be dispatched to the installation site to perform a spectrum analysis and isolate the cause of the data loss. Dispatching and engineer to the site may be a separately charged service.

**Perform the preceding two steps in any critical or error-prone installation location**

Access points intended to provide coverage for the most important locations should be validated as described above. Also, when a coverage area contains known sources of environmental noise or interference, the same steps should be performed.

**Do NOT install an entire system without testing and validating during the installation process.**

# EXECUTIVE OVERVIEW

## On-Site RF Analysis and Design

This report provides the data and conclusions of the on-site RF analysis performed at Perris Union High School District ("The District") during the week of January 11, 2016. Schools surveyed were Perris, Heritage, Paloma Valley, Pinacate, Perris Lake, The Academy, and California Military Institute. In-scope areas were called out in "Exhibit #1" submitted by The District as part of the RFP.

This project was comprised of the following elements:

- **On-site, real-time design of a wireless network.** The surveying engineer determined AP locations based on his experience and professional judgment. AP locations were validated by placing a test AP in each proposed location and surveying the actual coverage of the AP.
- **On-site RF spectrum analysis to identify interference and noise.** Using an RF spectrum analyzer, a walk-through of the site was performed to describe normal, unusual, and problematic characteristics related to noise or interference. Normal behavior was generalized and only abnormal or significant types of conditions were called out.

In order to deliver the installer's plans as quickly as possible, the spectrum analysis results will be presented in a separate document, to be delivered at a later date. This report contains only the installer's plans

## Summary of Results

The survey was completed successfully and the wireless network design was created. Coverage in the in-scope area is expected to exceed the project requirement of -67 dBm. The design takes into account the requested 30% cell overlap factor, which equates to an overlap margin of 3 dB, as described elsewhere in this report. Therefore, the target RSSI shown in this report is -64 dBm, not -67 dBm.

## Required Equipment

The design presented in this report requires the following radio equipment:

| Site | AP Count |
|---|---|
| Paloma Valley | 22 |
| Perris | 13 |
| Perris Lake | 3 |
| Academy | 1 |
| Pinacate | 9 |
| Heritage | 12 |
| California | 6 |
| **Total** | **68** |

# PROJECT ASSUMPTIONS

## Project Specifications

The following specifications were determined for use in the present project:

| | | |
|---|---|---|
| Air Standard: | 802.11n 2.4 GHz and 802.11ac 5 GHz | |
| Target RSSI: | -67 dBm | |
| Access Point Power: | 2.4 GHz: | 15-18 dBm |
| | 5 GHz: | 15-20 dBm |
| Cell Overlap: | 30% @ -64 dBm | |
| Access Point: | Meraki MR72 | |

Cell overlap is calculated using the method described in the “Designing Coverage Cell Overlap” section of the Technical Appendix at the end of this report. The target RSSI for the project is -67 dBm. Using that method, the relevant calculation to arrive at a 30% overlap is as follows.

$$Overlap\ RSSI = 10\ * \log\left(\frac{1.99 * 10^{-7}\ mW}{(1-0.3)^2}\right) = -64\ dBm$$

The target RSSI for the project is -67 dBm. In the equation the linear (i.e., not logarithmic) value for the target signal strength is 1.99 * $10^{-7}$ mW. The overlap percentage is 30%, or 0.3. These values are input to the equation to produce the target overlap RSSI of -64 dBm.

# Meraki MR72 Outdoor Access Point

Dual-band 2x2 MIMO 802.11ac Access Point
with dedicated security and RF optimization radio
and Bluetooth low energy Beacon and scanning radio

**High performance cloud-managed 802.11ac wireless**
The Cisco Meraki MR72 is a three–radio, cloud-managed 2x2 MIMO 802.11ac access point. Designed for general purpose next-generation deployments in harsh outdoor locations and industrial indoor conditions, the MR72 provides performance, security, and manageability.

The MR72 provides a maximum 1.2 Gbps data rate with concurrent 802.11ac and 802.11n 2x2:2 MIMO radios, and security and spectrum visibility via a third radio dedicated to 24x7 WIDS/WIPS and automated RF optimization. An integrated Bluetooth low energy (BLE) radio delivers Beacon functionality and BLE device scanning.

The combination of cloud management, 802.11ac, full-time RF environment scanning, and an integrated Bluetooth technology delivers the high throughput, reliability, and flexibility required by the most demanding business applications like voice and high-definition streaming video, both today and tomorrow.

**RF Performance Table**

| Operating Band | Operating Mode | Data Rate | TX Power | RX Sensitivity |
|---|---|---|---|---|
| 2.4 GHz | 802.11b | 11 Mb/s | 19 dBm | -84 |
| 2.4 GHz | 802.11g | 6 Mb/s | 17 dBm | -87 |
| | | 54 Mb/s | 17 dBm | -70 |
| 2.4 GHz | 802.11n (HT20) | MCS0/8/16 HT20 | 18 dBm | -85 |
| | | MCS7/15/23 HT20 | 15 dBm | -67 |
| 2.4 GHz | 802.11n (HT40) | MCS0/8/16 HT40 | 18 dBm | -83 |
| | | MCS7/15/23 HT40 | 15 dBm | -63 |
| 5 GHz | 802.11a | 6 Mb/s | 20 dBm | -92 |
| | | 54 Mb/s | 18 dBm | -73 |
| 5 GHz | 802.11n (HT20) | MCS0/8/16 HT20 | 20 dBm | -90 |
| | | MCS7/15/23 HT20 | 17 dBm | -70 |
| 5 GHz | 802.11n (HT40) | MCS0/8/16 HT40 | 20 dBm | -87 |
| | | MCS7/15/23 HT40 | 17 dBm | -68 |
| 5 GHz | 802.11ac (HT80) | VHT-MCS0/8/16 HT80 | 20 dBm | -84 |
| | | VHT-MCS9/15/23 HT80 | 15 dBm | -58 |

# ON-SITE DESIGN AND SURVEY

### Overall Purpose and Methodology

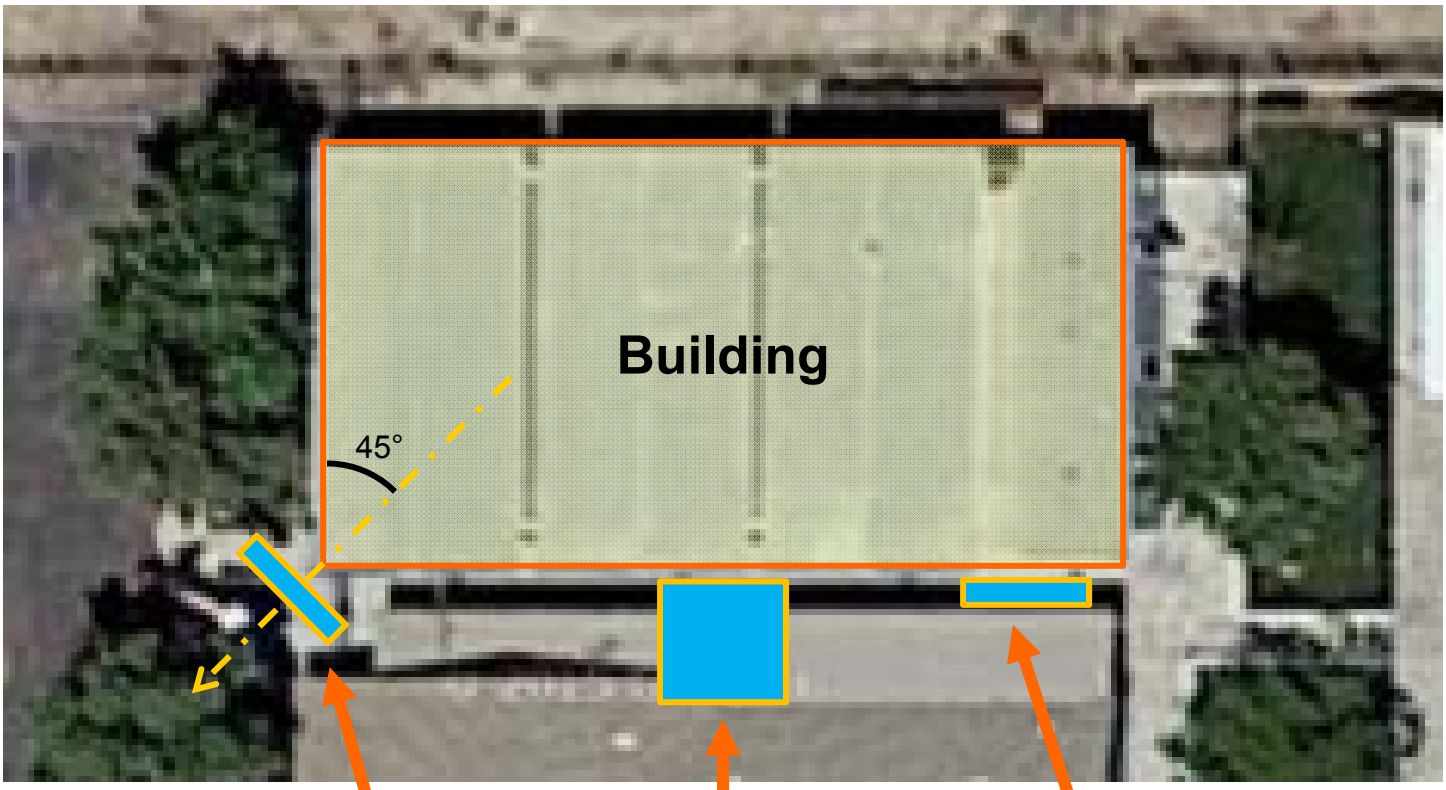
The surveying engineer determined AP locations based on his experience and professional judgment. AP locations were validated by placing a test AP in each proposed location and surveying the actual coverage of the AP. For each survey, a measurement point was taken approximately every 20-30 feet. In an outdoor area, this gives a sufficient density of measurement points to be able to verify the area within which coverage will meet project requirements.

Results of this section are presented as follows.

- **In-scope area.** A satellite image of the site shows the in-scope area for the site marked in green. This is copied from “Exhibit #1” of the RFP.
- **Overview of coverage for the entire site.** Individual APs’ heat maps are combined into a composite heat map that shows that the entire in-scope area is expected to meet project coverage requirements
- **Coverage from an individual AP.** For each AP, a heat map of just that AP’s coverage is presented. This image also depicts the AP’s installation location in more detail than the whole-site map.
- **Photograph of installation location.** For each AP, a photograph of the intended installation location is presented, with the AP’s exact location called out. Exact details of the installation, such as the method of mounting the AP and where to run cabling, are to be determined by the installer.

# Installation Notes

APs at these sites are installed on the exterior of buildings. Three general mounting styles are used for most of the locations. Two locations are mast-mounted, and do not exactly fit the below descriptions. The purpose of the mast-mounts is to give the APs additional elevation to help them clear obstacles.




**Corner mounting style** orients the AP at 45 degrees relative to a building corner. This mounting style is most sensitive to AP placement. The purpose of this style is to allow the AP to provide coverage to two sides of the building. Therefore, the AP must be installed with a standoff mount that places it on the diagonal relative to the corner. The standoff mount may straddle the corner, or it may anchor to one side of the corner. What matters is the AP's location and orientation relative to the corner.

If this AP were to be installed in the flat mounting style, it would be shadowed to one side of the building, and coverage would be compromised. The corner-mounting style allows one AP to cover two sides of the building, instead of two APs.

**Flat mounting style** orients the AP parallel to the building façade. The AP may be installed directly against the façade, or it may be installed in any other way that is practical, such as a right-angle mount installed to an overhang. The orientation of the AP relative to the façade is what matters.

**Down-facing mounting style** orients the AP facing directly downwards towards the ground. In almost all cases, this is because the AP is being mounted underneath an overhang, on the ceiling. An example would be an AP that is installed on the bottom surface of an I-beam ceiling rafter on a building eave.

# Paloma Valley High School
## Overall Coverage Heat Map


Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

# Paloma Valley High School
## Per-AP Heat Maps and Installation Location Photos

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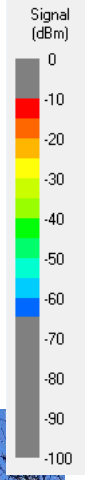


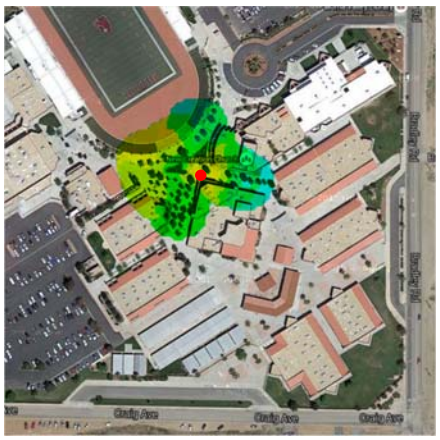

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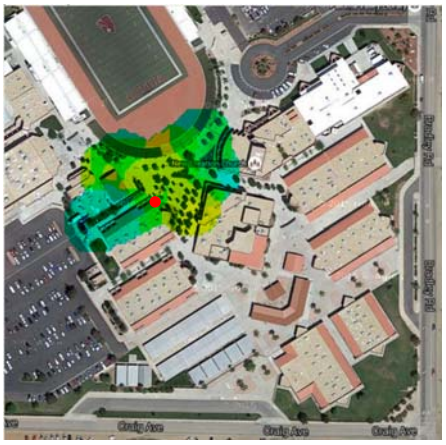

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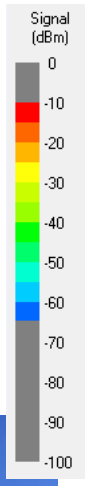


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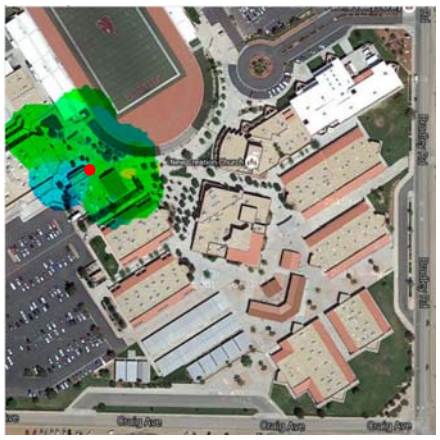

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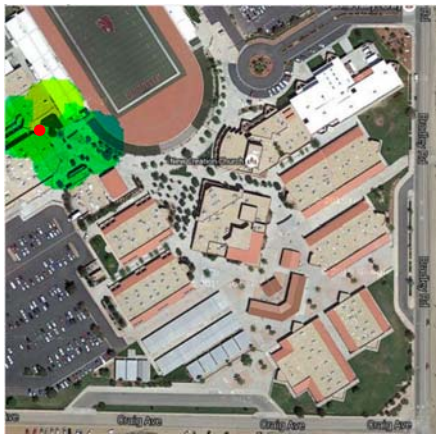

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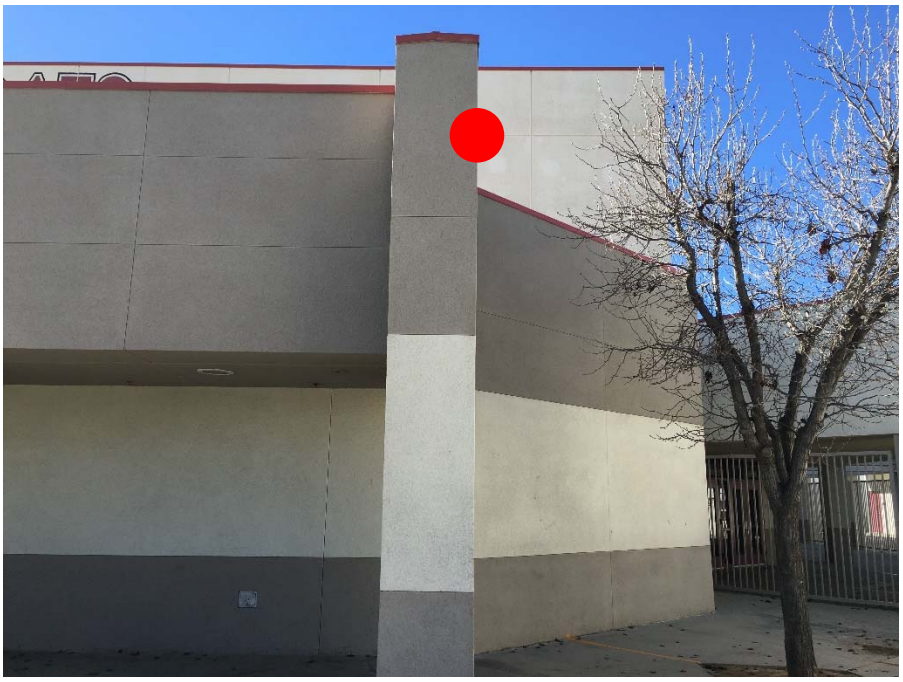

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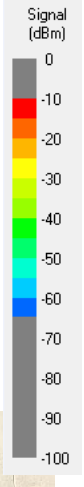


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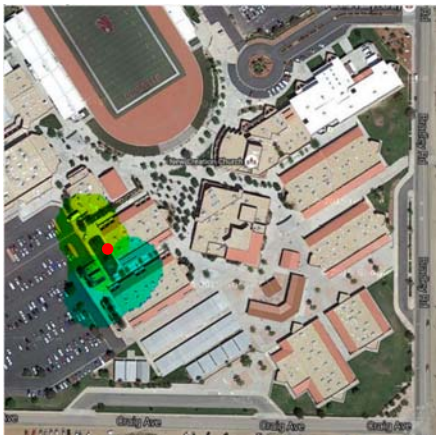

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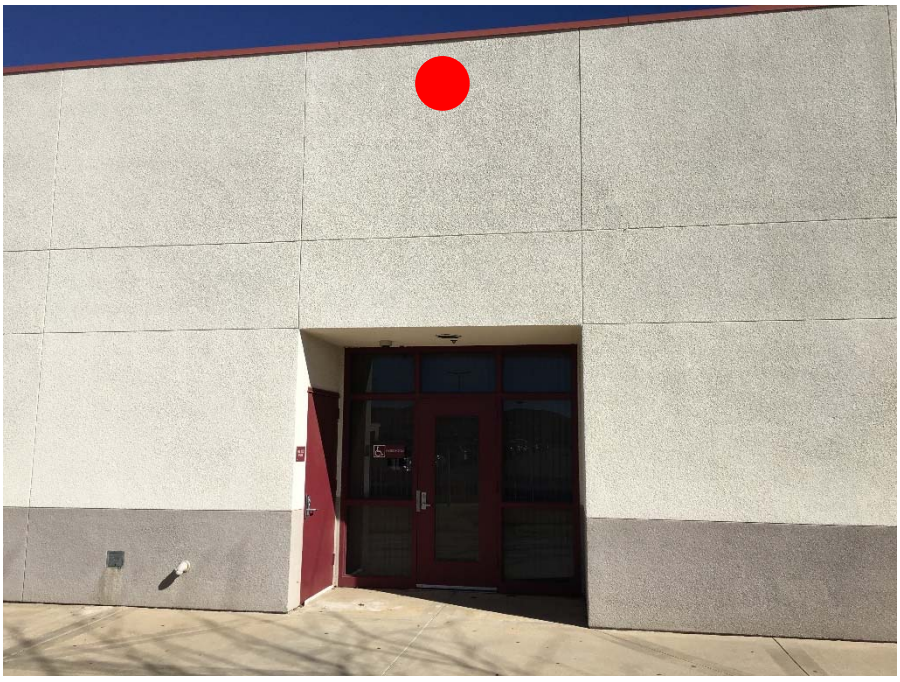

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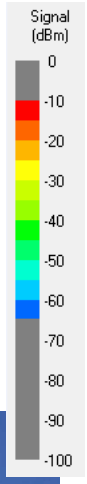


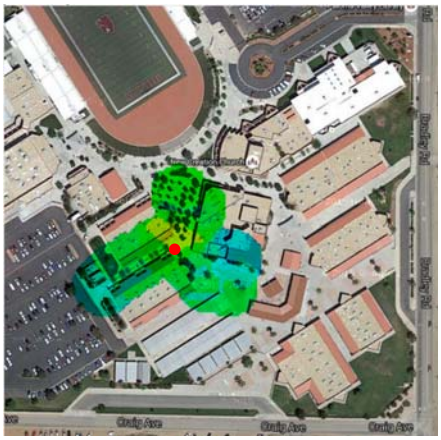

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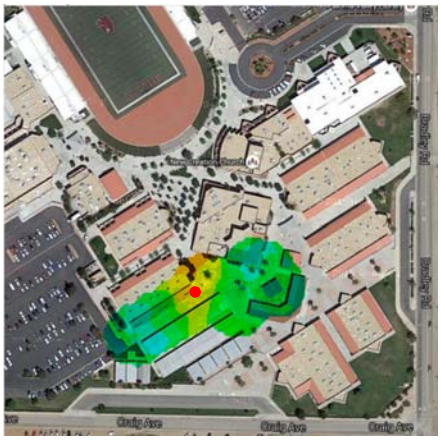

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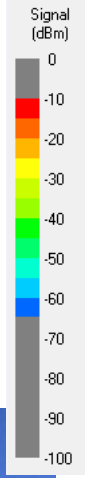


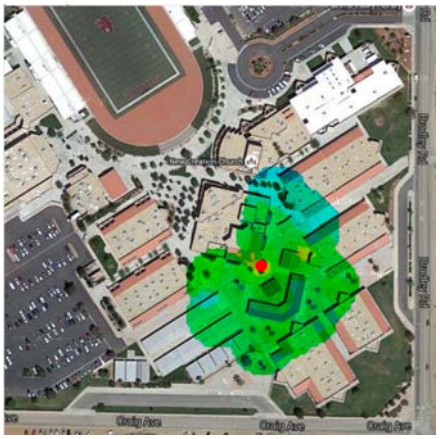

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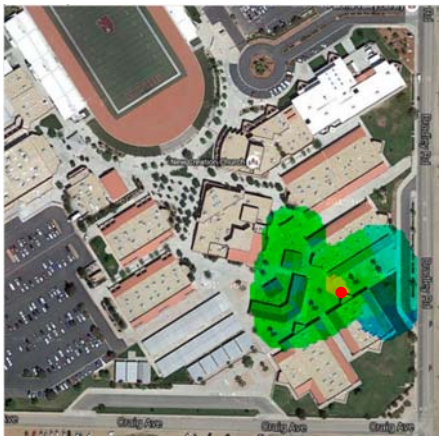

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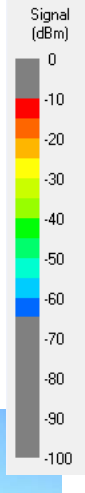


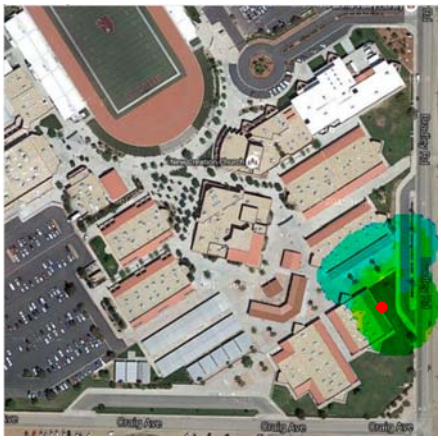

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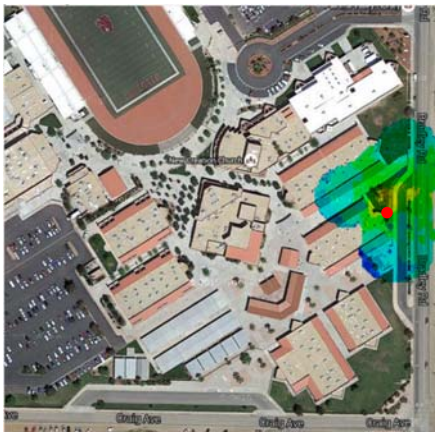

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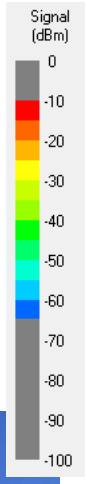


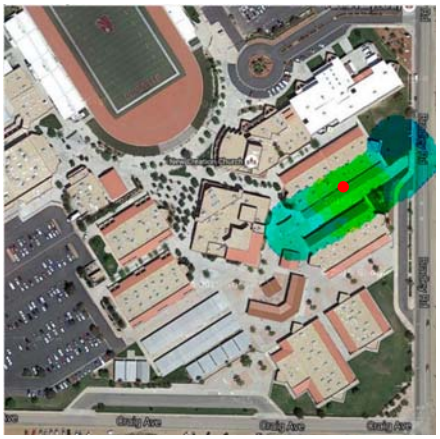

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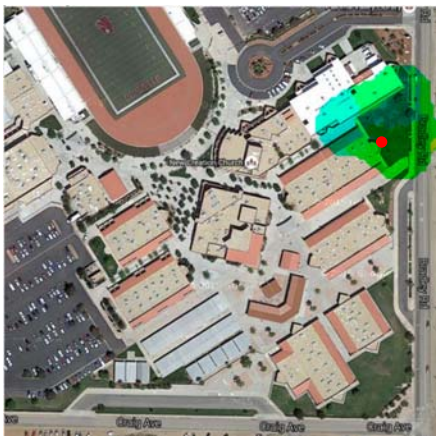

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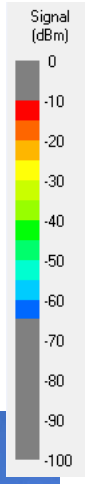
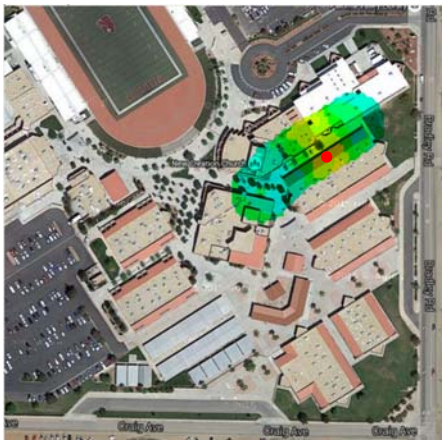
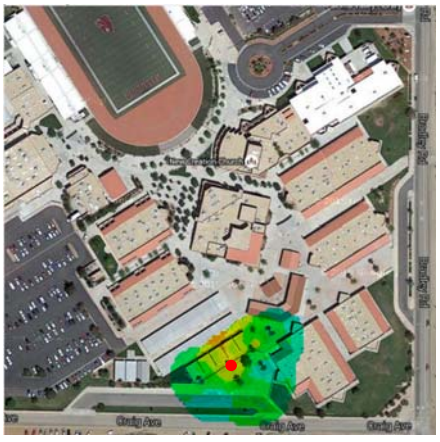


This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.

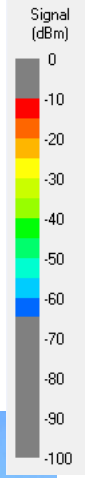


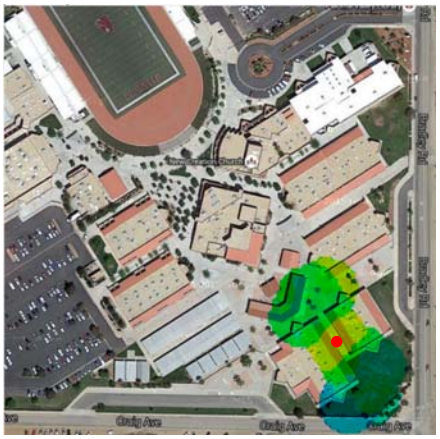
This AP is installed in the **down-facing** style. See the installation notes at the beginning of this report section for details.

# Paloma Valley High School

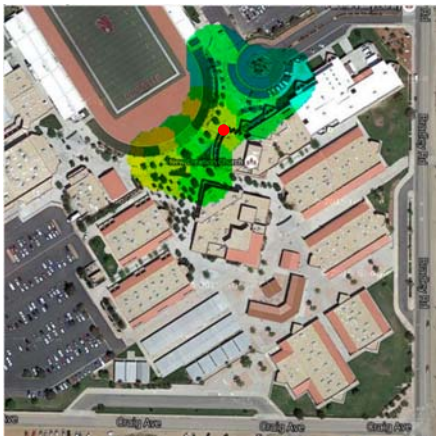
## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



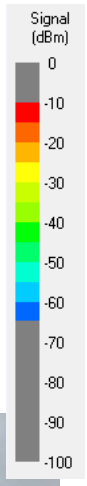
This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.



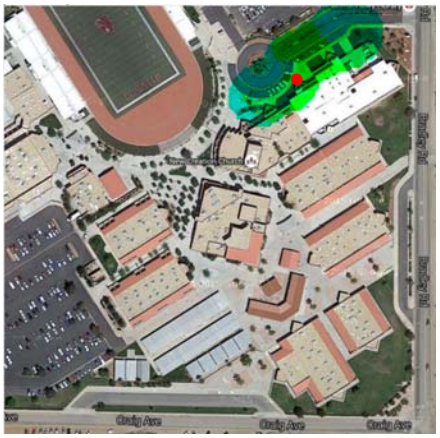
This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

# Paloma Valley High School

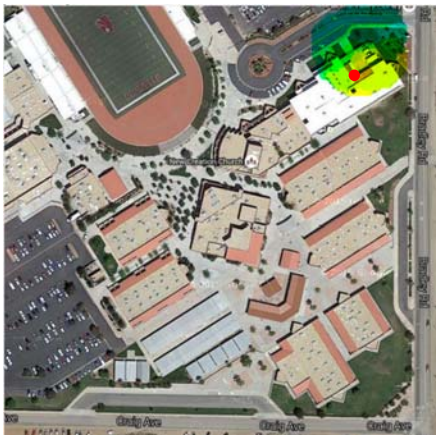
## Per-AP Heat Maps and Installation Location Photos




Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

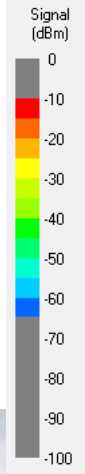


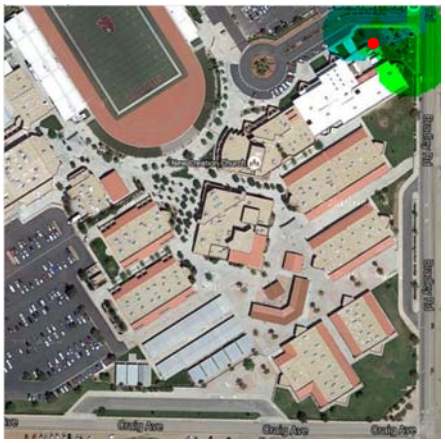
This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

# Paloma Valley High School

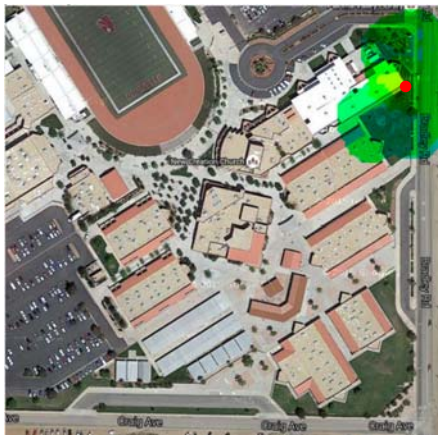
## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



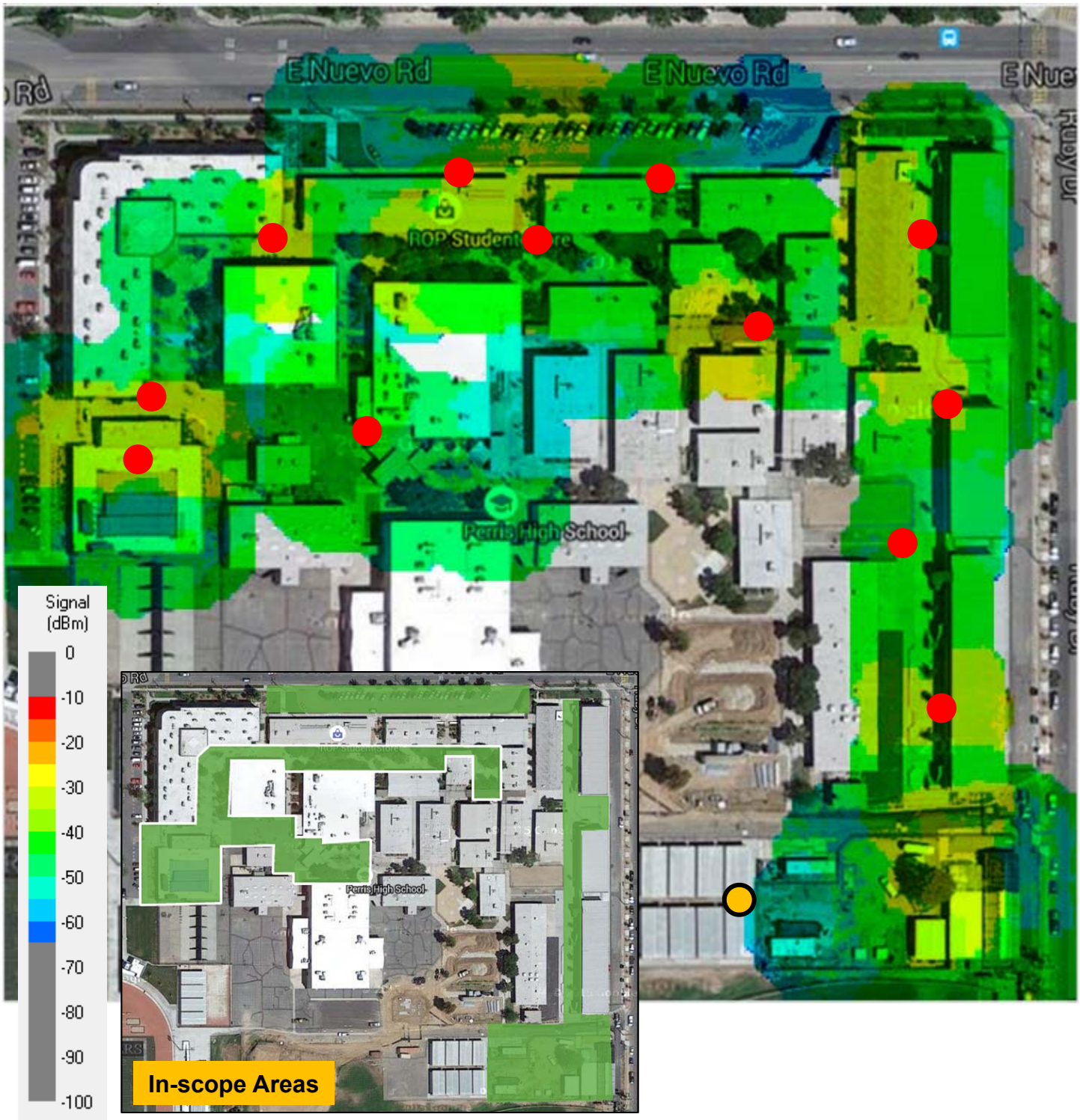
This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.



This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

# Perris High School
## Overall Coverage Heat Map

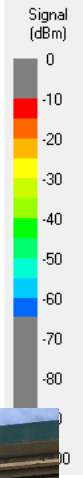
Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



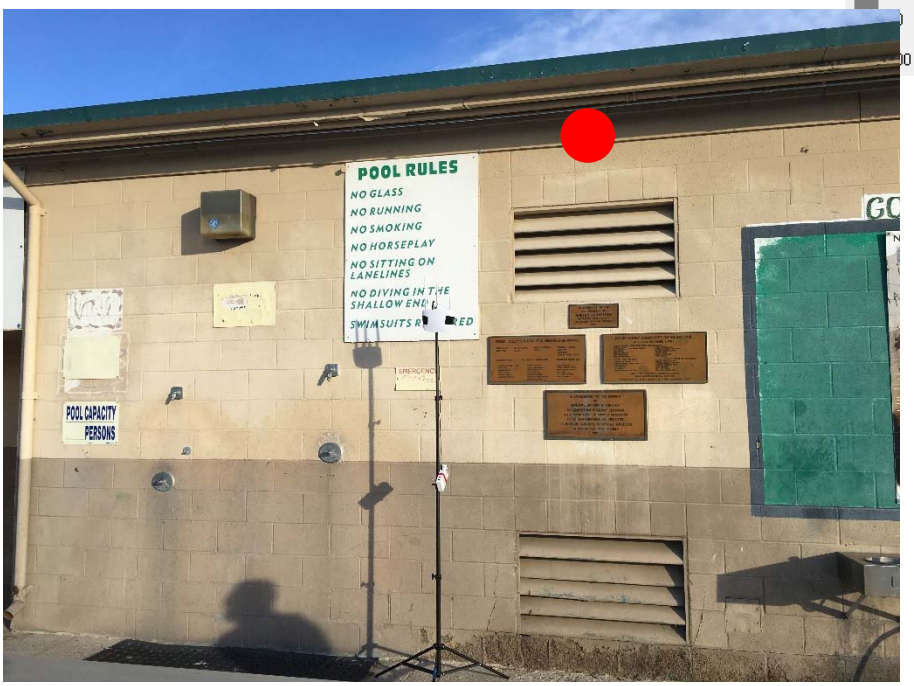
# Perris High School

## Per-AP Heat Maps and Installation Location Photos

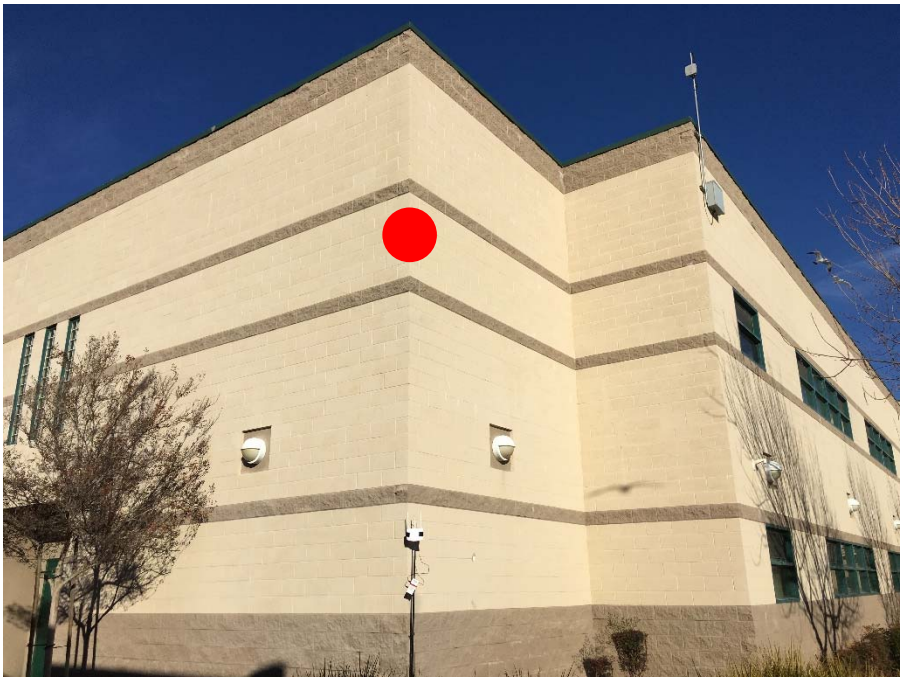
Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.




This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.



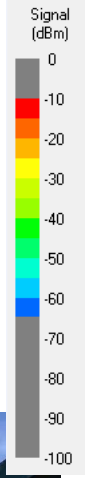

This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.



# Perris High School

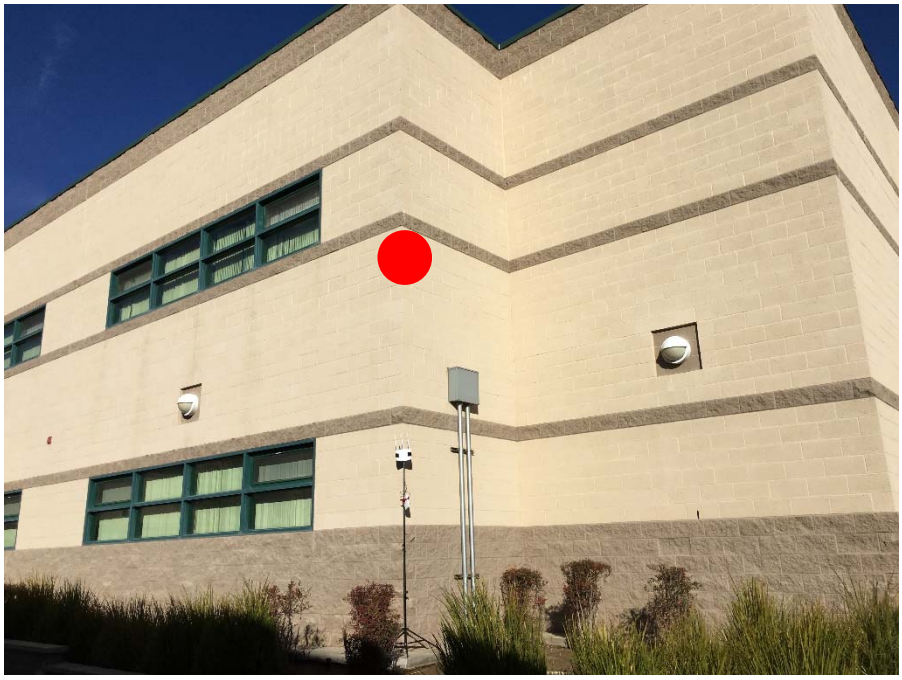
## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.




This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.

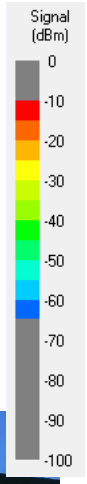
This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

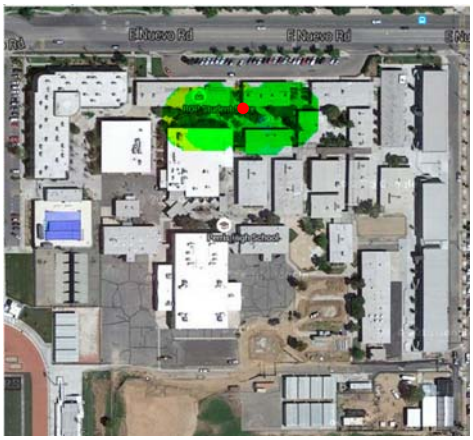


# Perris High School

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



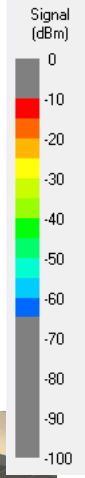
This AP is installed in the **down-facing** style. See the installation notes at the beginning of this report section for details.

This AP is installed in the **down-facing** style. See the installation notes at the beginning of this report section for details.

# Perris High School

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



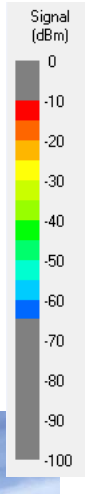

This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.

This AP is installed in the **down-facing** style. See the installation notes at the beginning of this report section for details.

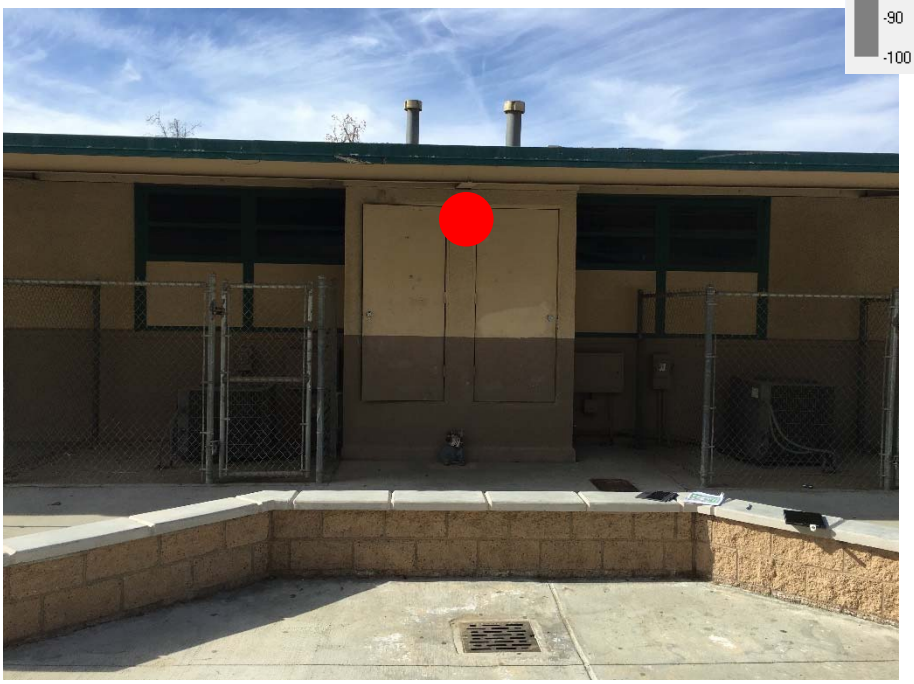
# Perris High School

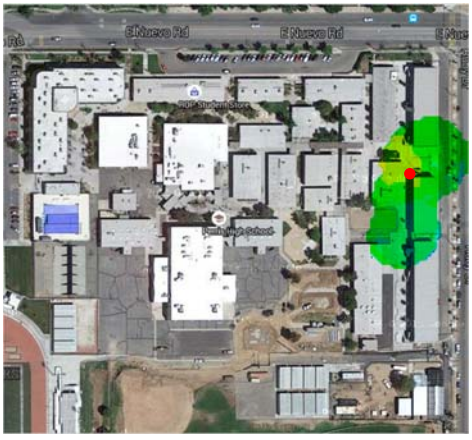
## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.




This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.



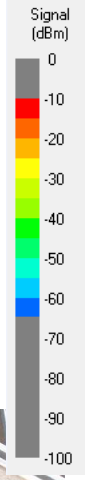


This AP is installed in the **down-facing** style. See the installation notes at the beginning of this report section for details.

# Perris High School

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

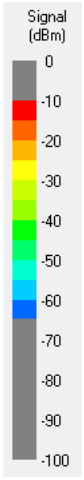



This AP is installed in the **down-facing** style. See the installation notes at the beginning of this report section for details.

# Perris High School

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.




This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.

The building that this AP is to be installed upon was under construction at the time of this survey. The AP is to be installed on the façade of the building near the location indicated on the map to the left.

# Perris High School

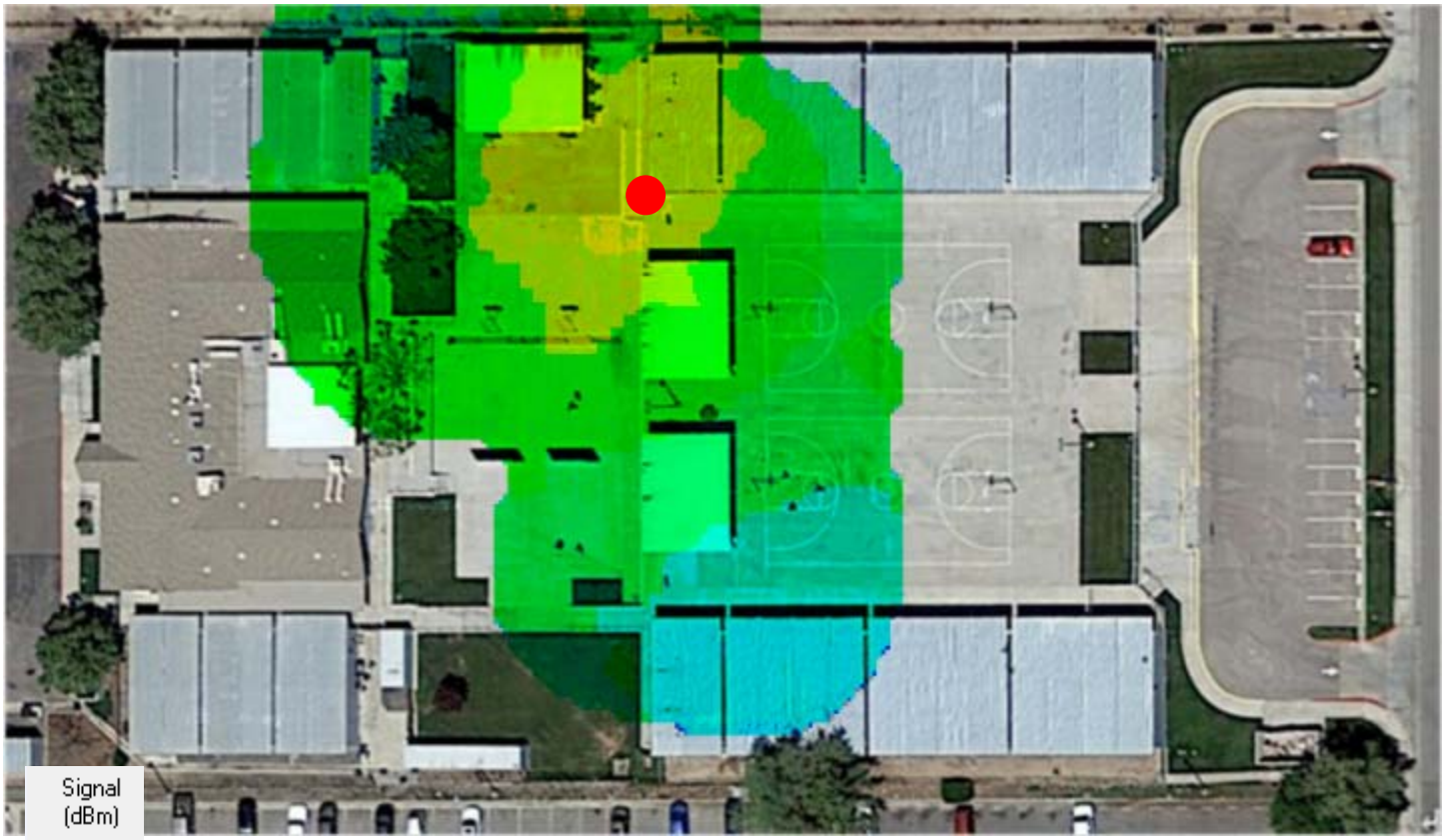
## Per-AP Heat Maps and Installation Location Photos

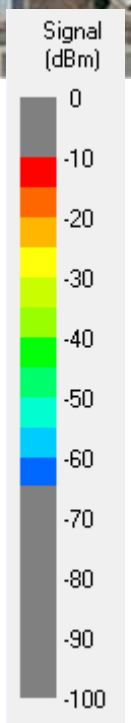
Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.


The area that this AP is to be installed upon was under construction at the time of this survey. Additionally, the area was not accessible for a survey. The AP is to be installed on a mounting device of the customer choice near the location indicated on the map above.

# The Academy
## Overall Coverage Heat Map

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

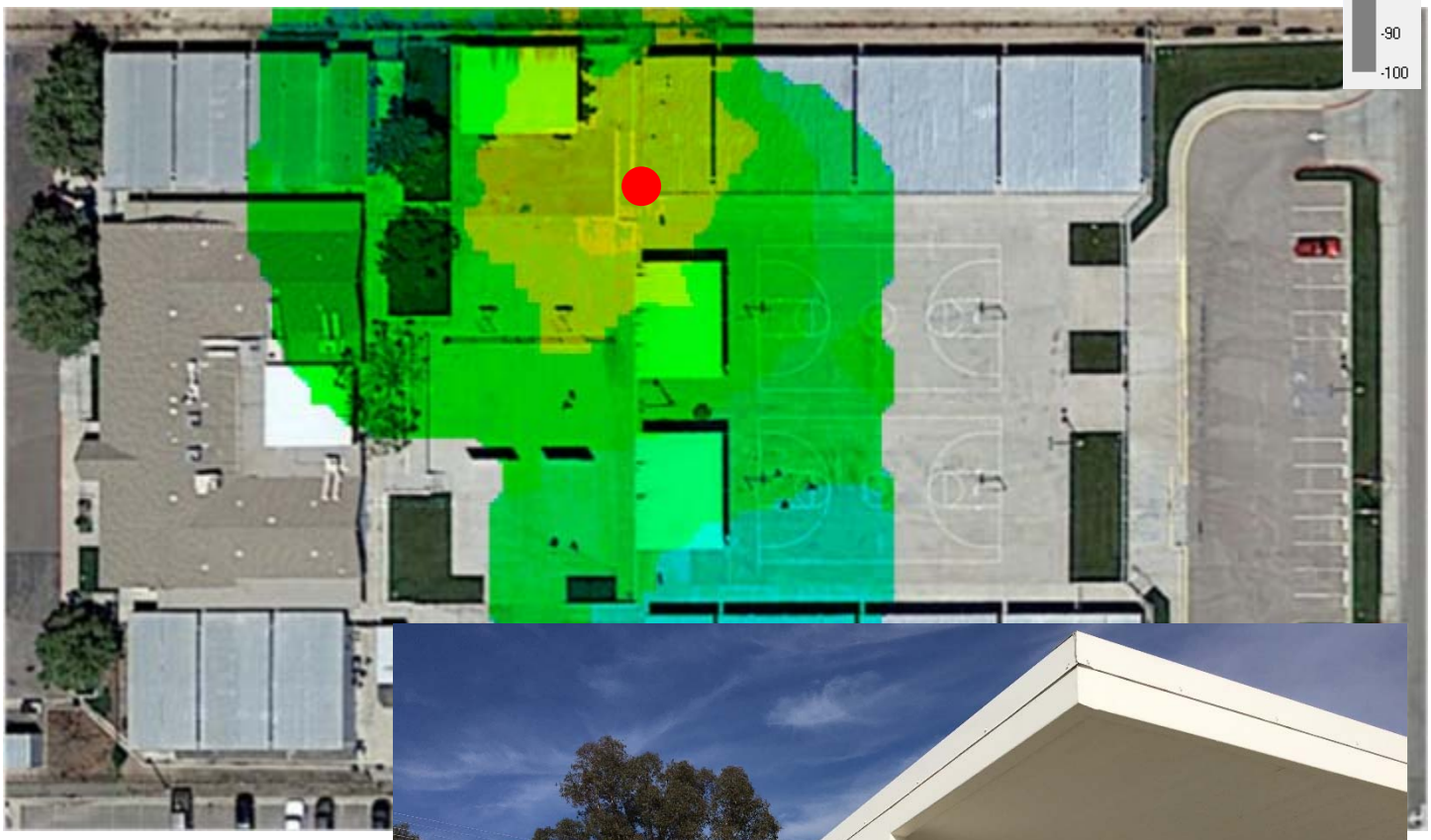


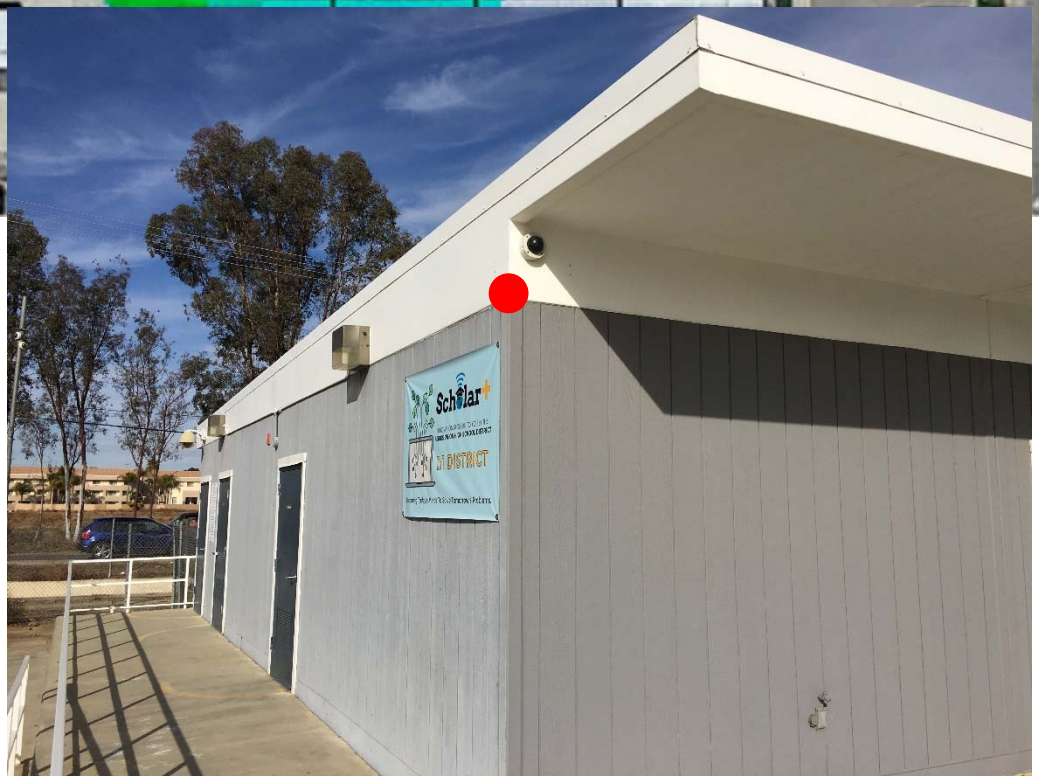



# The Academy

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

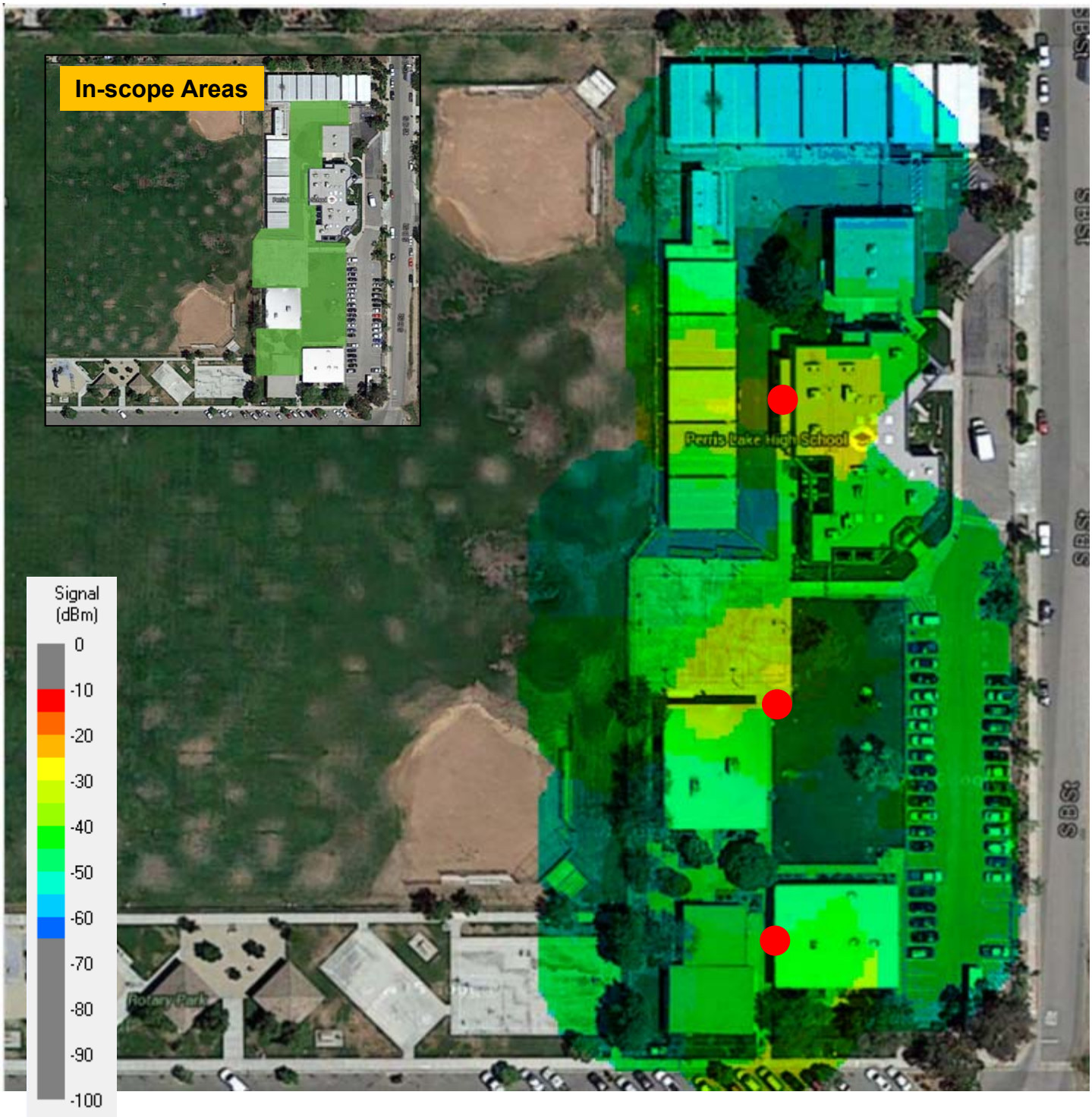



This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

# Perris Lake High School
## Overall Coverage Heat Map

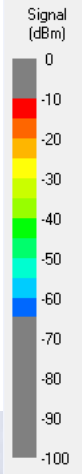
Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

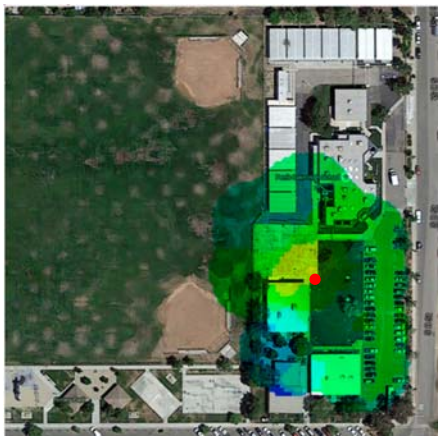


# Perris Lake High School

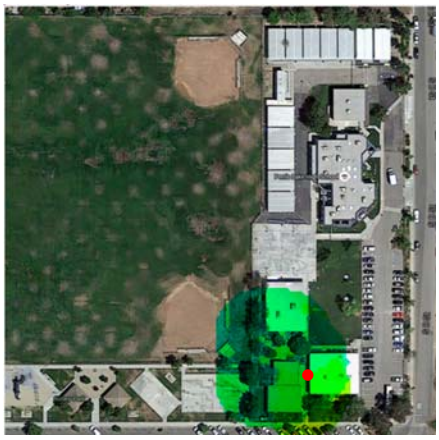
## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

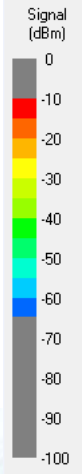


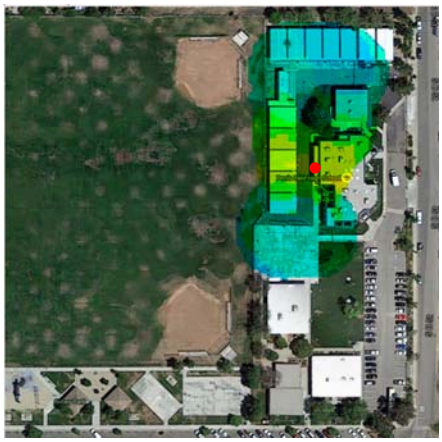
This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.

# Perris Lake High School

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

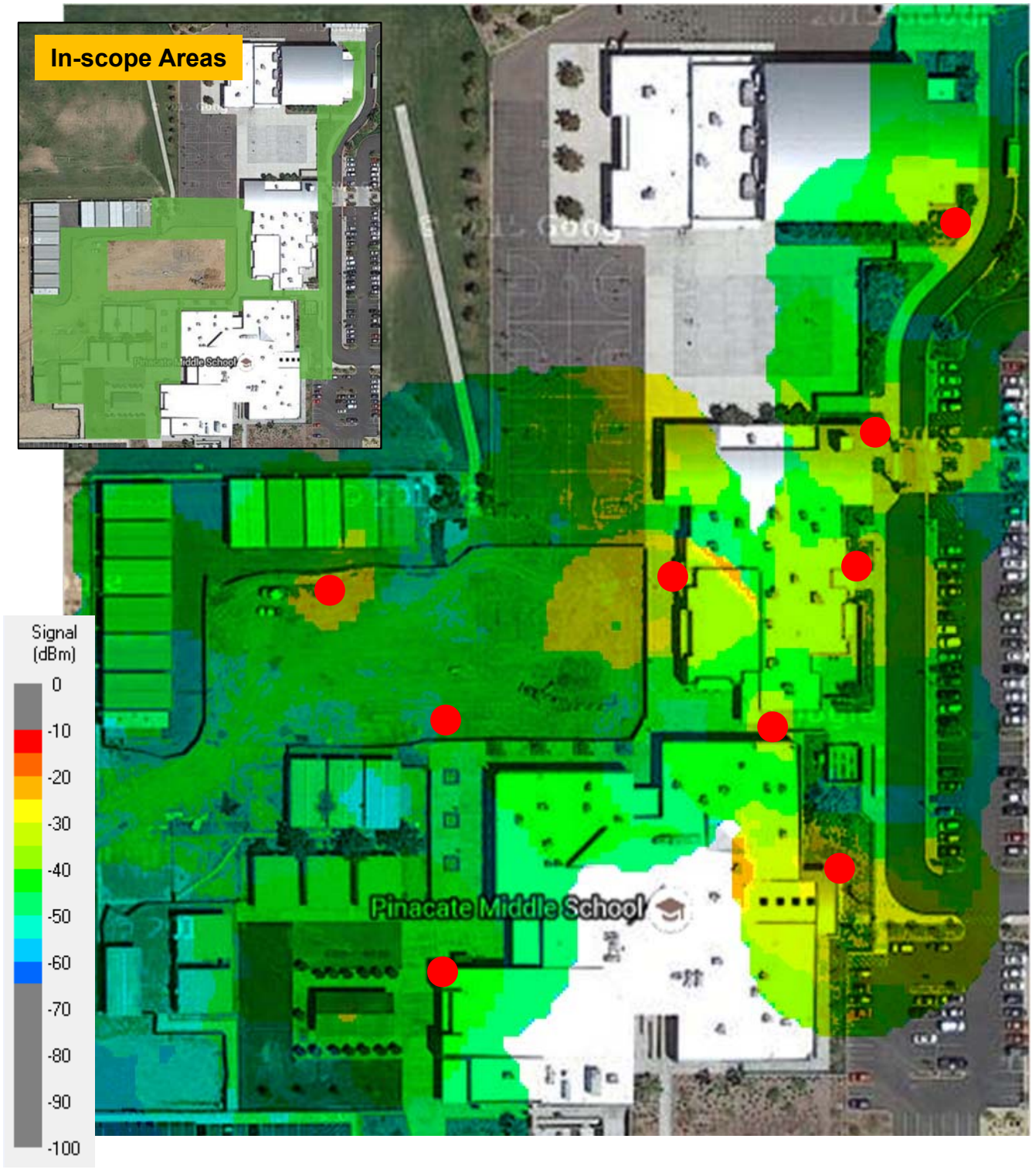


This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.

# Pinacate Middle School
## Overall Coverage Heat Map

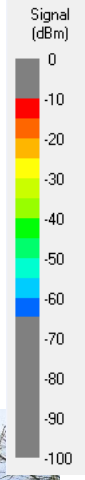
Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

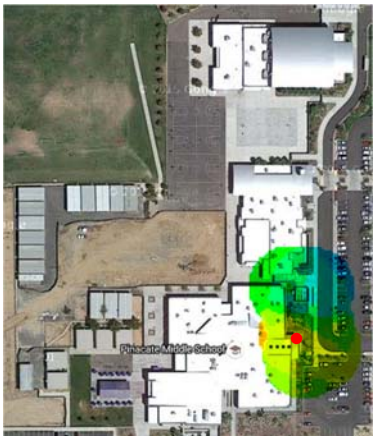


# Pinacate Middle School

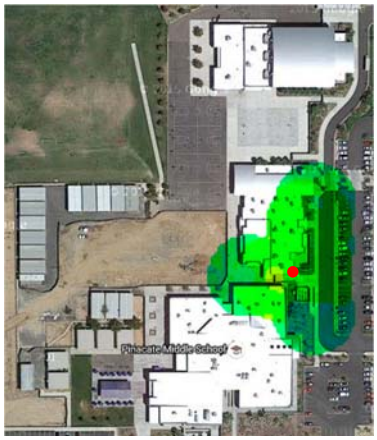
## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.

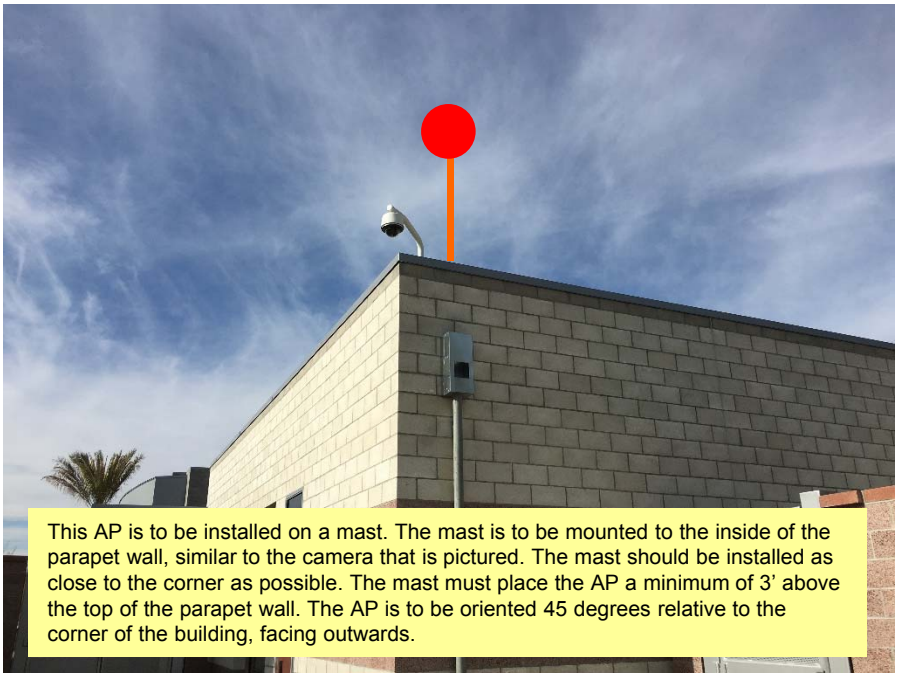


This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.



This AP is installed in the **corner-mounted** style. The AP is installed on a mast, and is oriented at 45° to the building corner. See the installation notes at the beginning of this report section for details.

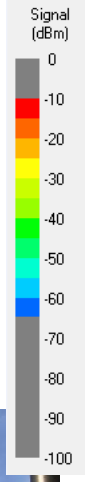


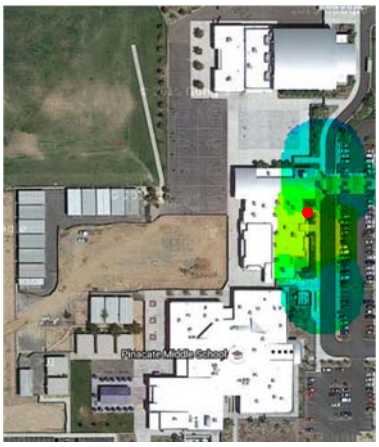
This AP is to be installed on a mast. The mast is to be mounted to the inside of the parapet wall, similar to the camera that is pictured. The mast should be installed as close to the corner as possible. The mast must place the AP a minimum of 3' above the top of the parapet wall. The AP is to be oriented 45 degrees relative to the corner of the building, facing outwards.

# Pinacate Middle School

## Per-AP Heat Maps and Installation Location Photos

Colored areas on the heat map below are at or above the project signal strength requirement. Areas below the project signal strength requirement would be depicted as a gray heat map. There should be none of these. Areas without a heat map over them were not surveyed.



This AP is installed in the **flat-mounted** style. See the installation notes at the beginning of this report section for details.


This AP is installed in the **corner-mounted** style. See the installation notes at the beginning of this report section for details.

# Pinacate Middle School

## Per-AP Heat Maps and Installation Location Photos

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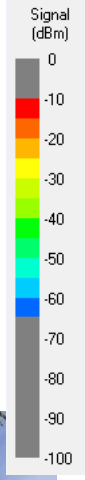


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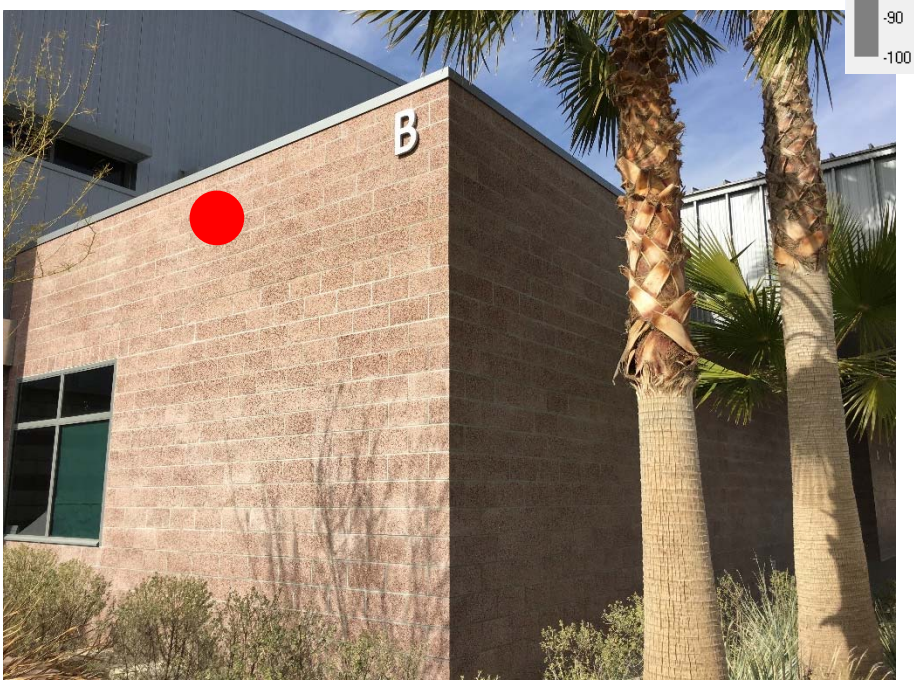


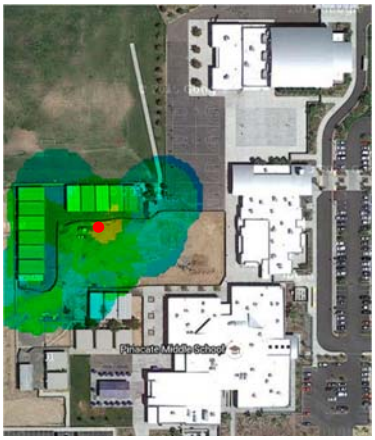

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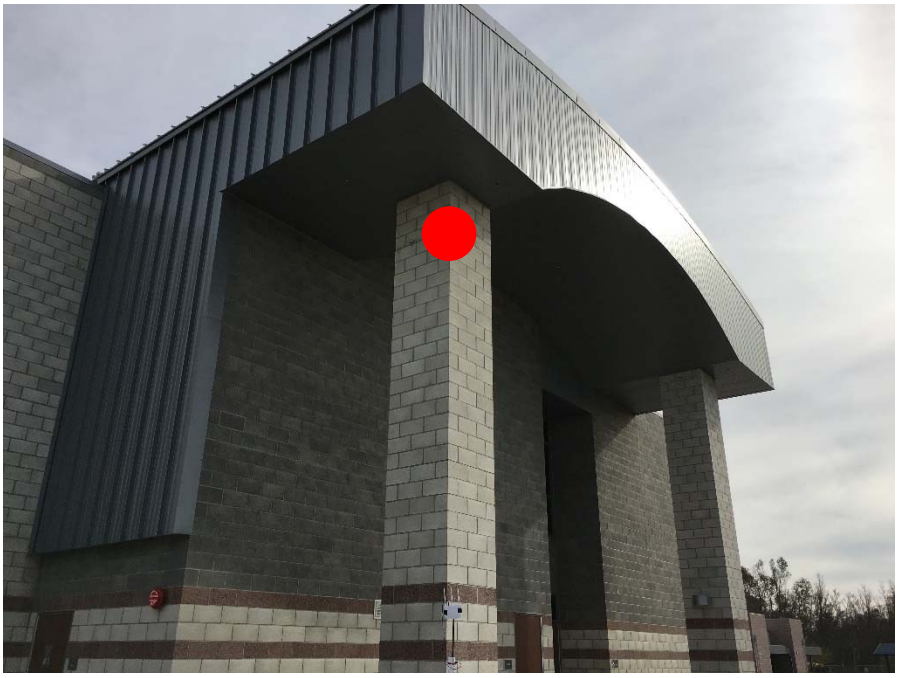

# Pinacate Middle School

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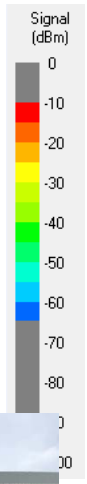


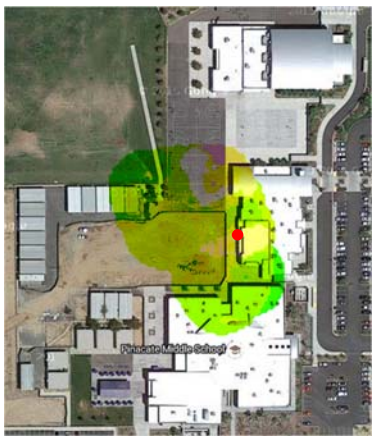

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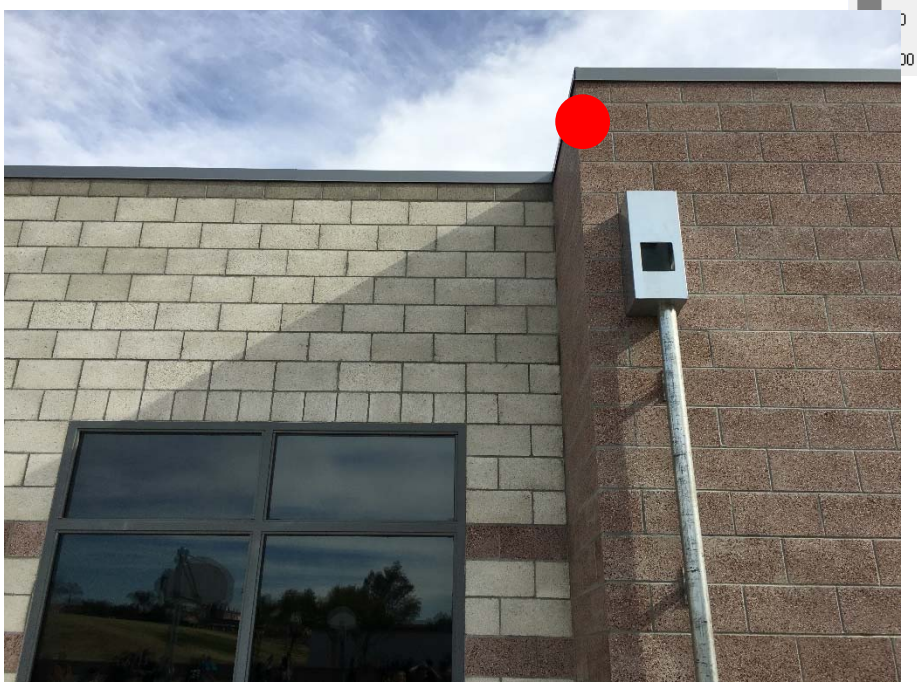

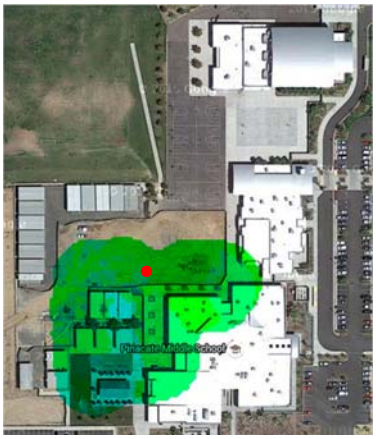

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# Pinacate Middle School

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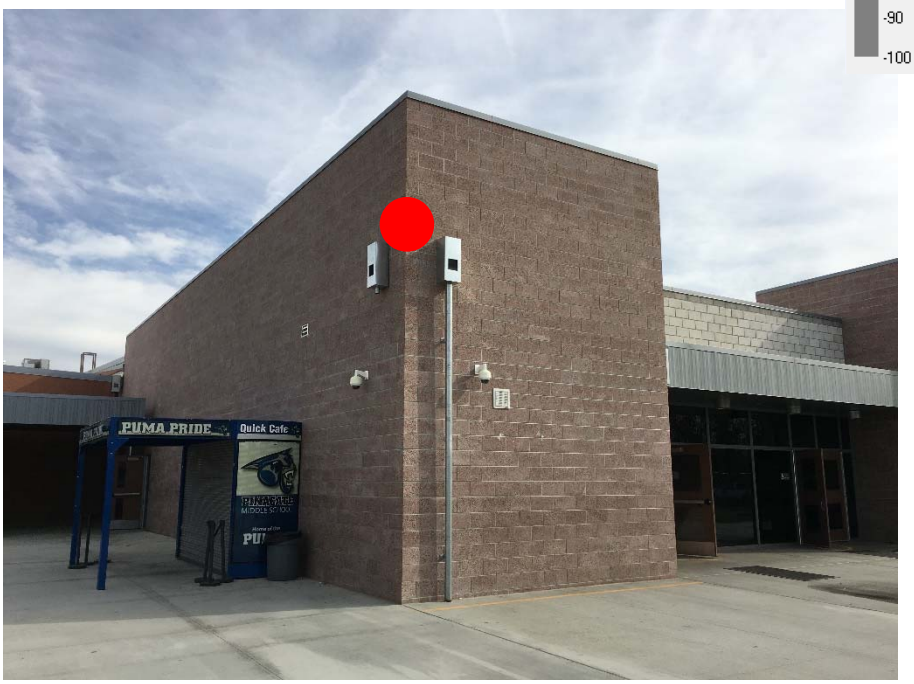

# California Military Institute
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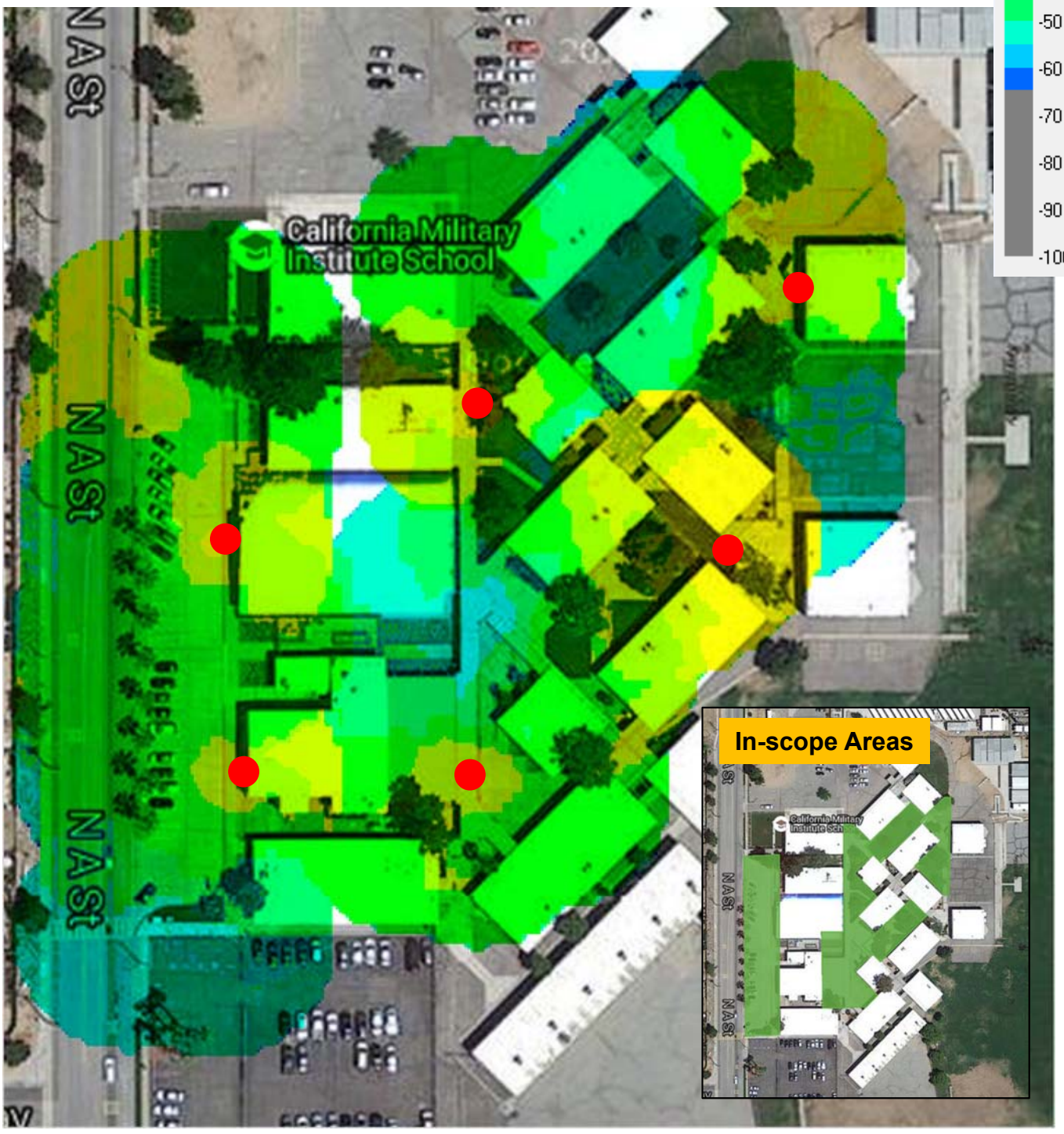
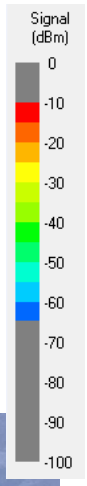


# California Military Institute

## Per-AP Heat Maps and Installation Location Photos

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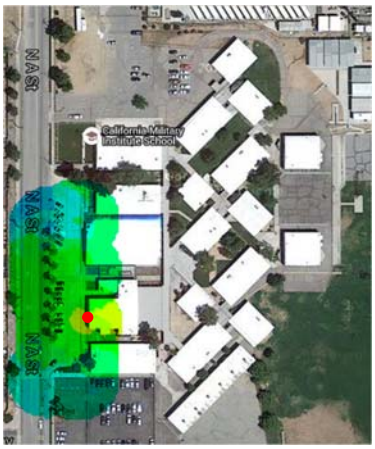

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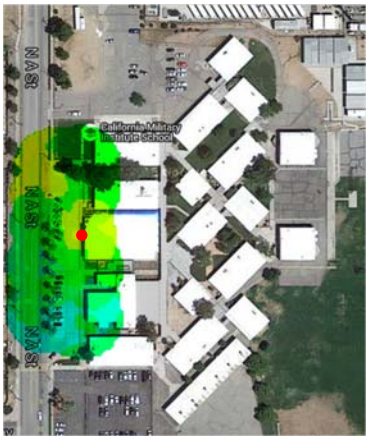

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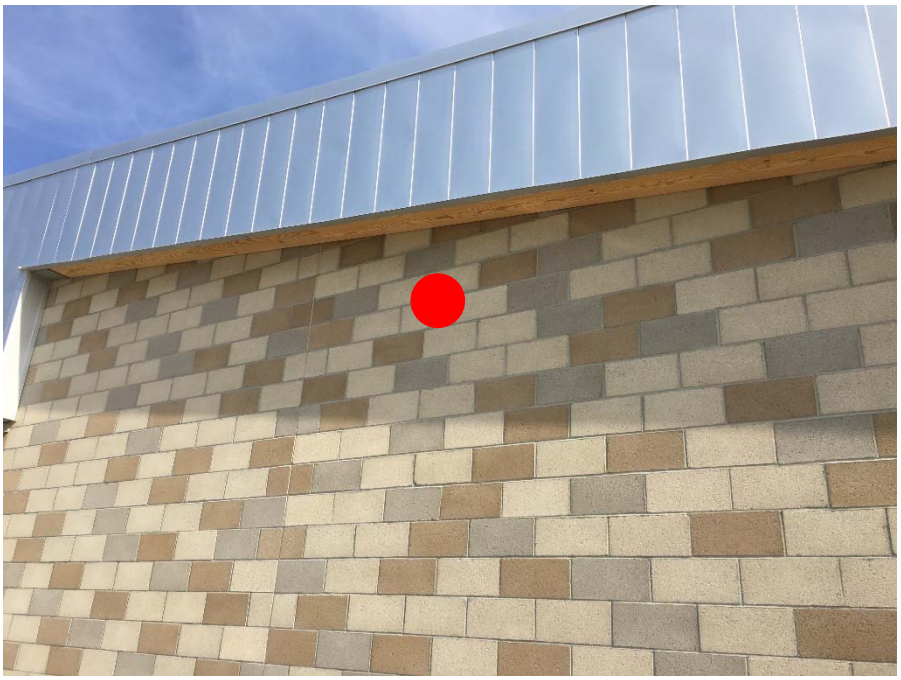

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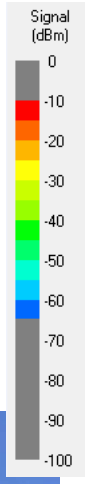


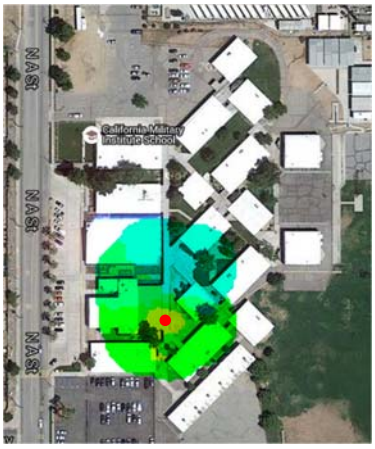


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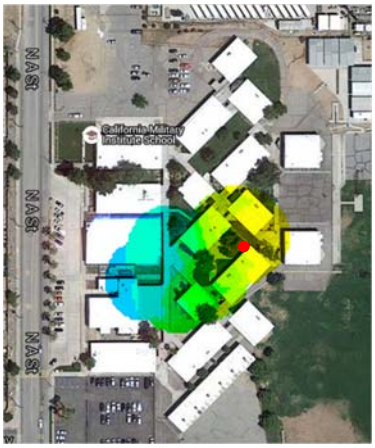


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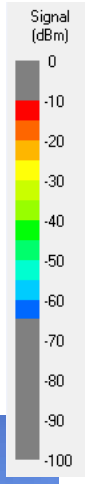


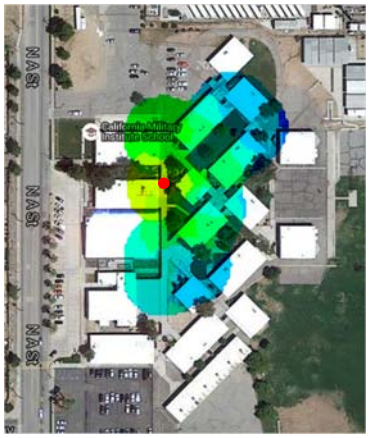

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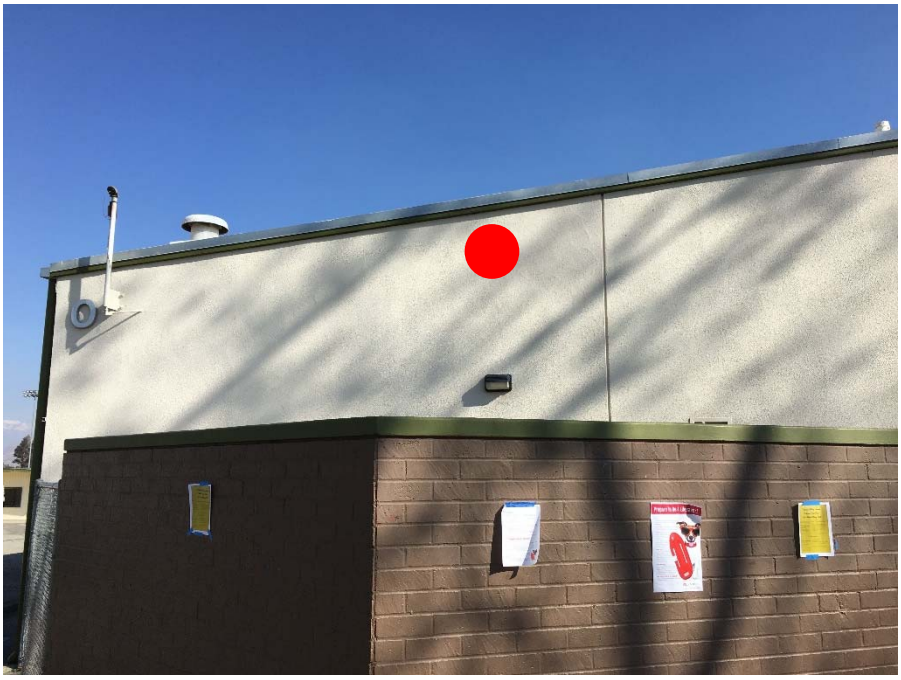

# Heritage High School
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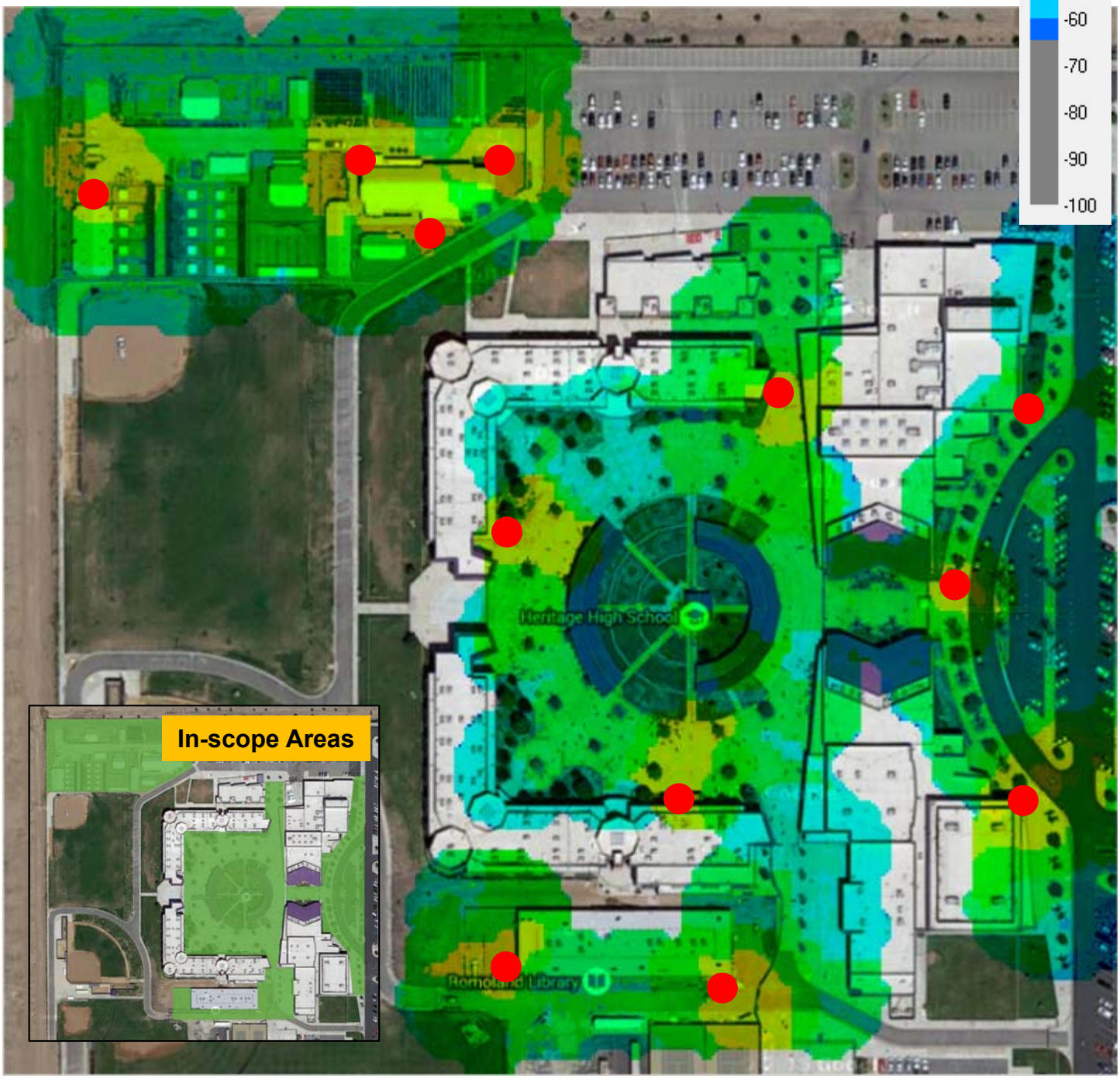

# Heritage High School

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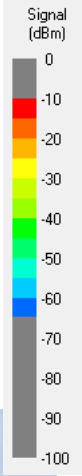


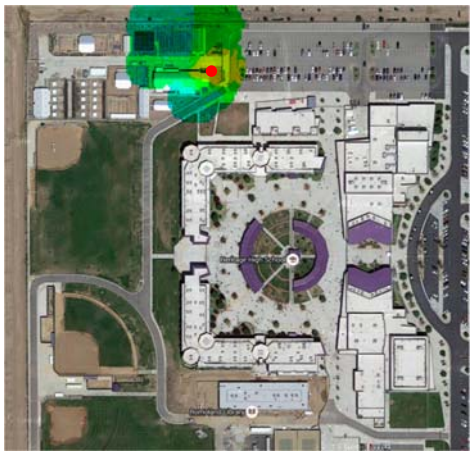

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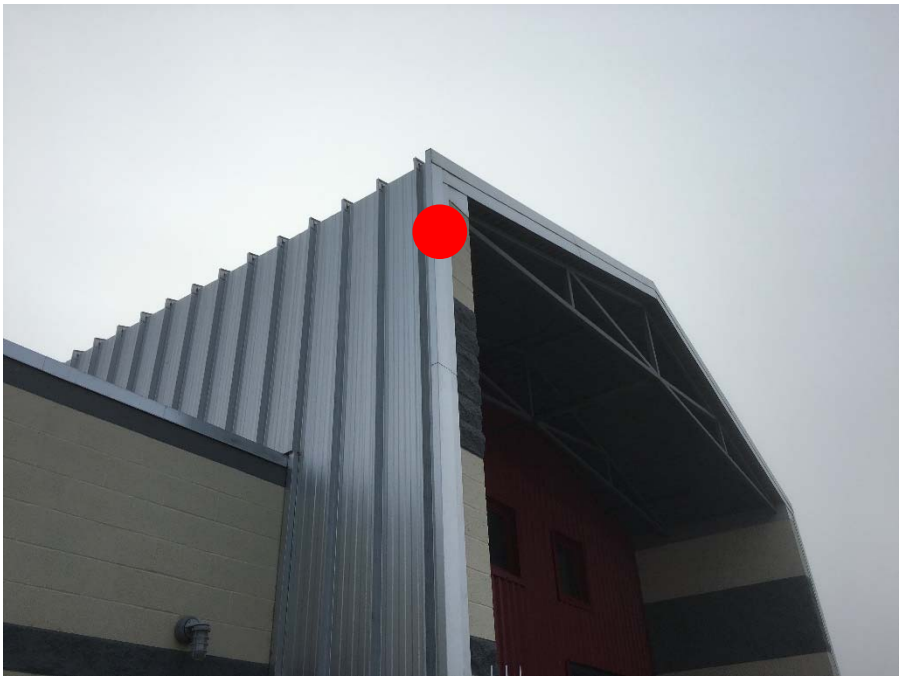

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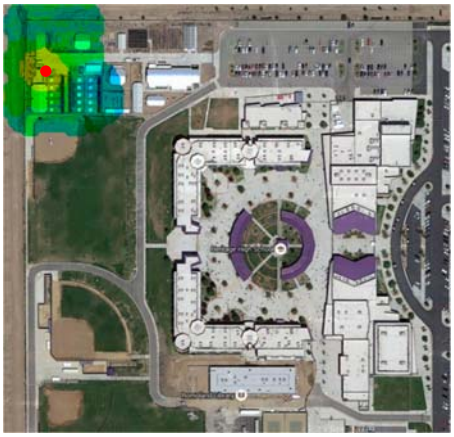

This AP is installed in the **flat-mounted** style. The AP is installed on a mast, and it is oriented parallel to the wall on which the mast is mounted. See the installation notes at the beginning of this report section for details.

This AP is to be installed on a mast. The mast is to be mounted to roof or corner of the building in the location shown.

# Heritage High School

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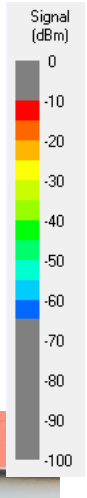


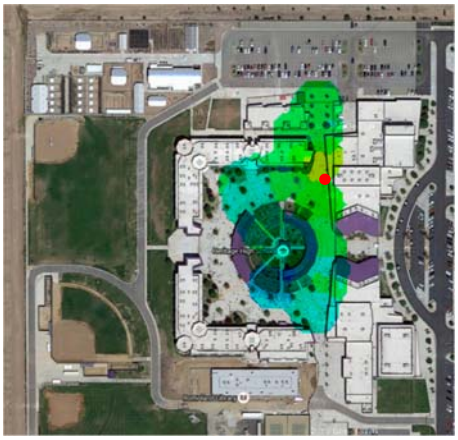

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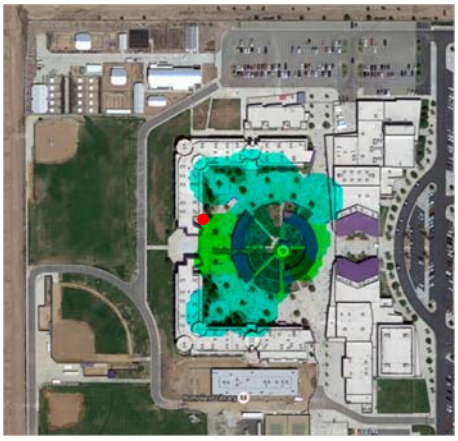

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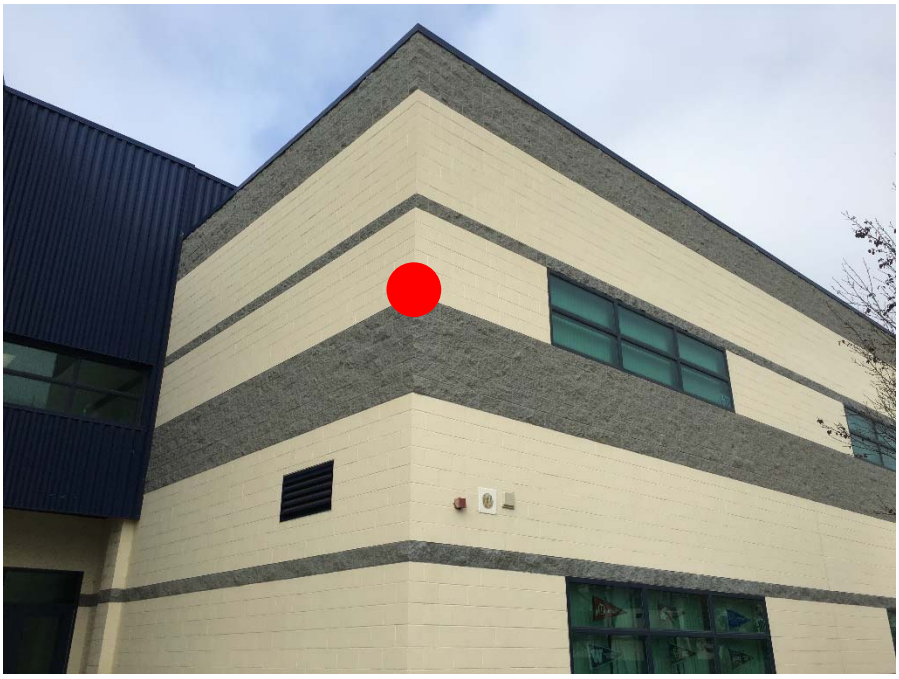

# Heritage High School

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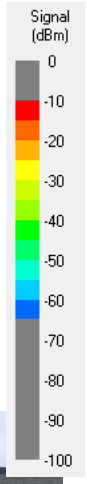


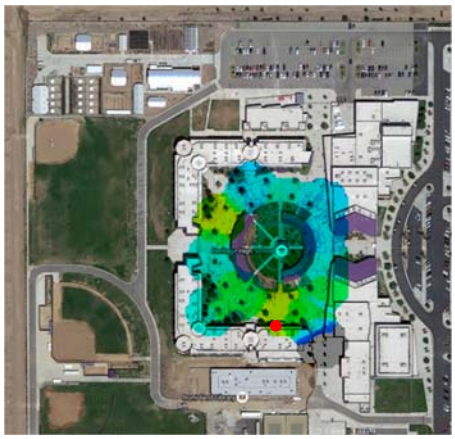

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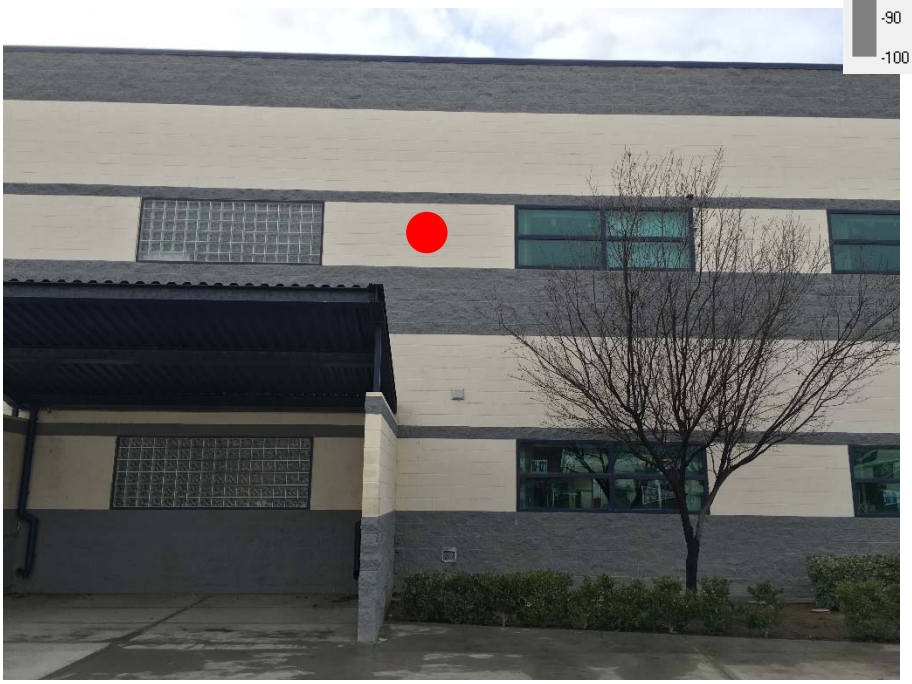

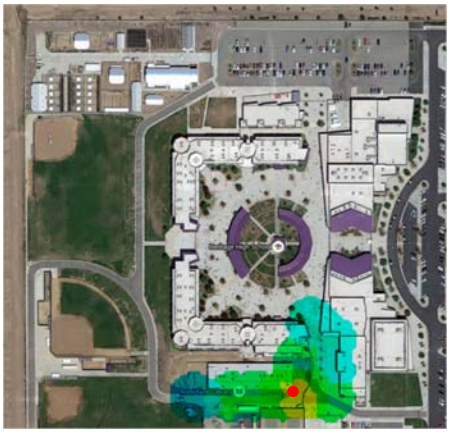

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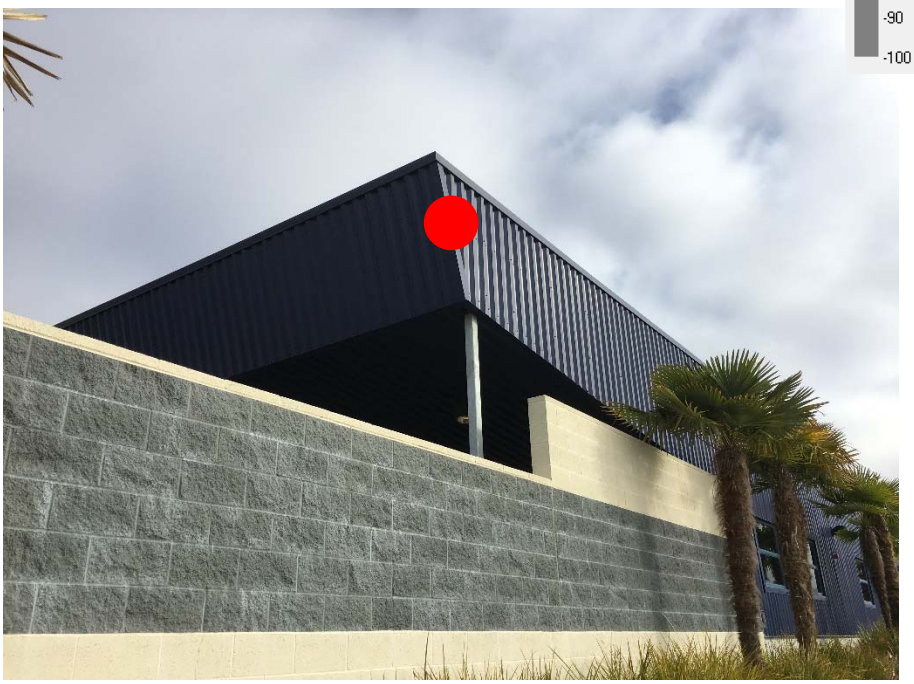

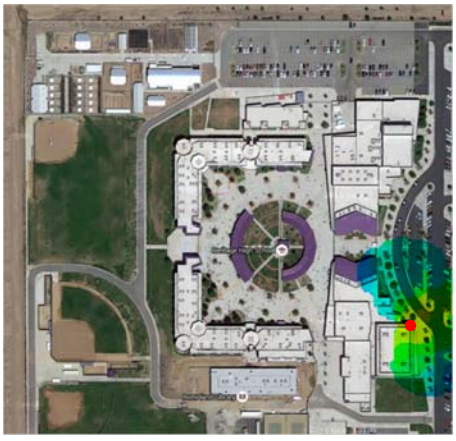

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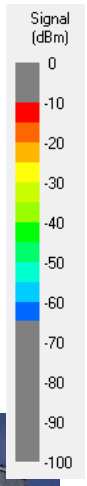


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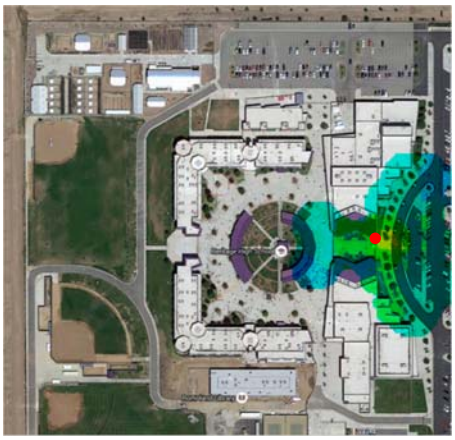

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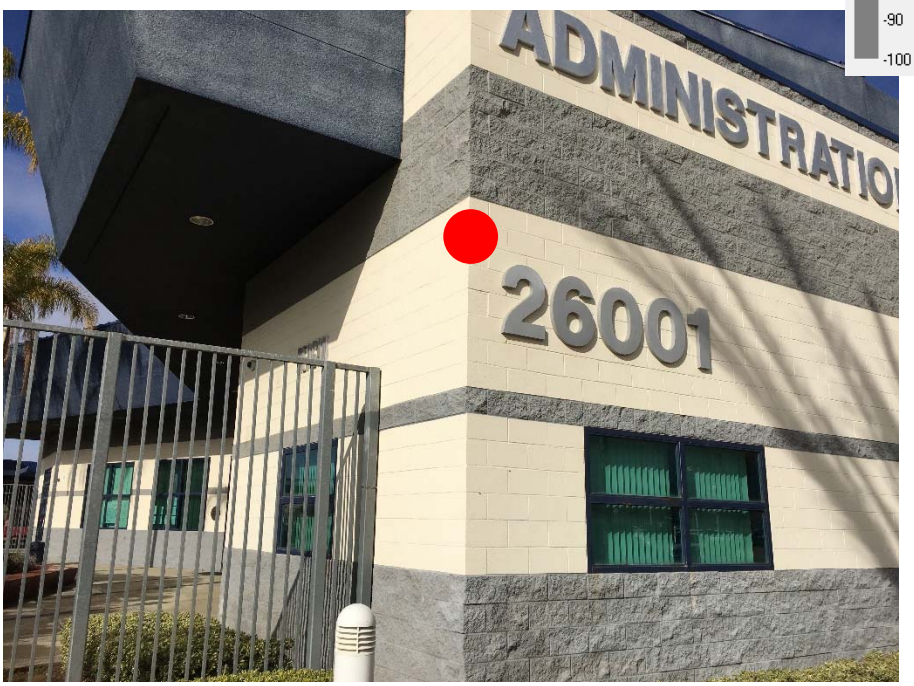


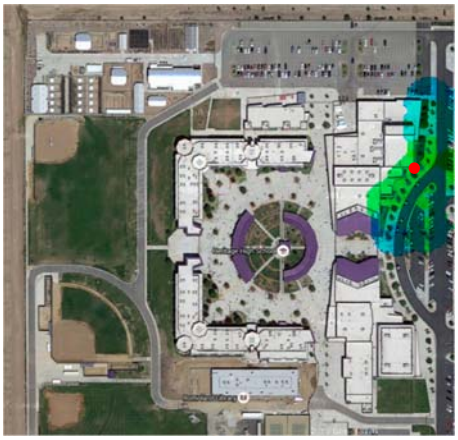

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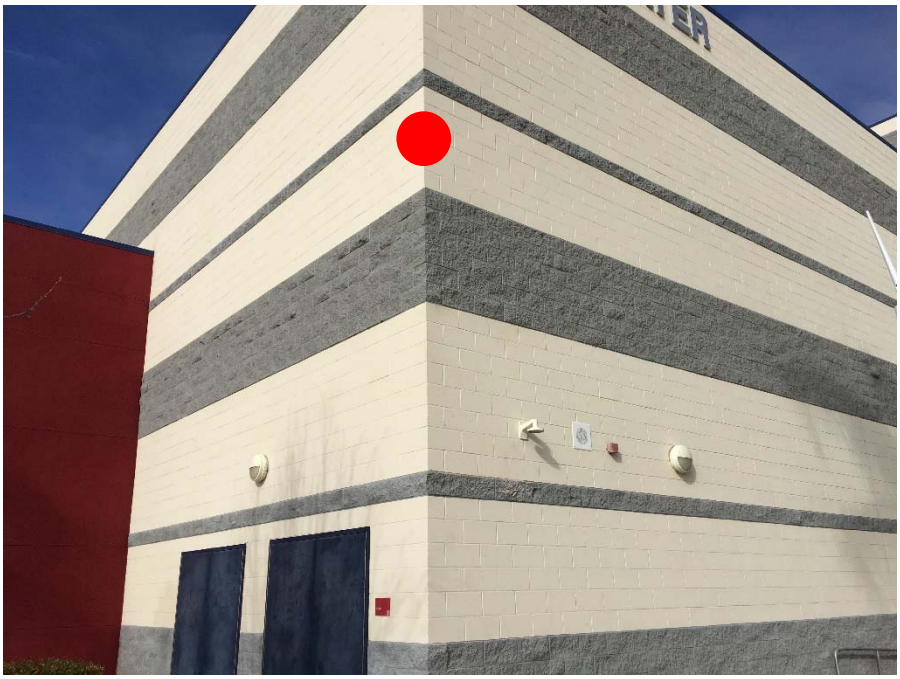
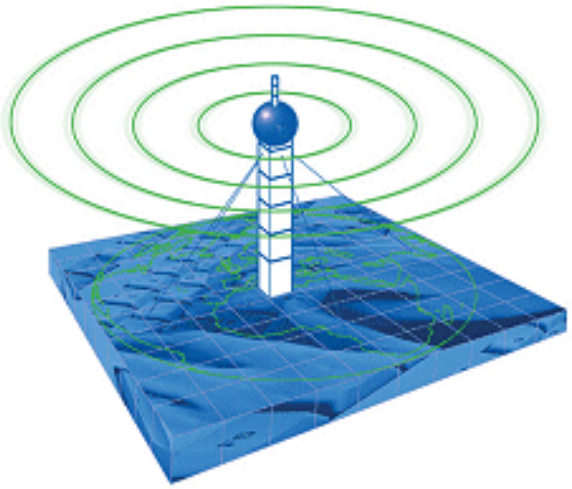


# Technical Appendix

**This section provides an engineering perspective and details on various analysis and design aspects discussed and applied in the report.**



# DESIGNING COVERAGE CELL OVERLAP

## Background

Several standard RF engineering calculations were performed as part of meeting this project's requirements for coverage cell overlap. This section of the Technical Appendix explains the underlying formulae and calculations in detail.

## Overlap Percentages Do Not Imply Changes in Circular Coverage Range

A design may call for a particular overlap percentage in adjacent coverage cells to provide redundancy in the event of access point failure or to otherwise improve the homogeneity and quality of coverage. Coverage cells bounded by a particular target signal level are not circular (nor are they spherical if considering them in three dimensions.)

The range (radius) at which an RF signal is received as some specified level varies in different directions from the access point due to variations in the environment (walls, doors, etc.) Consequently, an access point does not have a fixed radius of coverage associated with any particular signal level. As a further consequence, it is not possible to quantify overlap percentage based on distance measurements. Overlap relates to signal strength, not to range or radius of coverage. Signal strength decreases with distance based on the *Inverse Square Law*.

## The Inverse Square Law

Electromagnetic signals in free, unobstructed space decrease in strength in inverse proportion to the square of the relative distance at which they are measured. This is known as the Inverse Square Law. If a signal is measured at some particular distance from a transmitter, and then measured again twice as far away, the signal is 1/4 as strong; three times farther away the signal is 1/9 as strong. The Inverse Square Law may be stated as follows:

$$P_R = \frac{P_o}{D^2}$$

where $P_O$ is the original signal strength, D is the relative distance between measurements, and $P_R$ is the resulting signal strength. $P_R$ is the result of the contribution of the geometric expansion of the propagating electromagnetic field.

## Defining Coverage Cell Overlap

Consider a design where the minimum required signal strength is specified at $X_{min}$ dBm. In any direction from the transmitter there is a coverage cell boundary at which the measured signal level is $X_{min}$. The shape of the coverage cell varies based on the attenuation and reflection characteristics of the environment. To effect an "overlap" between adjacent coverage cell boundaries it is necessary to reference the degree to which the $X_{min}$ boundary for one cell overlaps the $X_{min}$ boundary of an adjacent cell. This relationship is defined (based on the relative size of the coverage cells) by the Inverse Square Law.

Creating a design that meets a particular coverage cell overlap requirement is accomplished by calculating the overlap between adjacent $X_{min}$ boundaries based on the Inverse Square Law with appropriate attention being given to the fact that typical signal level measurements use dBm units of measurement. These, being logarithmic in nature, must be converted to their linear mW equivalents for use in calculation and then be converted back to dBm units to present the result in typical form.

## Calculating Coverage Cell Overlap

To define a particular percentage of overlap for two adjacent coverage cells requires that the corresponding signal power be determined at the point of intended overlap. If all other variables are held constant then overlap is accomplished by having the two cell's transmitters closer together. Because RF signals decrease in power inversely as the square of the distance (and not in a linear fashion) the distance between transmitters varies inversely in an exponential manner with the percentage of overlap.

The overlap percentage is the "D" in the Inverse Square Law formula. It's the relative change in the distance between the boundary of a coverage cell at $X_{min}$ and the boundary of the same cell at the point of overlap. The original signal power ($P_O$) is $X_{min}$ and $P_R$ is the signal power at the new boundary representing the percentage overlap. The Inverse Square Law is thus represented as follows:

$$X_{TARGET} = \frac{X_{min\ (mW)}}{(1+\Delta P)^2}$$

..where Xmin is the original minimum required signal strength (represented in linear, mW units), ΔP is the percentage change in the cell boundary creating the overlap (either a positive or negative change), and $X_{TARGET}$ is the resulting target design signal strength required to achieve the overlap.

Notice that Xmin is represented using mW units and not dBm units. Minimum required receive signal strength (RSSI) is normally given dBm units, a logarithmic unit of power measurement. The Inverse Square formula must use mW (a linear power unit) to allow a proper ratio calculation. The calculation requires that dBm units must be converted to mW by the standard formula:

$$mW = 10^{(dBm\ /\ 10)}$$

After computing XTARGET as a mW result, convention dictates that the result be converted back to dBm units for standard engineering use. This is accomplished by the standard formula:

$$dBm = 10 * LOG_{10}\ (mW)$$

## Example

A design specification requires -65 dBm to support wireless VoIP. A 10 dB fade margin is applied to account for environmental variability. This makes the design target signal strength = -55 dBm. The design specification requires a coverage cell overlap of 20%.

Xmin = -55 dBm

By dBm-to-mW conversion, Xmin = 3.162278E-7 mW

ΔP = -0.2

Hence: $$X_{TARGET} = 10 * LOG_{10}\left(\frac{3.162278\ E\text{-}7}{(1 - 0.2)^2}\right) = -53\ dBm$$

The design would be created to target -53 dBm throughout the required coverage area and this would result in a 20% overlap between -65 dBm coverage cells in the presence of as much as 10 dB of environmental fading.