GRC/LARC URBAN RF ENVIRONMENT COLLABORATION DISCUSSION
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ELECTROMAGNETIC SIMULATIONS

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PRESENTATION OUTLINE

PART 1: A FEW EXAMPLES OF COMPUTATIONAL ELECTROMAGNETIC MODELING

- Antenna placement on airplane (AirSTAR GMATT 2014).
- Radiation penetrating an enclosure aperture (CERES 2016).
- Magnetic Suspension (6-Inch MSBS 2017).
- Conformal antenna design (CLAS-ACT 2019).
- Radiated power from multiple RF sources at LaRC (SWS 2020).

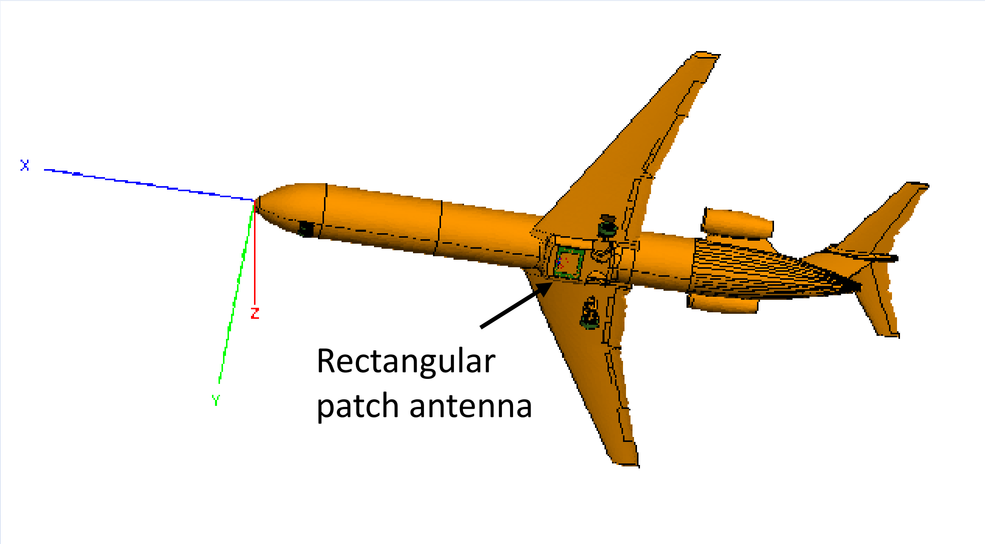
PART 2: SIMULATED VERSUS MEASURED UHF RADIATED POWER AT LARC STREET LEVEL

- WinPROP computational electromagnetic modeling by ray tracing: steps.
- WinPROP modeling by ray tracing, an example: Modeling the LaRC NextNav geolocation system for the System-Wide Safety Program.
- Validation of modeling by measurements made at street level.
- How can this type of modeling be used?
- Simulation improvements?

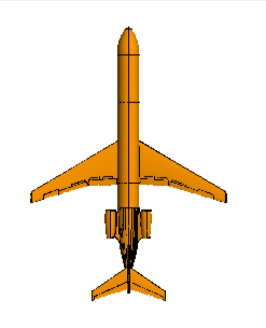
PART 1: A FEW EXAMPLES OF COMPUTATIONAL ELECTROMAGNETIC MODELING

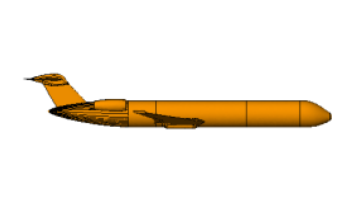
ANTENNA PLACEMENT ON AIRCRAFT
EXAMPLE: 425 MHZ PATCH ANTENNA ON GMATT UAV (AIRSTAR)

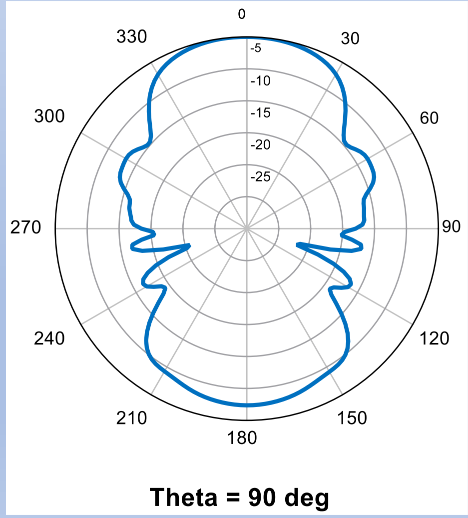
Generic Modular Aircraft T-Tail, 15.8% scale model of regional transport jet, UAV length = 17 ft. , wingspan = 12 ft.

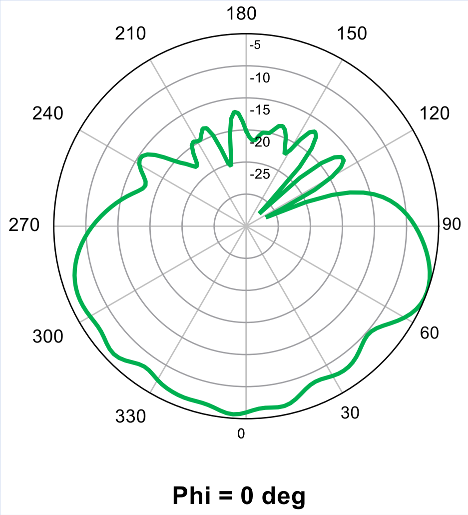


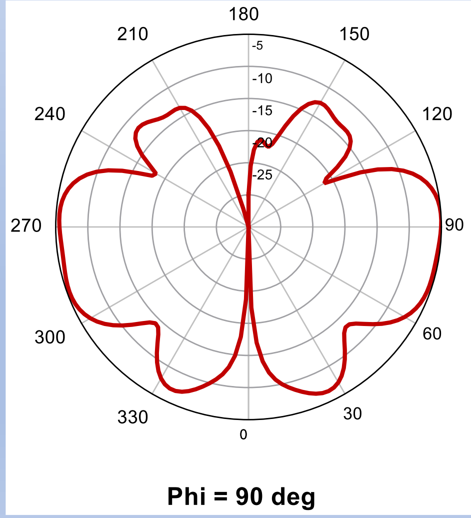
Under the fuselage_one of many possible locations for an antenna.







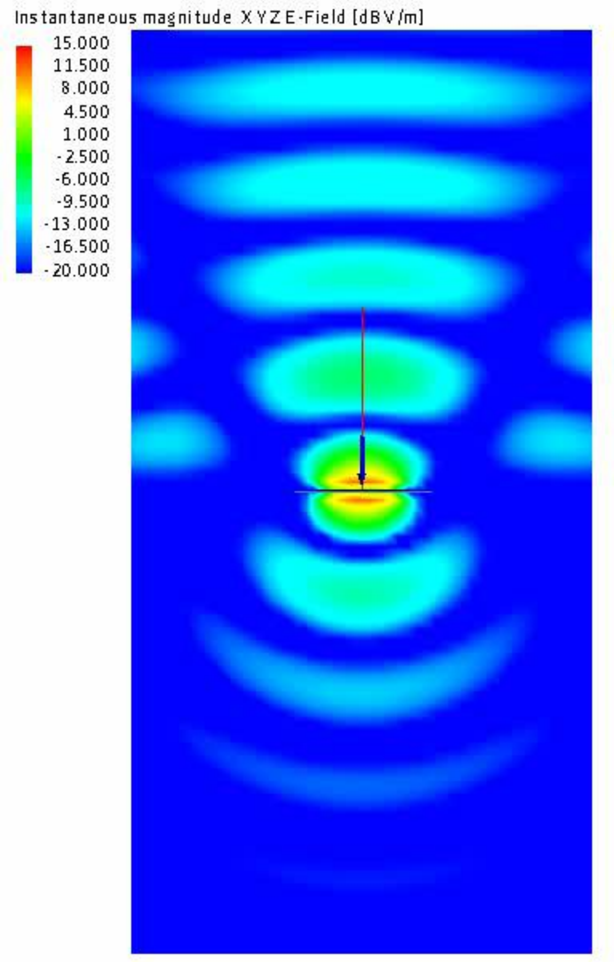




Use: Calculate radiation patterns for various antenna locations to find which location produces the most desirable pattern.

Resulting pattern in three planes for the under-fuselage location.

RADIATION PENETRATING AN ENCLOSURE APERTURE
EXAMPLE: RADIATION LEAKING THROUGH A HALF-WAVE OPENING (CERES)

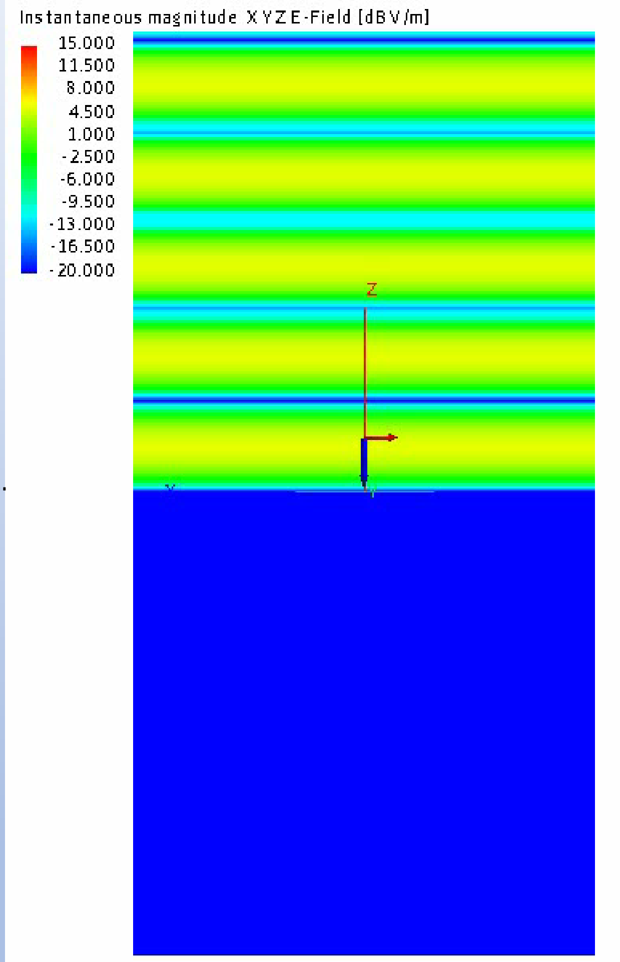


E-field vector 1 V/m perpendicular to a narrow opening.

Incident and reflected waves

Interface

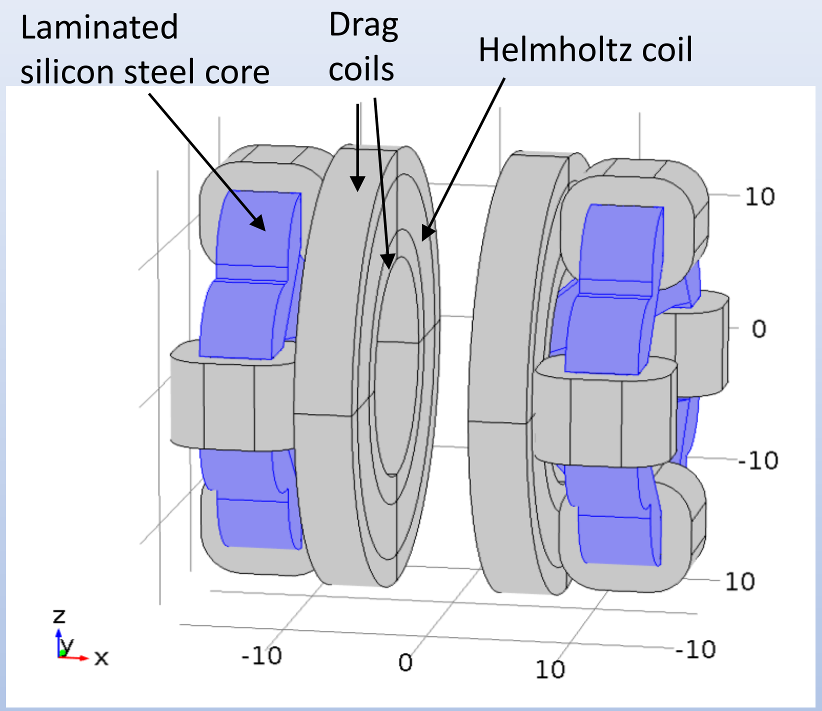
Transmitted waves



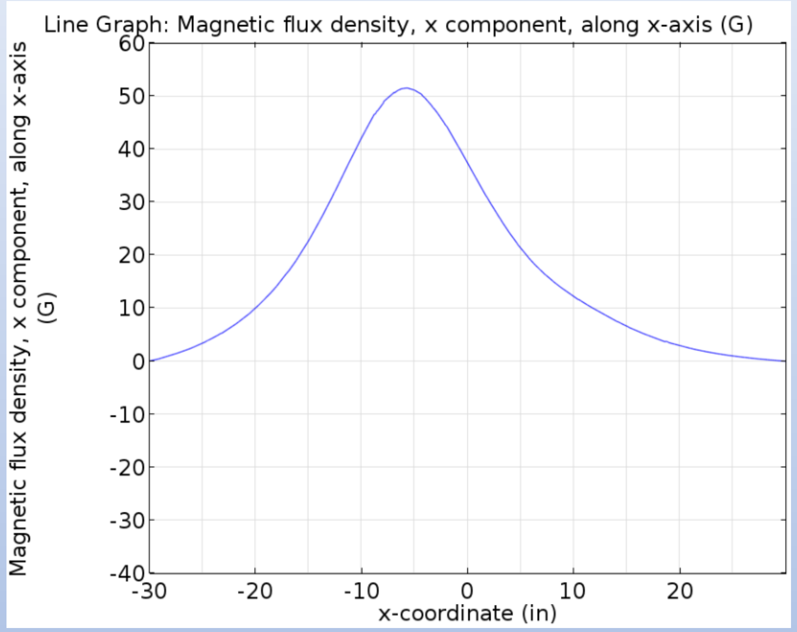
E-field vector 1 V/m parallel to a narrow opening.

Use: Calculate the electric field strength of energy leaking through an aperture.

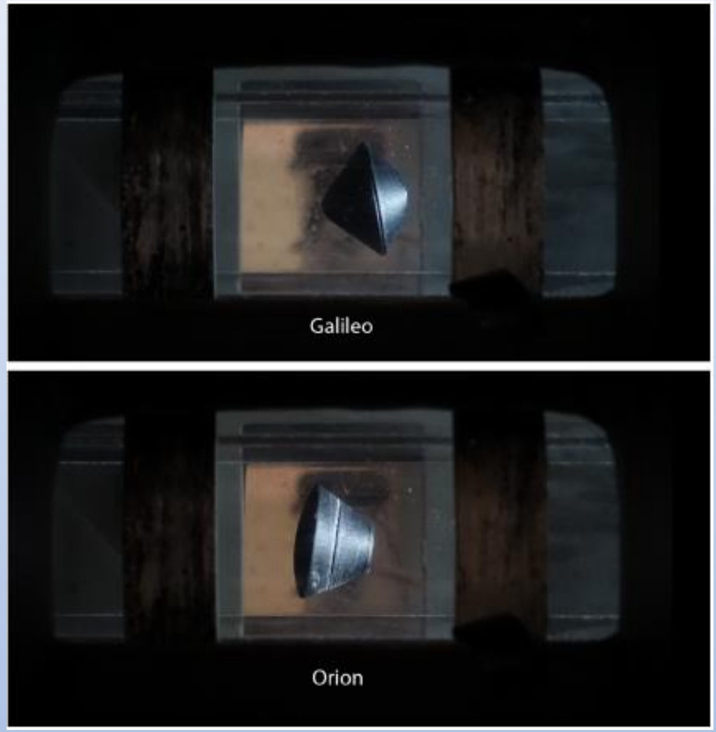
MAGNETIC SUSPENSION
EXAMPLE:6-INCH MAGNETIC SUSPENSION & BALANCE SYSTEM
(MAGNETIC SUSPENSION SUB/SUPERSONIC DYNAMIC STABILITY WIND TUNNEL)



Helmholtz coils, side and lift coils apply forces in 3 dimensions. Drag coils create a magnetic flux gradient in the open space where an iron ball can be suspended.



Magnetic flux density (B) along the x-axis, all coils energized. Linearly decreasing values are achieved in the central portion between -5 and +5 in.

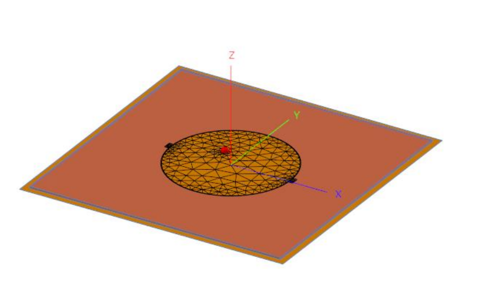


Suspended blunt-nosed entry vehicle models containing embedded iron spheres *.

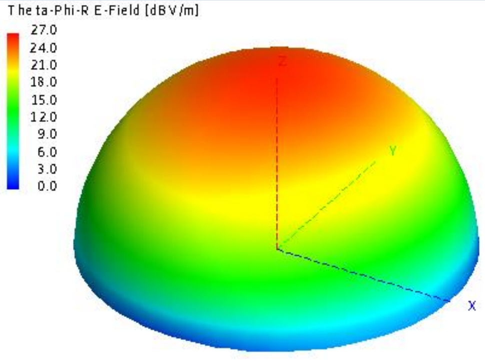
Force on a suspended object depends on magnetization, gradient of B; e.g. $F_x = \int M_x B_{xx} dv$
Use: Calculate region where magnetic suspension can be achieved and magnetic forces on the target.

* Mark Schoenenberger, Colin Britcher, et al., “Preliminary Aerodynamic Measurements from a Magnetic Suspension and Balance System in a Low-Speed Wind Tunnel,” 2018 AIAA Aviation Conference Paper, June 25, 2018.

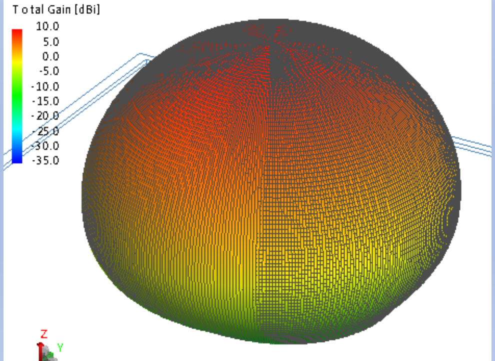
CONFORMAL ANTENNA DESIGN
EXAMPLE: 8X8 PATCH ARRAY, 14.25 GHZ (CLAS-ACT)



Patch geometry

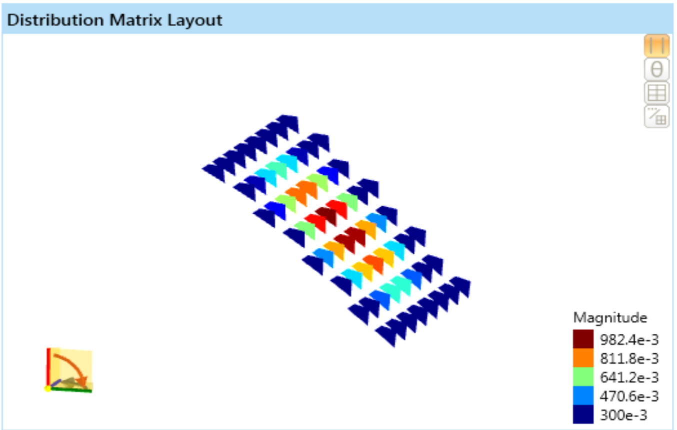


Near field at 1 cm.

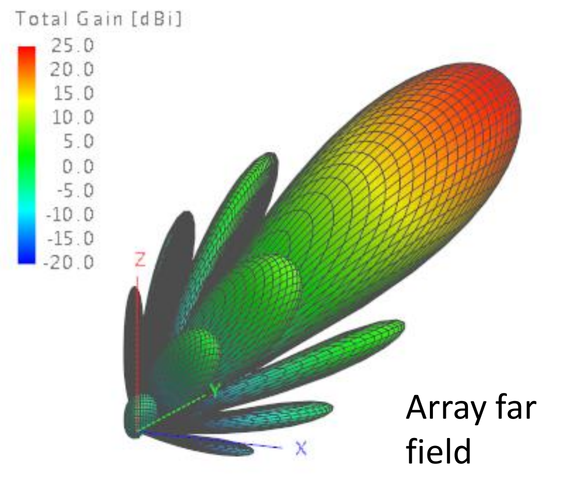


Patch far field

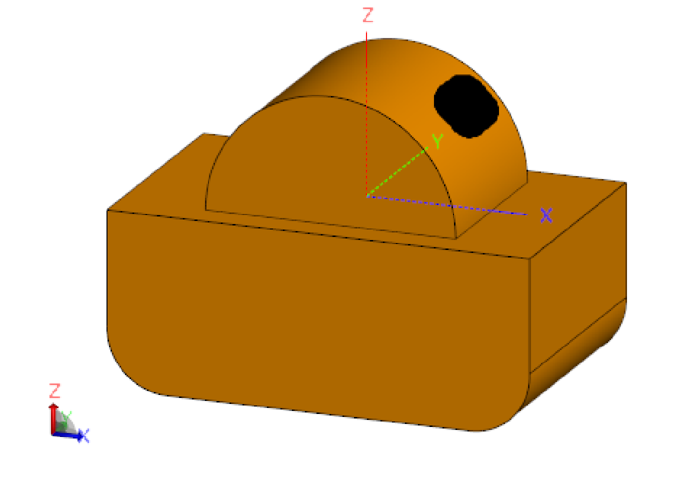
Step 1: Design patch.



Step 2: Design array geometry and taper for desired beamwidth and sidelobes. Platform curve is incorporated into geometry.



Array far field

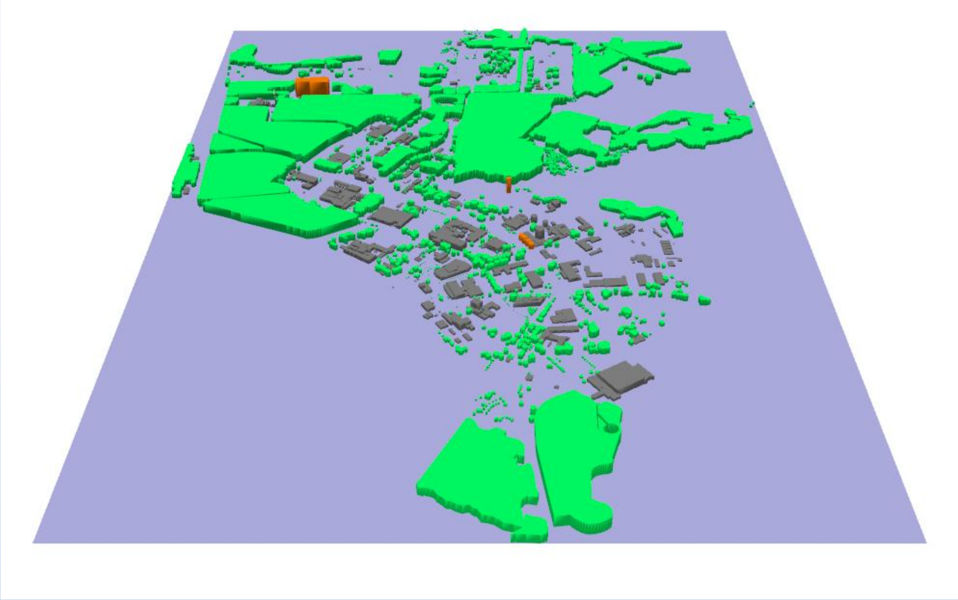


Step 3: Simulate array far field using patch near fields as equivalent sources over a section of the platform.

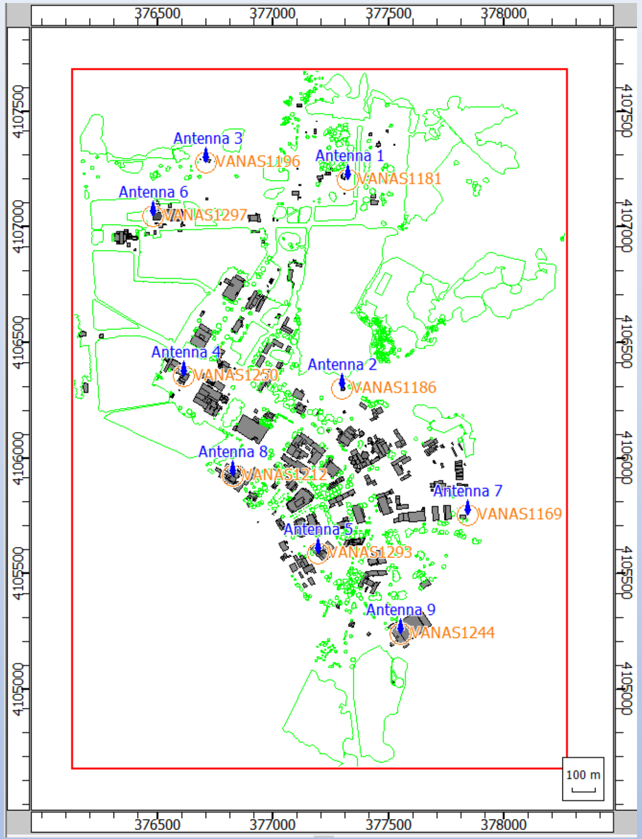
Step 4: Test antenna on airplane.

Use: Design a conformal antenna to mount on a particular surface.

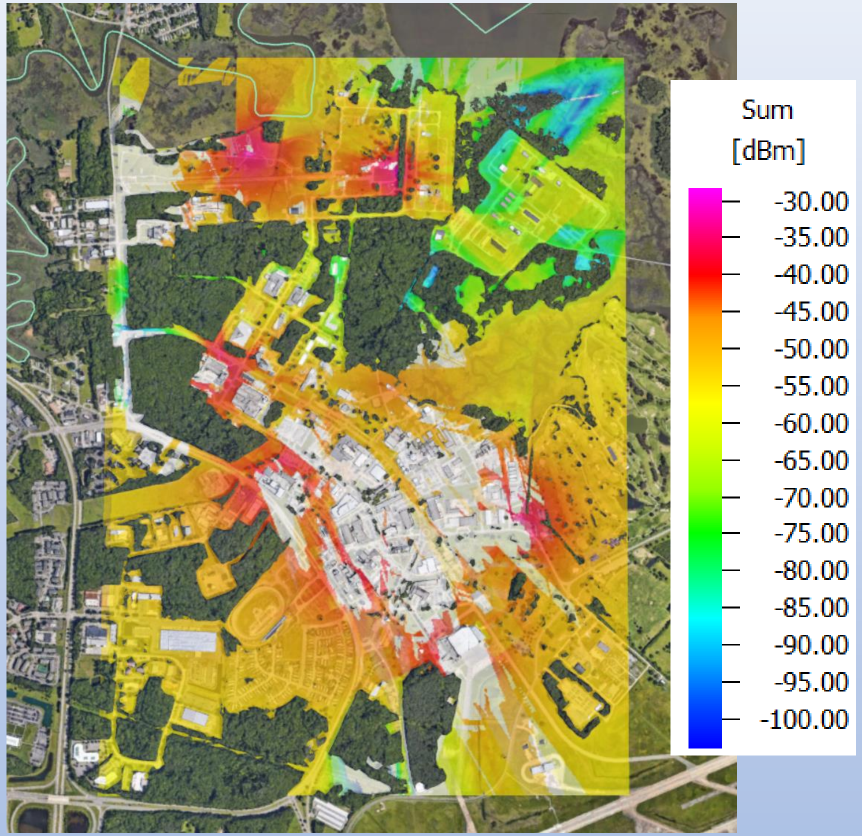
RADIATED POWER FROM MULTIPLE RF SOURCES AT LARC
EXAMPLE: NEXTNAV NAVIGATION SYSTEM (SWS)



Model of Langley Research Center based on Spring 2018 lidar measurements.



Nine NextNav transmitter positions identified using UTM coordinates.



Sum of radiated power calculated at 2.8 m AGL for comparison to ground-based measurements.

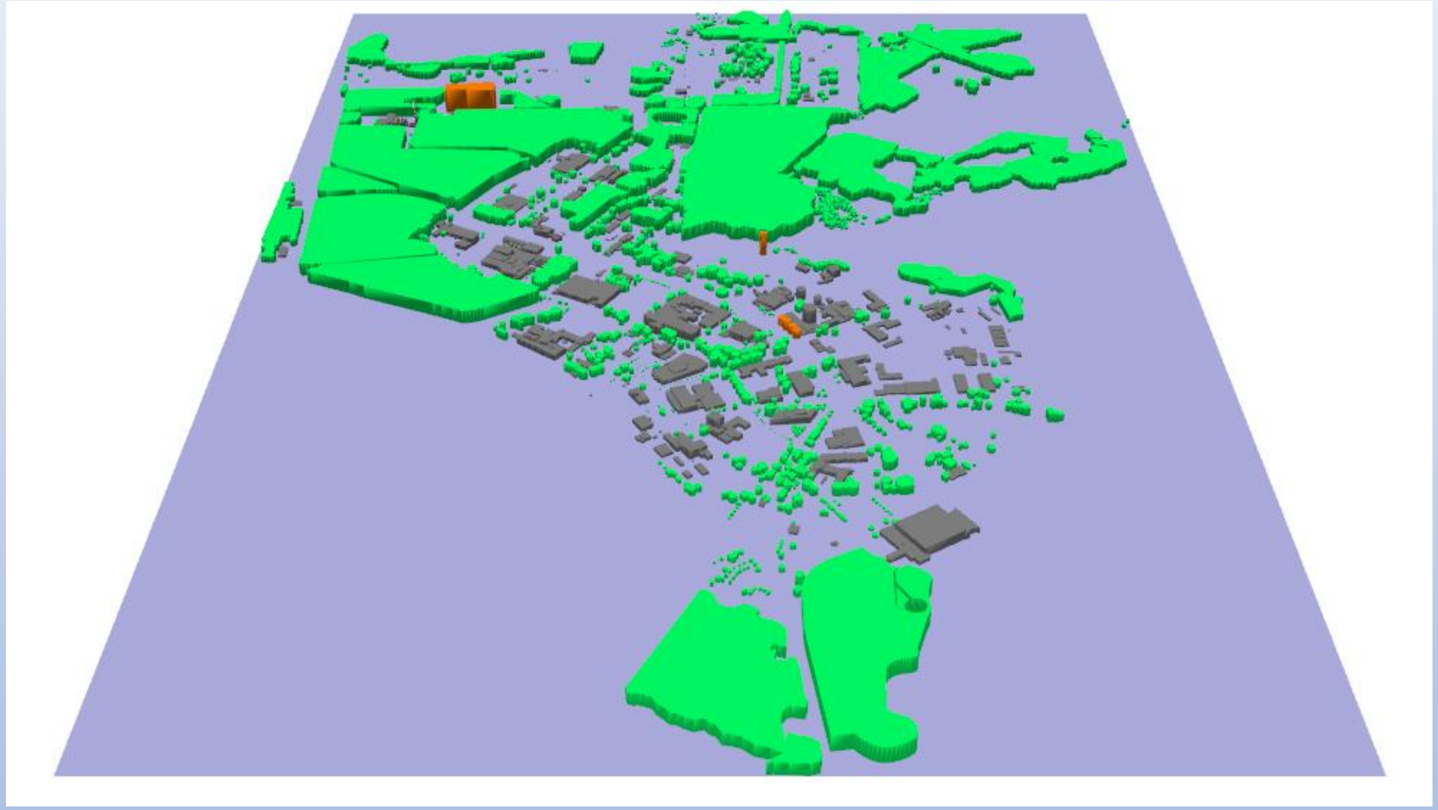
Use: Calculate radiated power at an altitude where interference may prevent proper controllability or performance of a UAV.

PART 2: SIMULATED VERSUS MEASURED UHF RADIATED POWER AT LARC STREET LEVEL

WINPROP COMPUTATIONAL ELECTROMAGNETIC MODELING BY RAY TRACING: STEPS

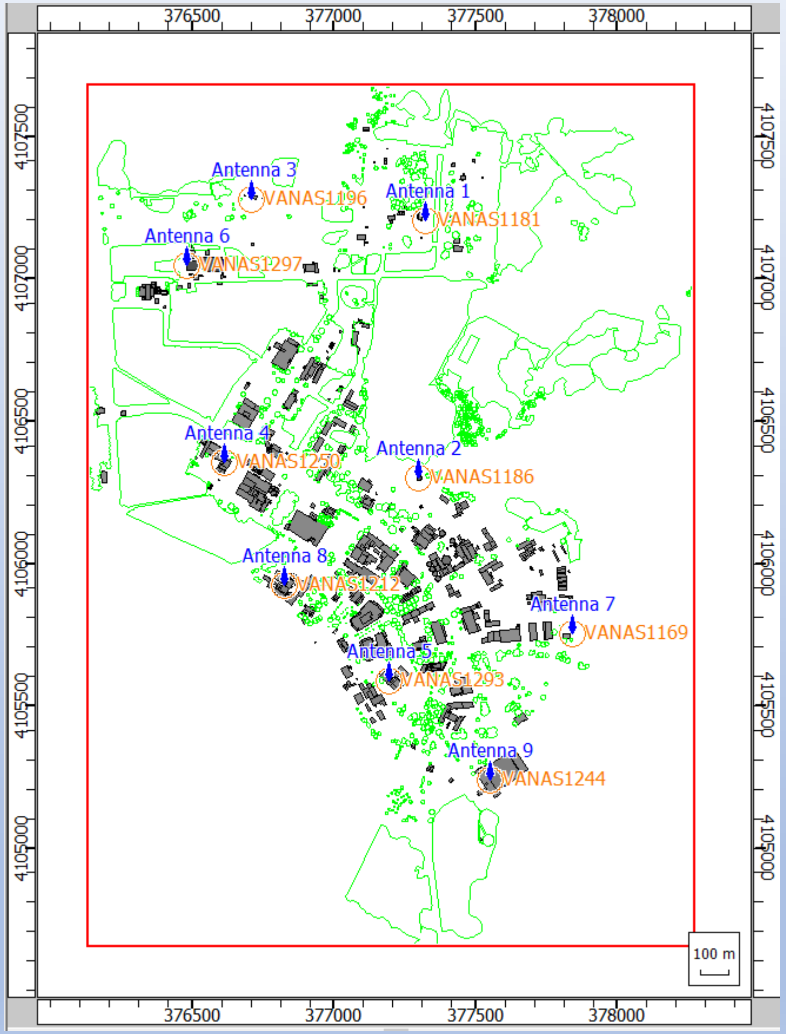
- Draw land contour, buildings, trees.
- Assign material properties, including reflection, transmission, diffraction, scattering.
- Choose model type.
- Choose prediction height, grid resolution, number of interactions.
- Define radiation sources.
  - Latitude, longitude, elevation
  - Frequency
  - Total power
  - Radiation pattern
  - Polarization
- Compute radiated power at a desired altitude, over a defined area.
- Results are given as seen by an isotropic antenna.

DRAWING THE MODEL STRUCTURES



Current state of the 3-D simulation model of Langley Research Center West Area. Buildings are shown in grey, metallic structures in orange, and trees in green.

PLACING THE RADIATING SOURCES



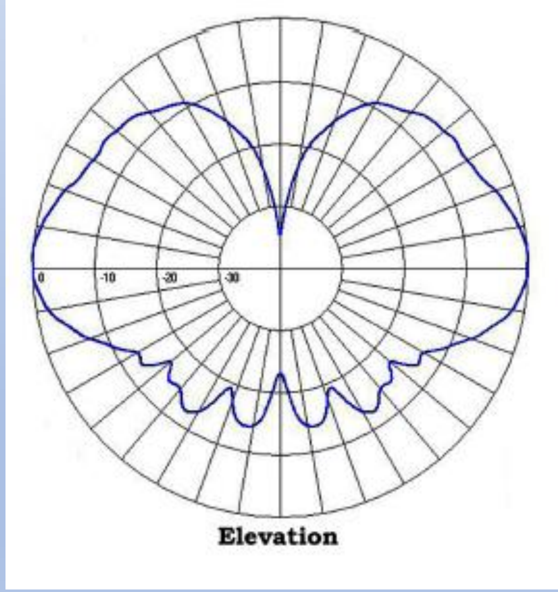
2-D model of the Langley Research Center West Area, showing placement of NextNav transmitters in UTM coordinates for Zone 18 N

NEXTNAV

From Wikipedia: "NextNav is the developer of Metropolitan Beacon System (MBS), a wide area location and timing technology designed to provide services in areas where GPS or other satellite location signals cannot be reliably received."

Can work indoors.

Operating frequency at LaRC: 926.227 MHz.



NextNav antenna elevation pattern, Sinclair SC433-HF6LDF(D00).

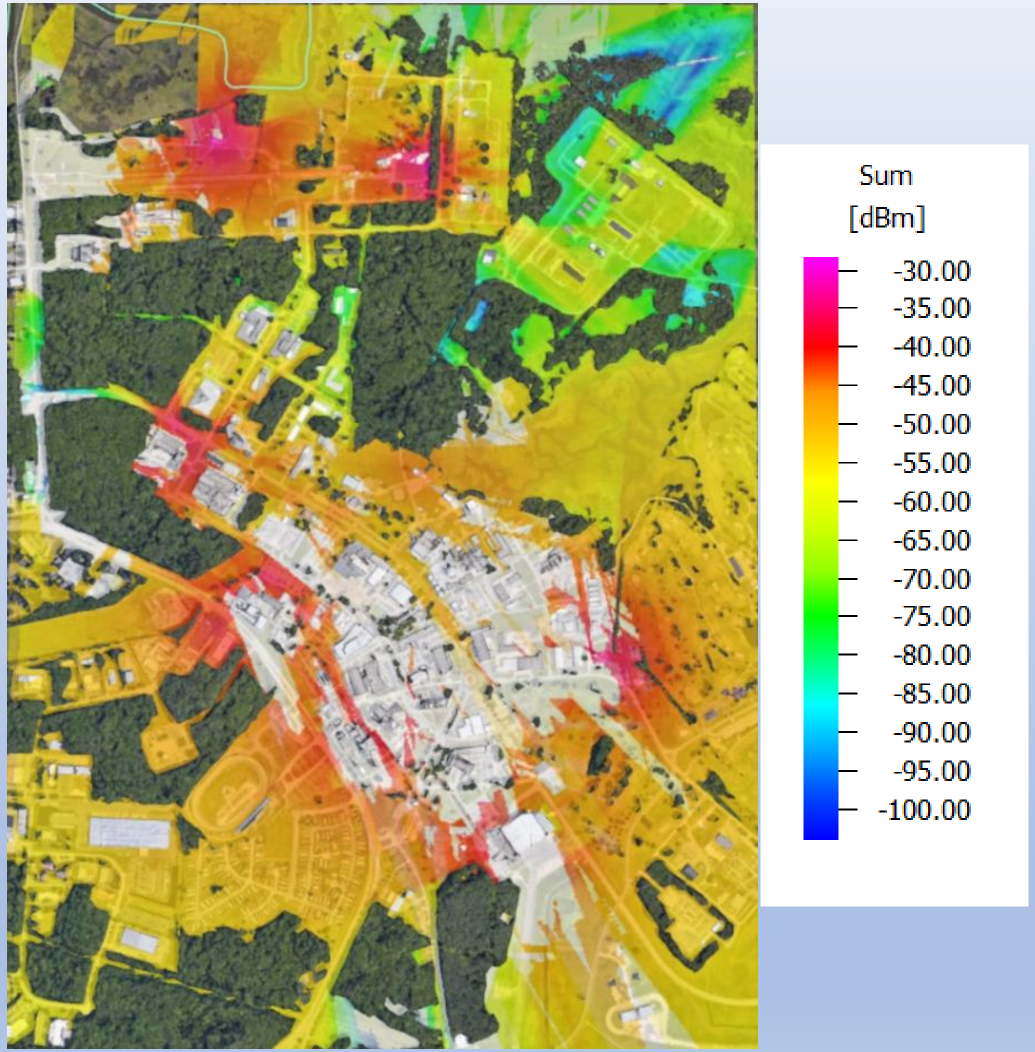
NextNav antenna, Sinclair SC433-HF6LDF(D00). Gain = 4.6 dBi.

COMPUTATIONAL SETTINGS

Model type: Intelligent Ray Tracing
Grid resolution: 5 m
Result height: 2.82 m (9.25 ft), to compare with ground-based measurements
Number of interactions: 2

Preprocessed model size: 11.6 GB

NEXTNAV SIMULATION RESULT AT 2.82 M



Simulated power sum at 2.82 m AGL, as seen by an isotropic antenna, superimposed on a Google Earth photograph of LaRC

“WAR DRIVE” MEASUREMENTS

Data collection vehicle

Omnidirectional antenna Electro-Metrics 6853 installed on the van, ultra-wideband (300 MHz-40 GHz), 2.82 m above ground level

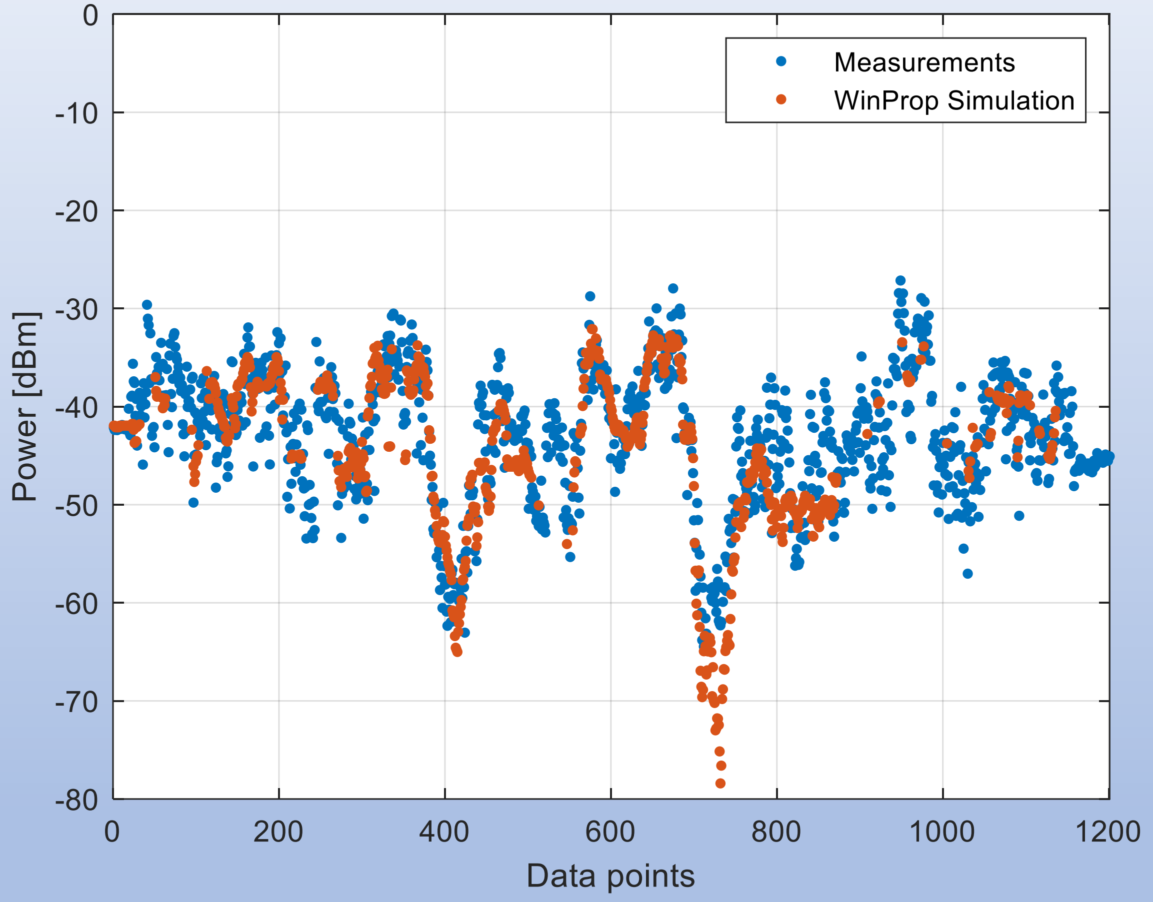
Spectrum Analyzer: Signal Hound BB60C (9 KHz – 6 GHz)
Measurement frequency range: 800 MHz to 1000 MHz
Reference level: -10 dBm
Resolution bandwidth: 100 KHz
Sweep time: 0 ms (for the fastest rate set by the instrument)
Sweep interval: 2 s
Trace type: maximum hold
Detector: maximum

Receiver settings for Signal Hound Spectrum Analyzer inside van

MEASUREMENT DRIVE ROUTE

Route driven through Langley Research Center, plotted using OpenStreetMap

RESULT COMPARISON



Description of the experiment in NASA/TM-20210013542, “Simulated Versus Measured UHF Radiated Power at LaRC Street Level” by Anne Mackenzie, Truong Nguyen, Kevin Barnes, and Michael Scherner.

WinProp simulated power versus measured power from nine NextNav transmitters at 926.227 MHz, 2.82 m AGL. Measurements were taken along the driving route on January 15, 2021, starting at 10:24:43 am.

HOW CAN THIS TYPE OF MODELING BE USED?

Calculate radiation at various altitudes from known sources

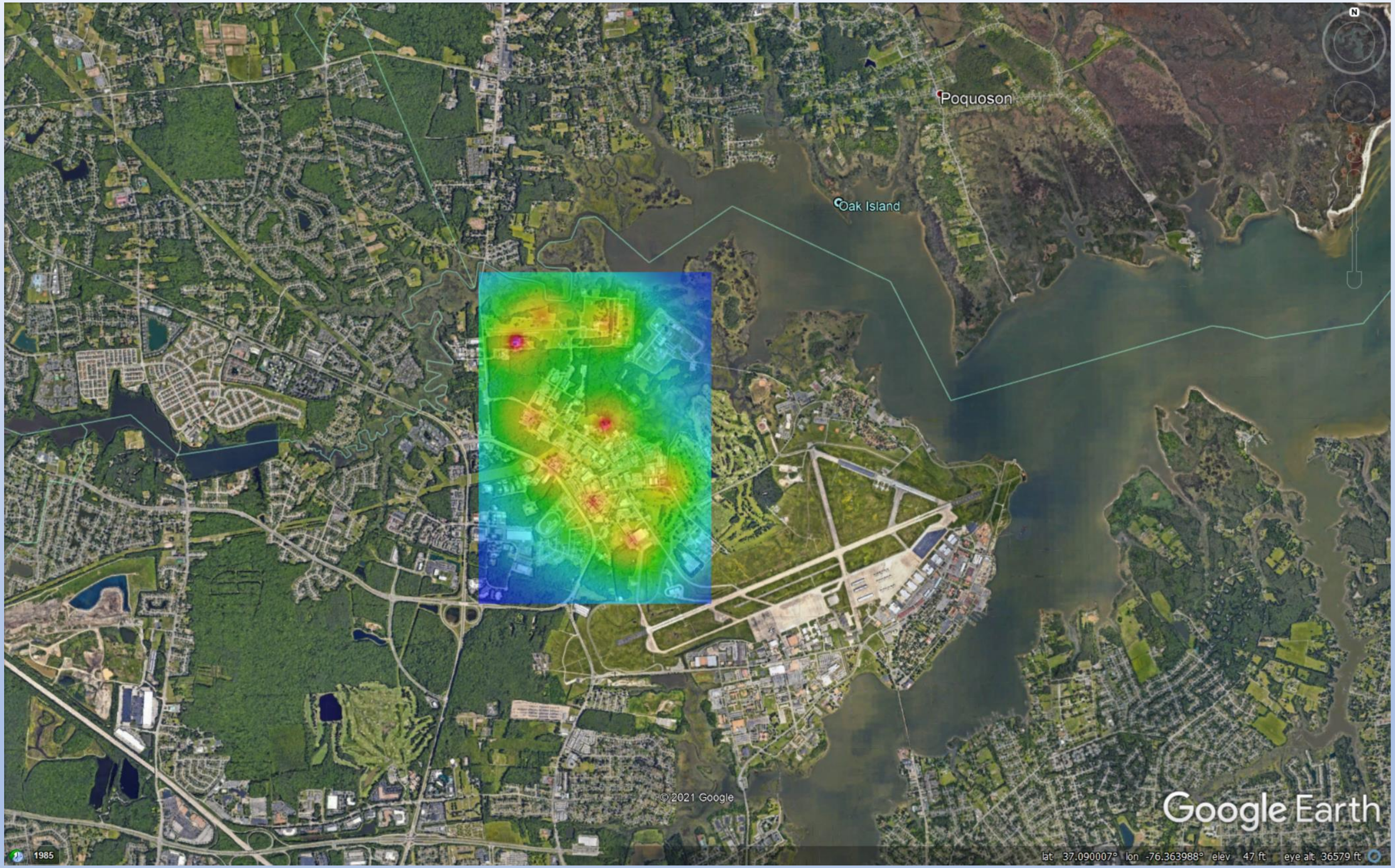
or

Detect unknown sources, assume a radiation pattern, and calculate radiation.

[Photos courtesy of KNB]

Radio frequency monitoring system (RFMS):
System-Wide Safety Installation

NEXTNAV SIMULATION RESULTS AT 122 M (400 FT)



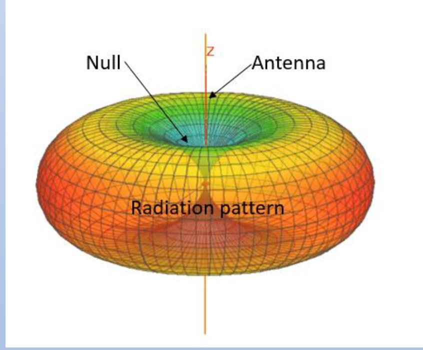
Radiated power can be calculated at flight altitude.

SIMULATION IMPROVEMENTS ?

Draw structures more accurately. (WinProp model currently represents all structures with flat tops.) – *Improvements are being explored.*

Locate radiation sources more accurately. (Current RFMS detects source position latitude and longitude, not elevation.) – *More expensive detection system could place radiation source in 3-D.*

Define source radiation patterns more accurately. (Possible over or underestimation of radiation intensity if source radiation pattern is incorrectly assumed.) – *Radiation patterns cannot be remotely detected.*



Omnidirectional pattern

THE END