# Experimental Results Using Satellite Illuminator for Passive Bistatic Radar

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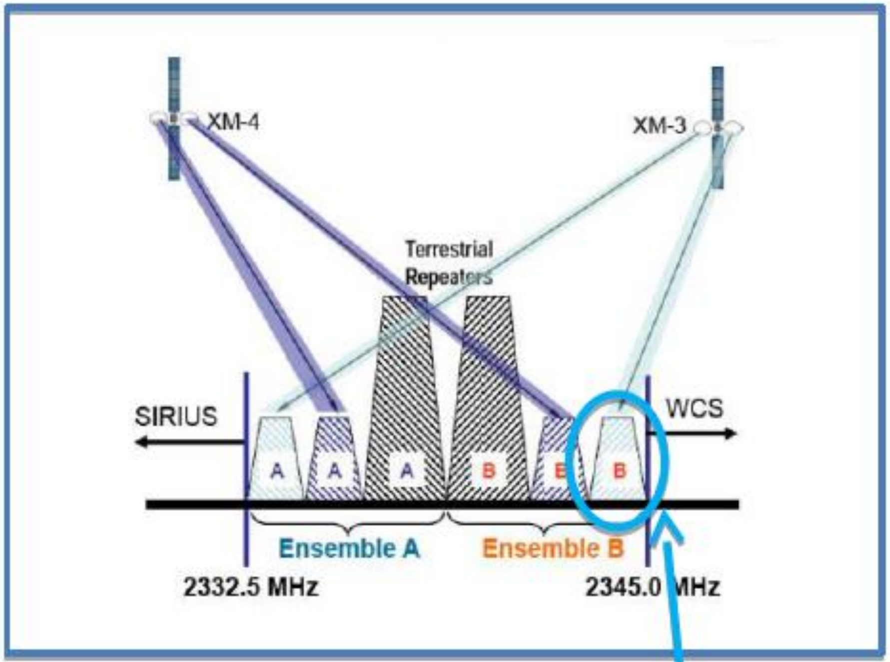
# Motivation

- Conventional (monostatic) radars are generally expensive to deploy and operate, and require transmission of a high-power, wide-band interrogation signal
- Passive bistatic radar is a cheaper alternative to conventional radar
  - A dedicated transmitter is not required
  - Can be built with commercial, off-the-shelf components
  - Satellite illuminators offer wide coverage areas
- Unique viewing geometries using bistatic radar are not generally achievable by monostatic systems
  - Particularly if a satellite illuminator is used (high incidence angles)

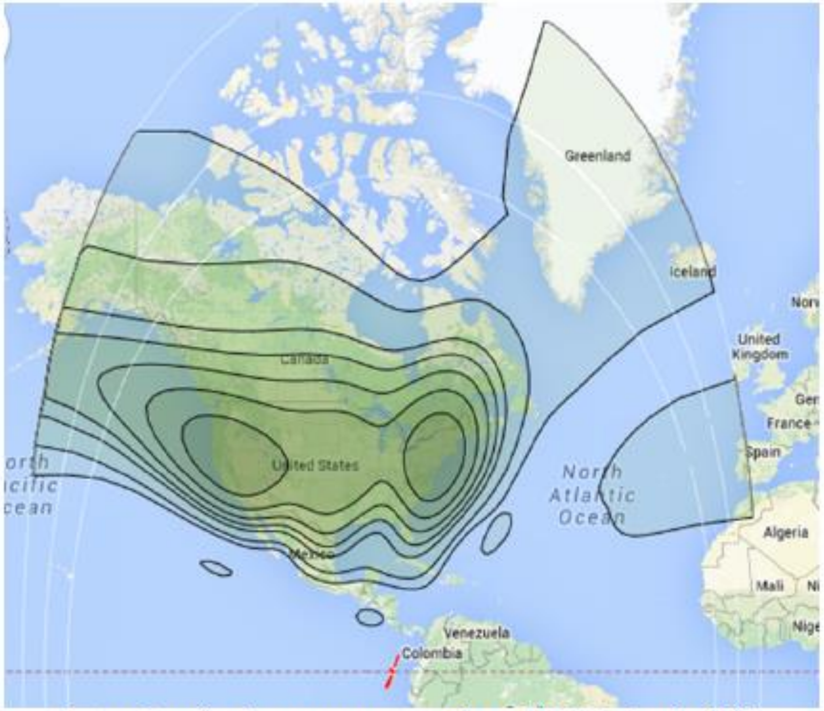
# Outline

- Description of satellite illuminator (XM Radio)
- Data reception/processing
  - Reception/processing chain
  - The ambiguity function
  - Range-Doppler processing
- Results
  - Experimental setups
  - Sample range-Doppler maps
    - Aircraft
    - Watercraft
- Conclusions

# Satellite Illuminator: XM Radio



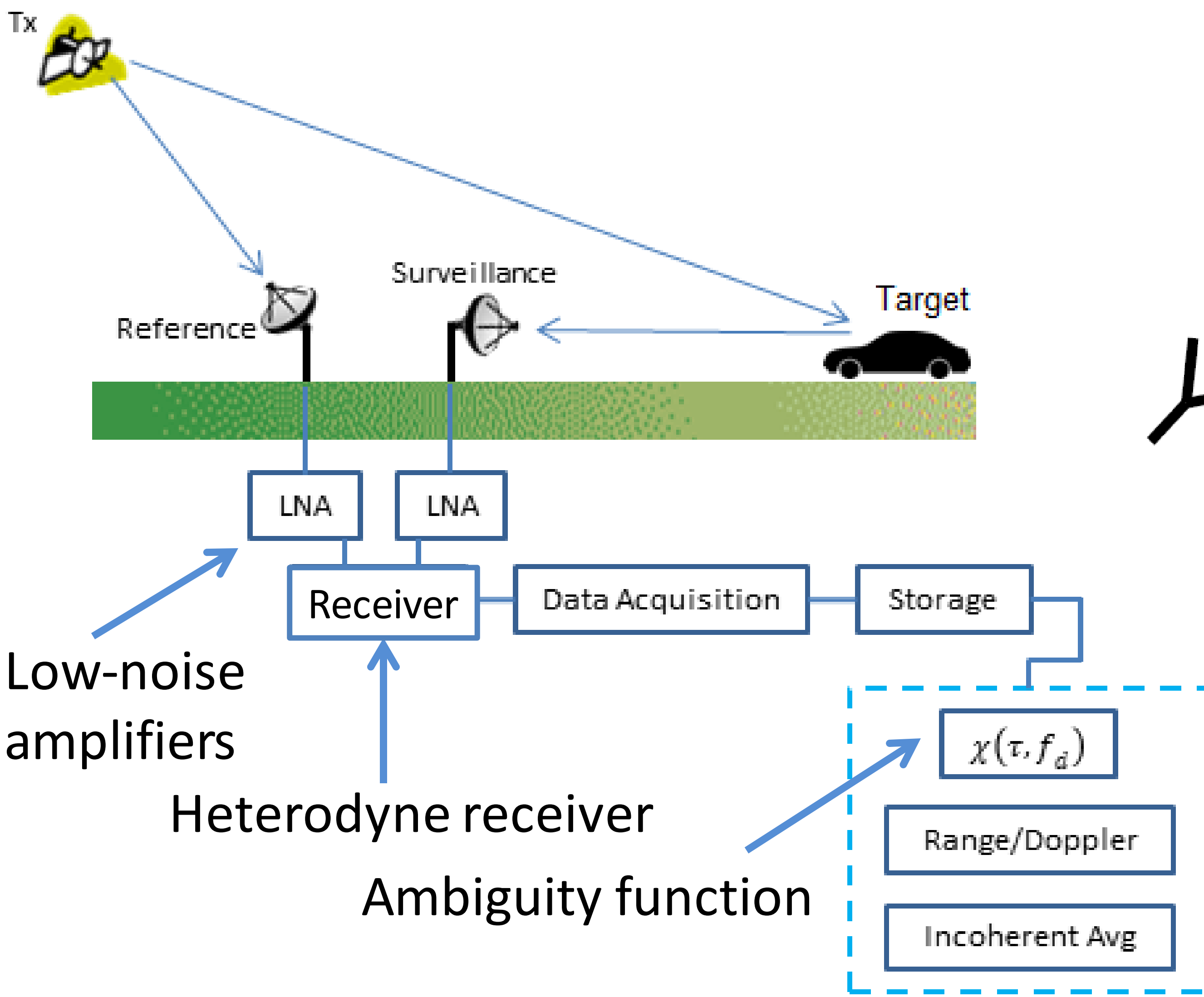

XM Satellite Downlink

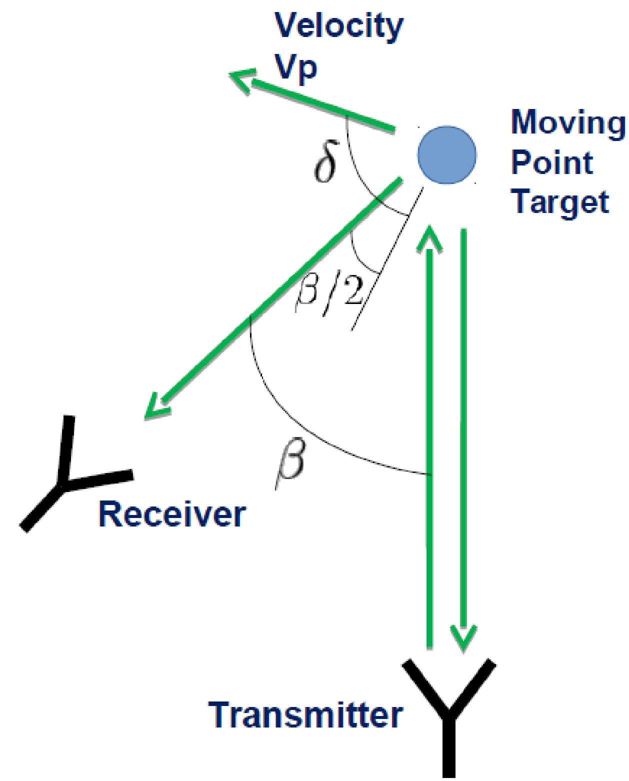



Footprint coverage for XM3 Satellite

- Single Transmitter BW = 1.8MHz (>83m range resolution)
- 2.3GHz (S-band), Left-Hand Circular Polarization (LHCP)
- Geostationary orbit – no need to track satellite
- Effective Isotropic Radiated Power (EIRP) of 68.5dBW
- Power at sea-level in DC area: -121dBW

# Receiving/Processing Chain




$$f_D = \frac{2V_p}{\lambda} \cos\delta \cos(\beta/2)$$

# Range/Doppler Processing: The Ambiguity Function

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**The ambiguity function is the analogue to matched filtering in monostatic radar.**

# of frames for incoherent averaging

Coherent Processing Interval

Time delay (range)

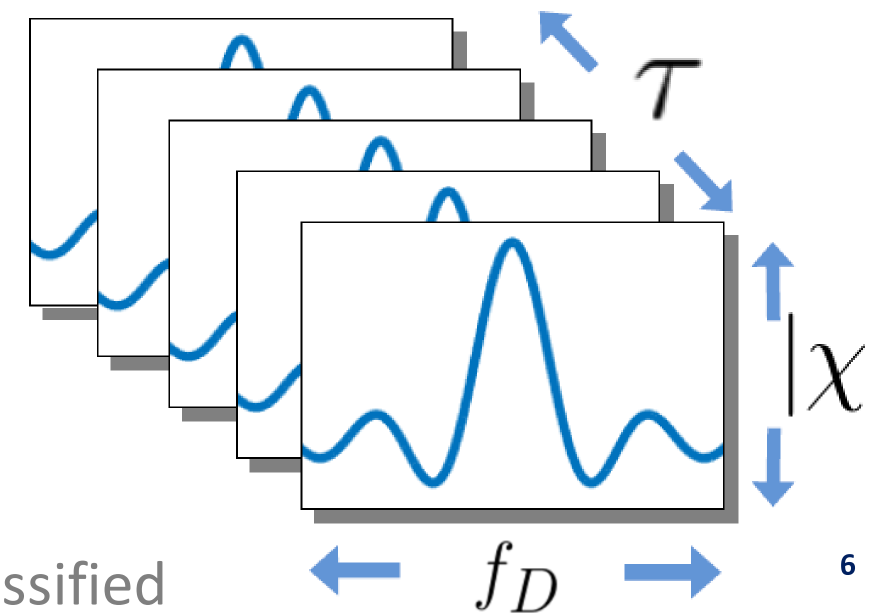
Doppler freq.

Reference channel data

Surveillance channel data

$$\chi(\tau, f_D) = \sum_{i=1}^{N} \int_0^{T_{CPI}} u_r(t) u_s^*(t+\tau) e^{j2\pi f_D t} dt$$

**The amplitude of the ambiguity function is plotted as a function of time delay and Doppler to detect targets.**



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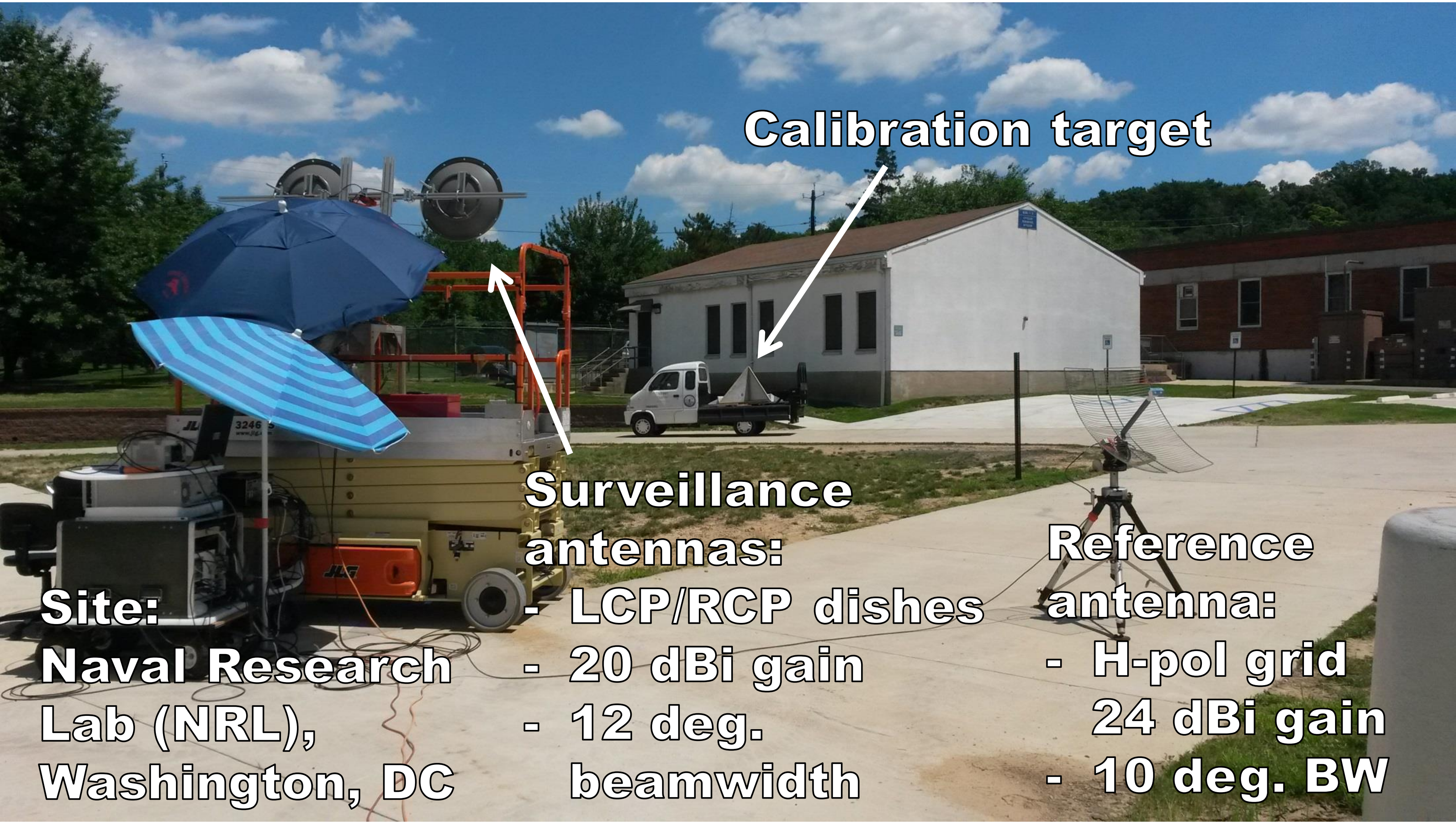
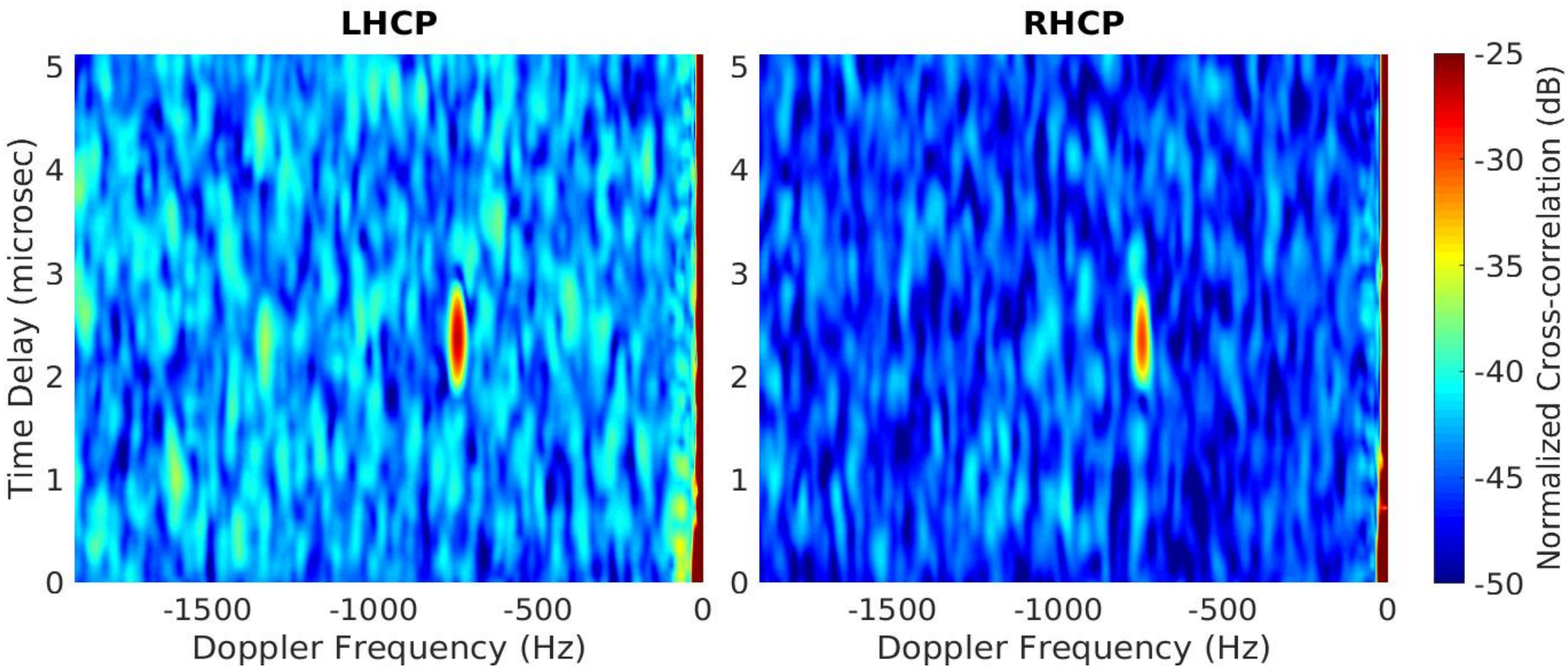
# Aircraft Detection: Experimental Setup



# Aircraft Detection: Range-Doppler Map

**Target: Northbound commercial aircraft**


- **Azimuth = 19 deg. NNE**
- **Elevation angle: 6.5 deg.**
- **CPI: 0.067 sec**
- **14-frame average**
- **Trajectory: landing approach**

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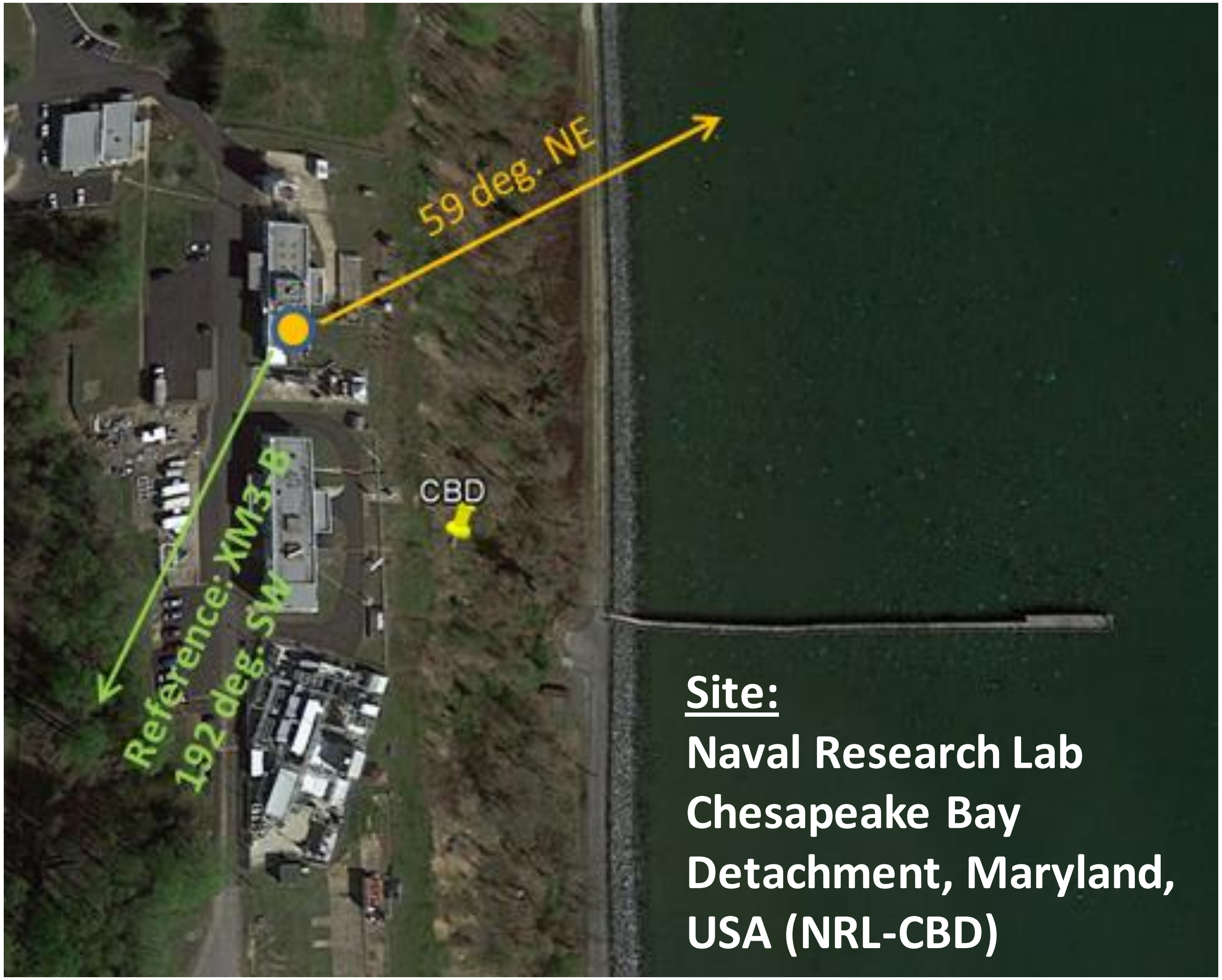
# Ship Detection: Experimental Setup



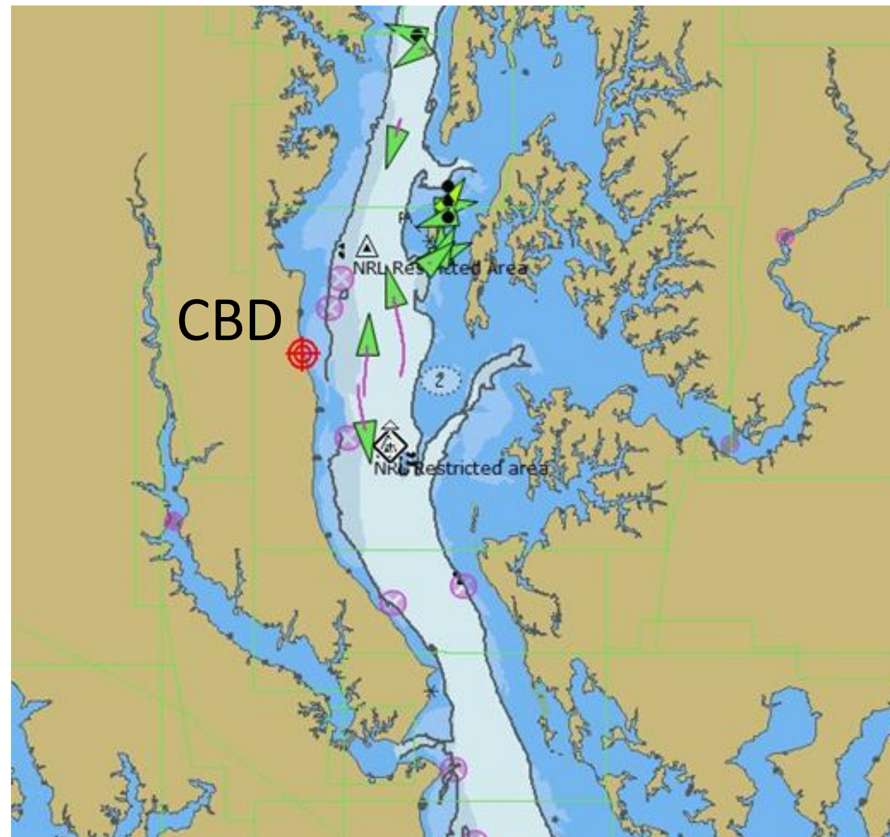

**Site:**
Naval Research Lab Chesapeake Bay Detachment, Maryland, USA (NRL-CBD)

**Surveillance antenna:**
- H-pol horn
- 9 dBi gain
- 30 deg. beamwidth

**Reference antenna:**
- H-pol grid reflector
- 24 dBi gain
- 10 deg. beamwidth

# Ship Detection: Experimental Setup

- AIS data for vessel tracking was available via the Test Control facility at NRL-CBD
- Data provides vessel speed, range, and bearing, and ship dimensions
- High-power binoculars also used for target confirmation



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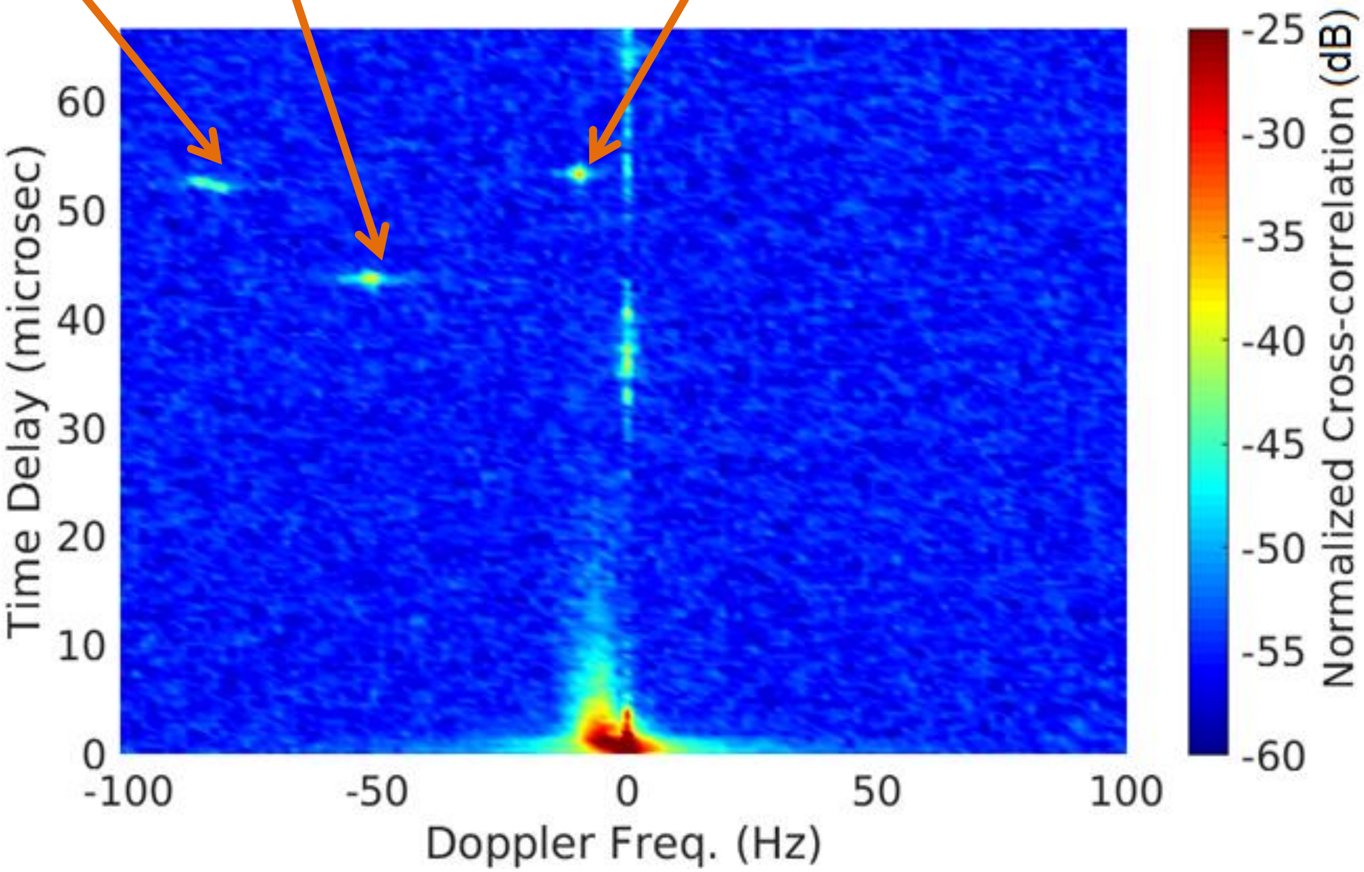
# Ship Detection: Range-Doppler Map

S&T organization

**Targets: Northbound ships; cargo ship and tug boats**

- **Azimuth = 59 deg. NE**
- **Depression angle: 3.5 deg.**
- **CPI: 0.629 sec**
- **28-frame average**

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# Conclusions

- Passive bistatic radar can be used as a cheaper alternative to conventional radar and does not need a dedicated transmitter
- Satellite illuminators offer wide area coverage and unique bistatic geometries
- Data processing is straight-forward, flexible, and inexpensive
- Results demonstrate that passive bistatic radar using satellite-based signals can be used for effective aircraft and vessel detection and tracking