

Finding an Active Shooter with GNURadio





Active Shooter Tactical Response Assistant Team ASTRA:

George Mason University Students:

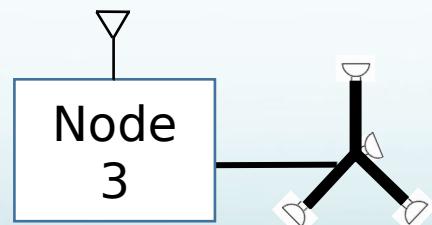
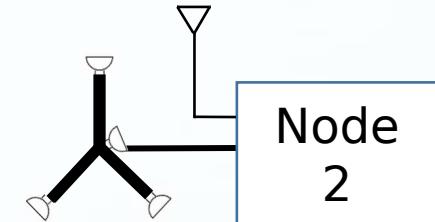
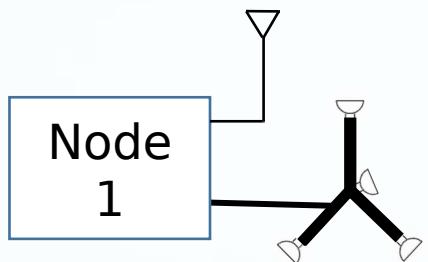
Ben McCall, Puja Patel, Joel Williams, Rohini Shah, Aryan Toughiry

GMU Sponsors: Dr. Kenneth Hintz & Dr. Kathleen Wage

Possible Approaches and Barriers

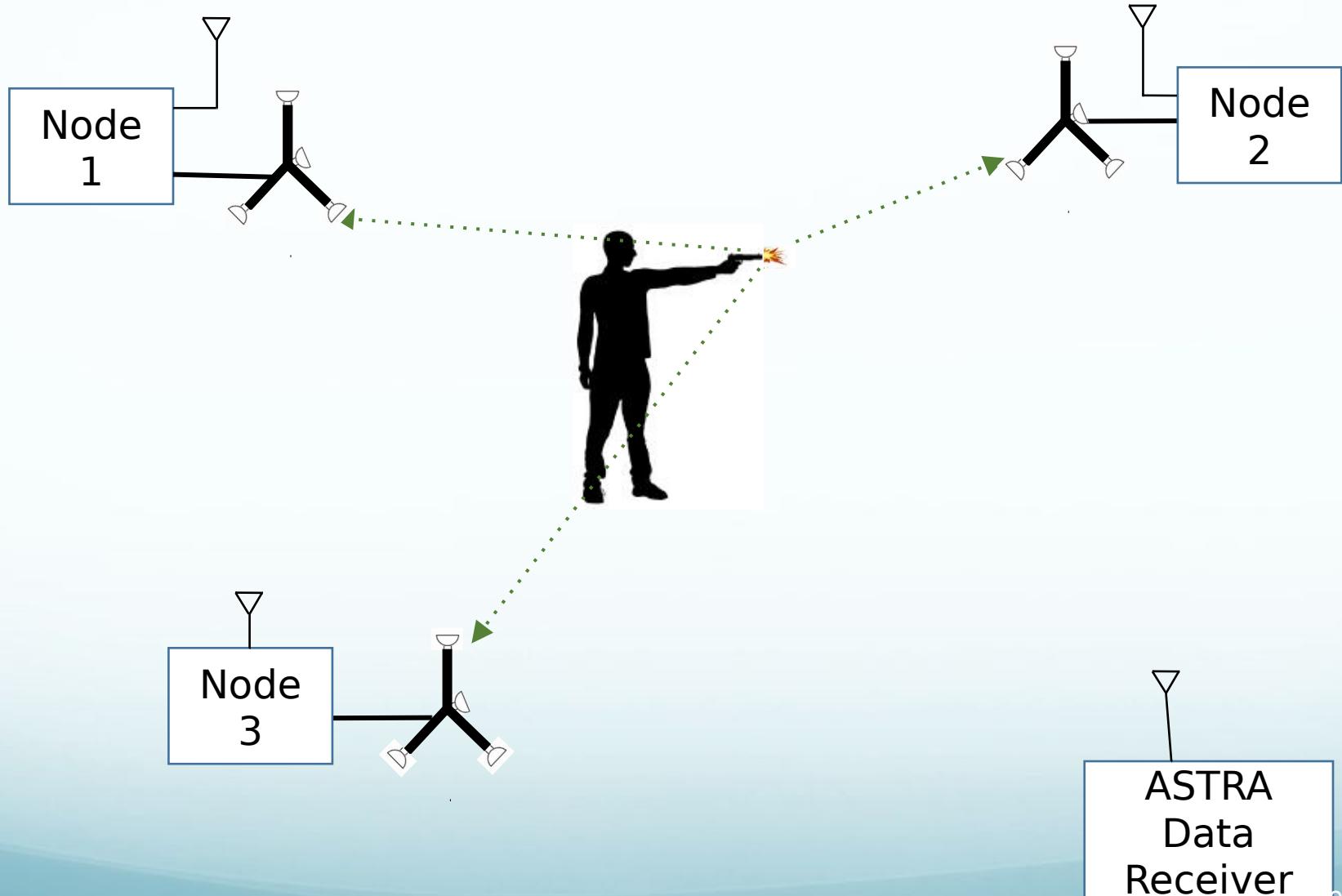
- TDoA Network
 - timing issues (only using 1pps from GPS)
 - Simple-ish hardware
- Direction Finding/Acoustic Phased array
 - Timing between elements easier than TdoA
 - Hard to capture distance to source
- Network of Direction Finding/Acoustic Phased arrays
 - Best of both worlds
 - Geographic spacing with no node-to-node timing needed
 - Gather distance to source through node intersections

ASTRA Walkthrough

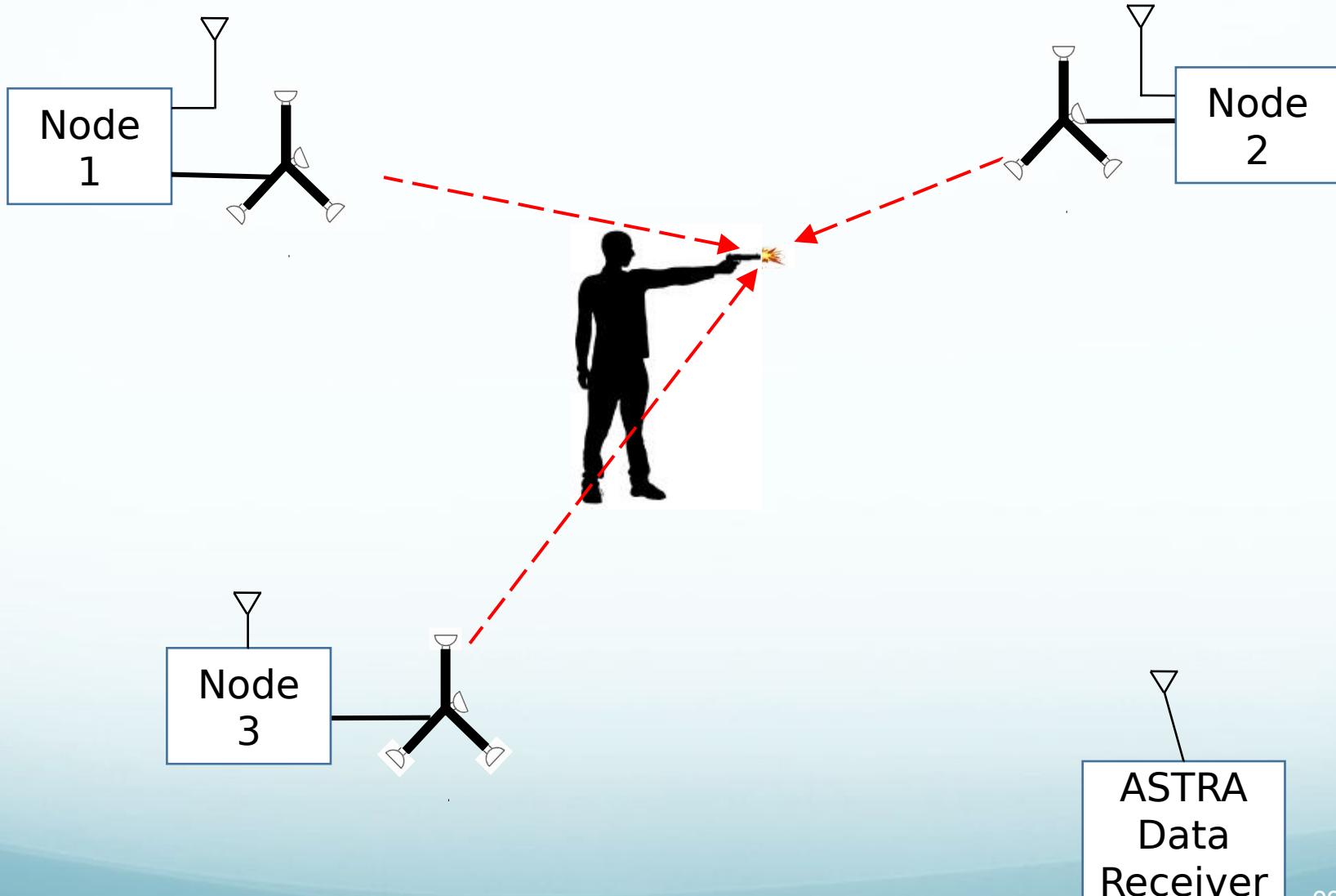


A diagram showing a blue rectangular box labeled "ASTRA Data Receiver". A black Y-shaped antenna is connected to it. One arm of the Y-antenna has a small white dish-like reflector at its end. A line from the top of the Y-antenna leads to a white dish-like reflector.

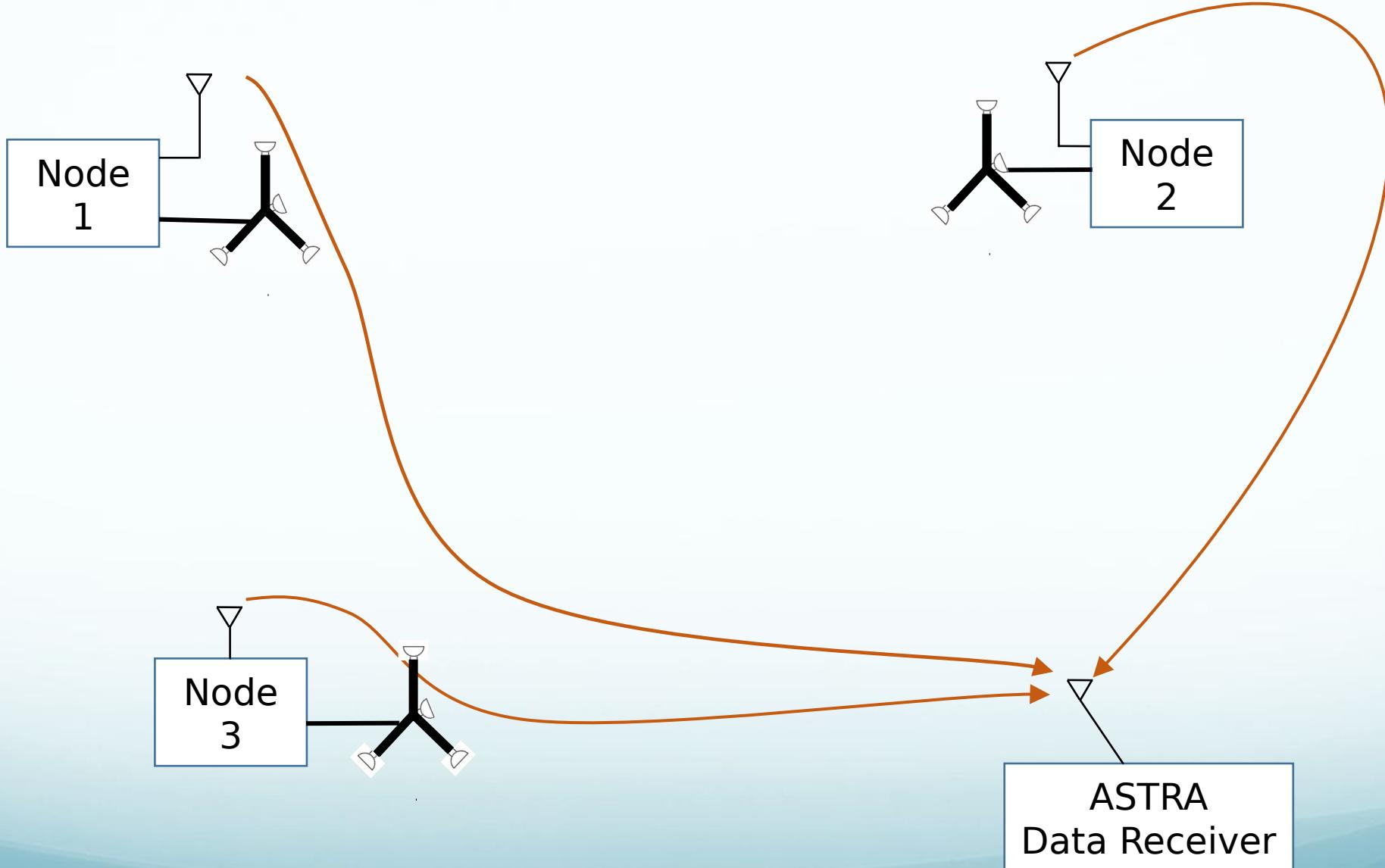
ASTRA M Shot is detected by Acoustic Sensor Array of Nodes



Each Node plots back a directional vector back to the source

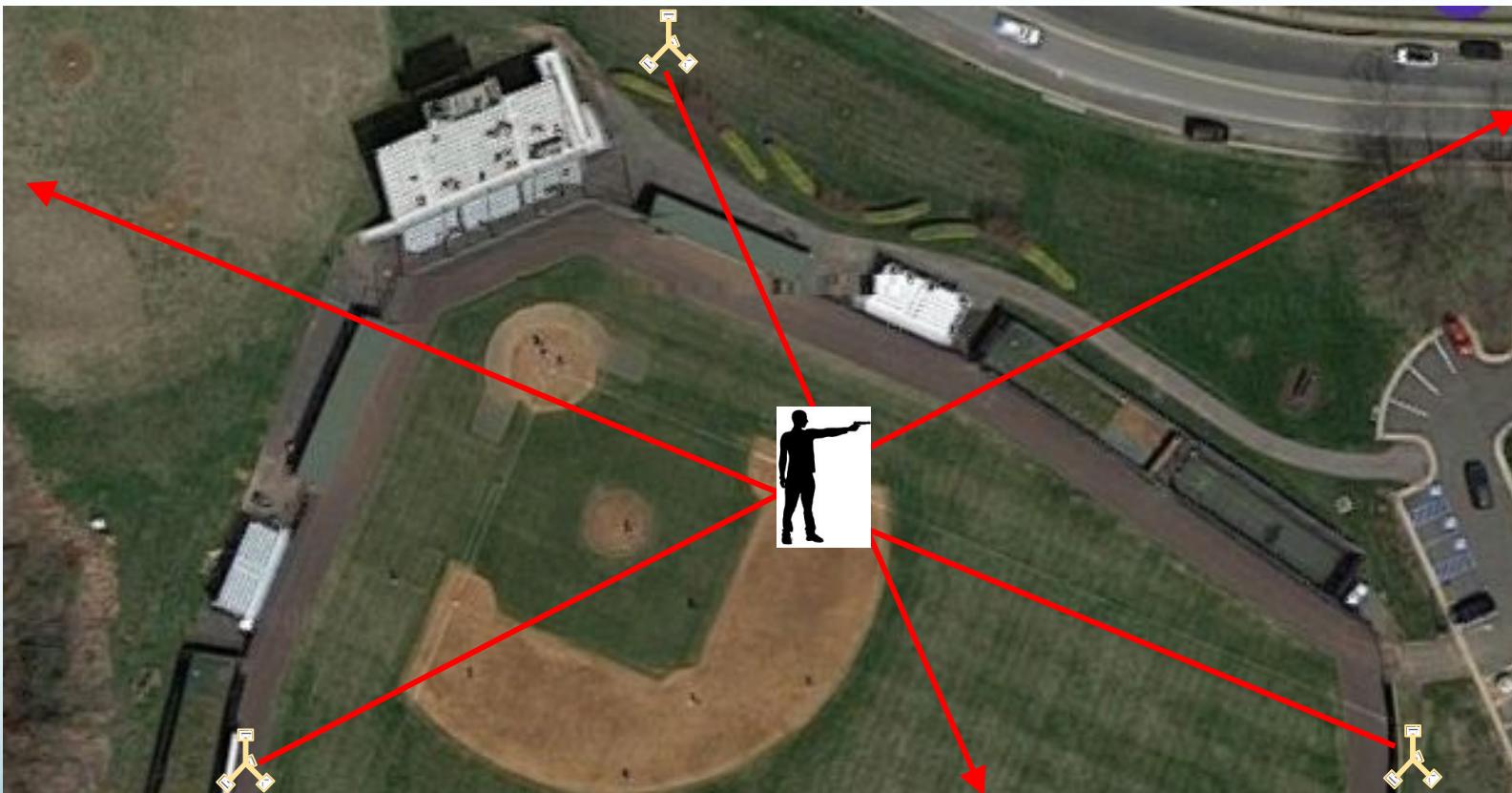


ASTRA M Vector Data is sent to the ASTRA Data Receiver



Intersection of Directional Vectors Shows Approx. Shooter Location

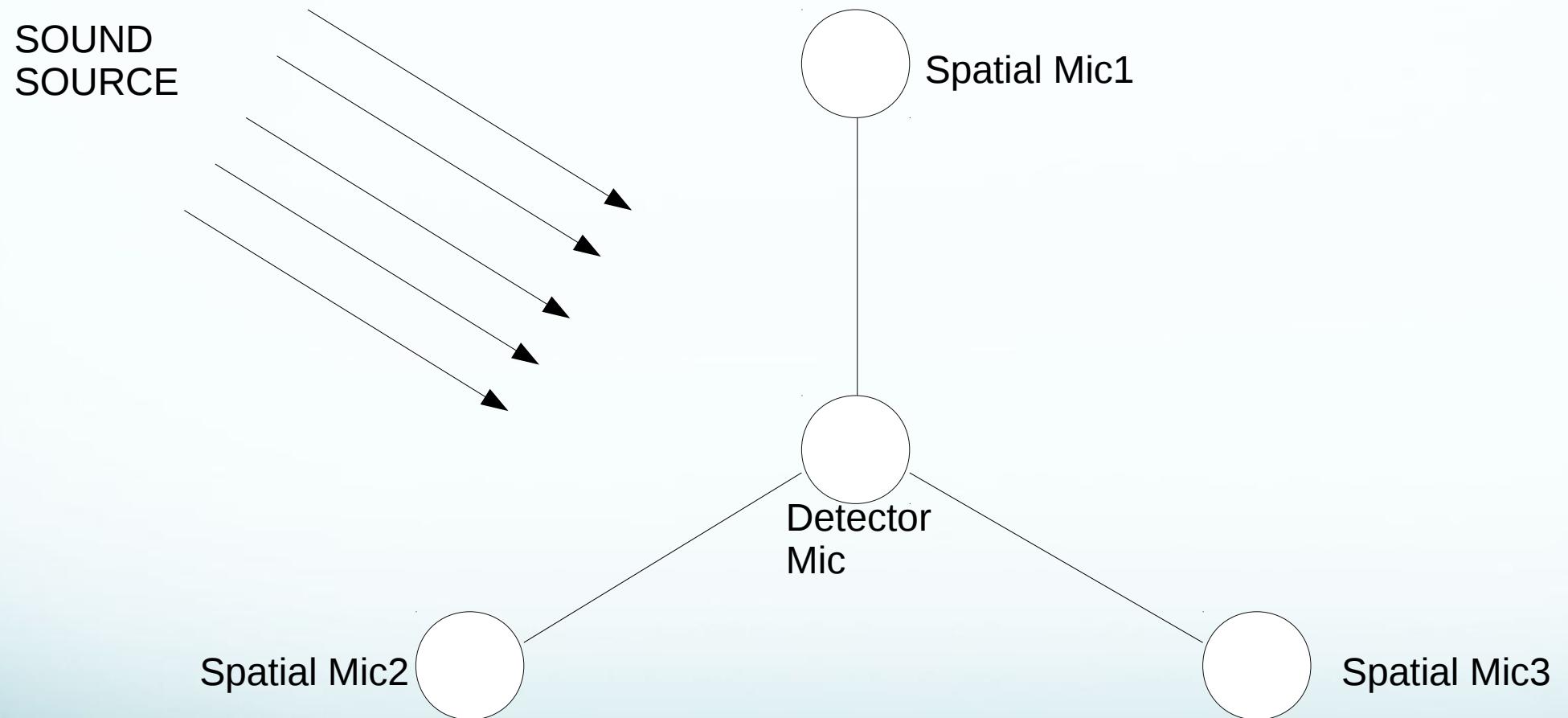
ASTRA User Terminal



Approach

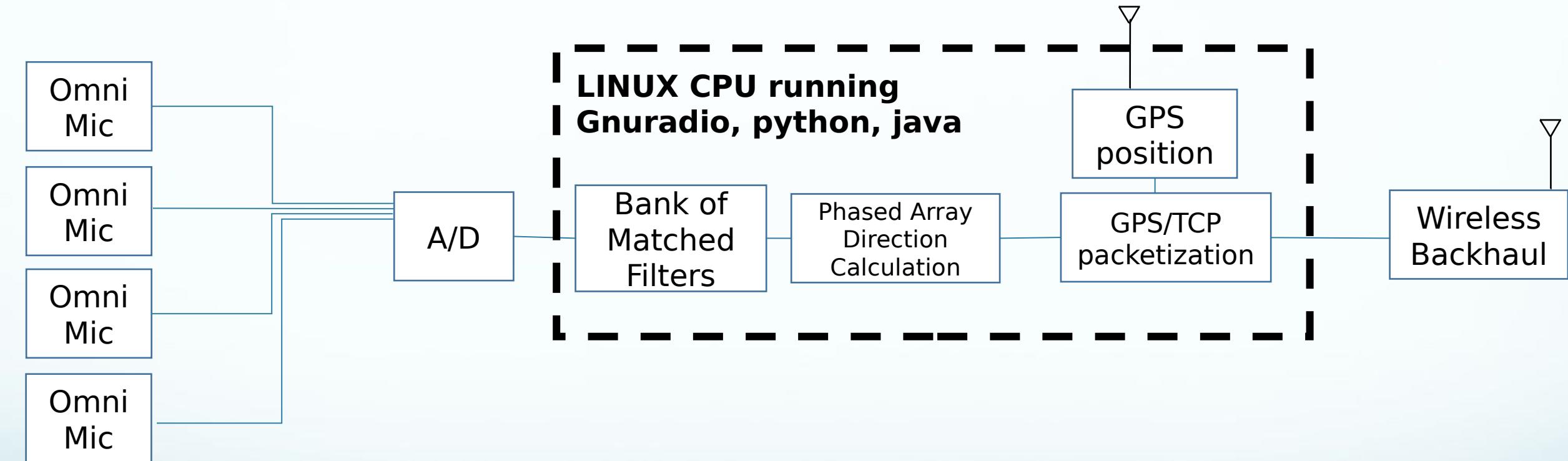
- Detecting the Gunshot:
 - Matched Filtering
 - Tested FFT multiply vs time domain convolution
 - FFT Multiply produced %30 increase in processor efficiency
 - Fixed threshold using visual observation (for now)
- Determining the Direction of the Gunshot:
 - Auto/Cross Correlation to extract delays (lags)
- Locate the Gunshot (and Hopefully the Shooter)
 - Determine Region of Intersection
 - Determine Region of Uncertainty

2D Phased Array

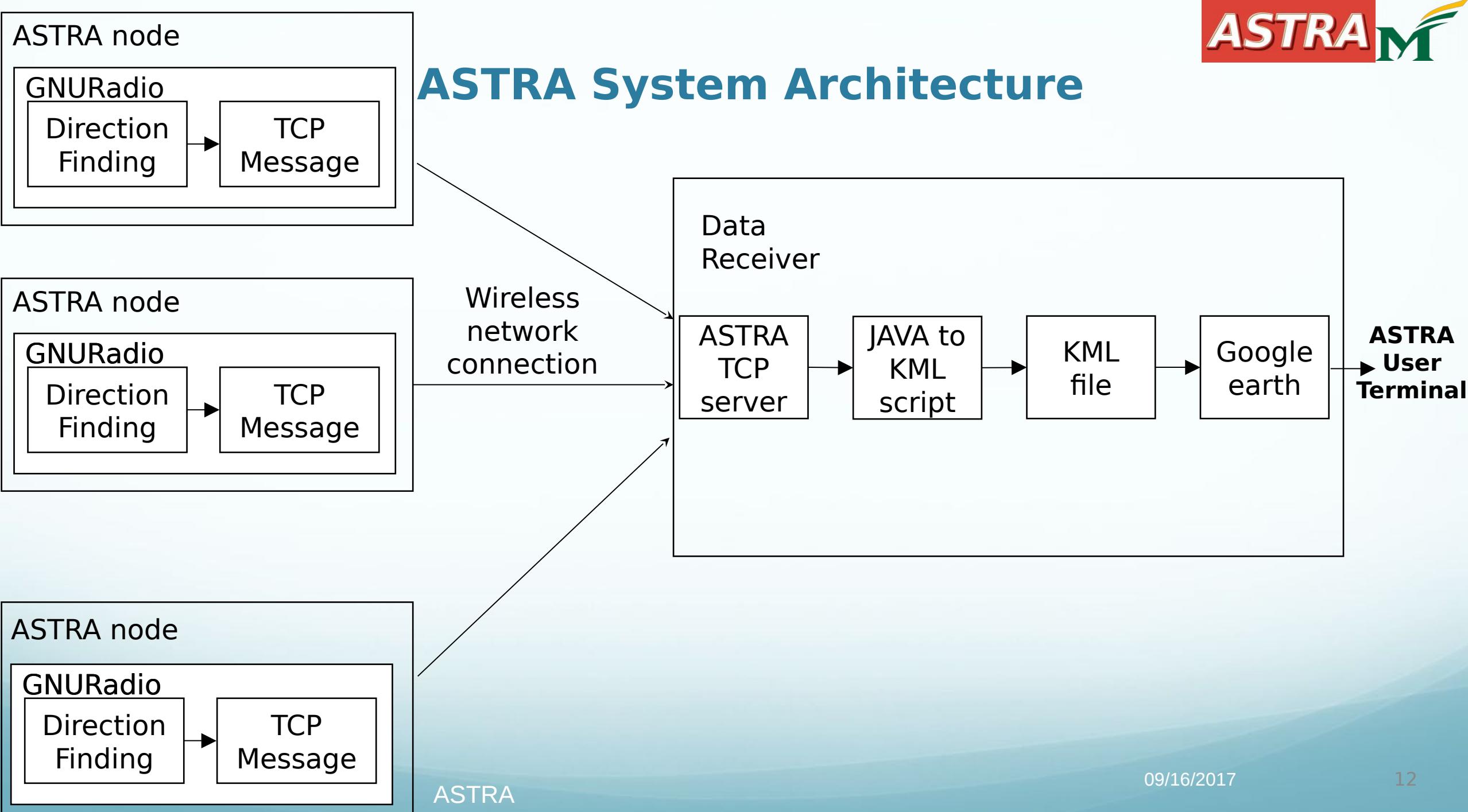


Thanks to M. Rhudy Univ Pitt

Single Node Architecture



ASTRA System Architecture



Materials list:

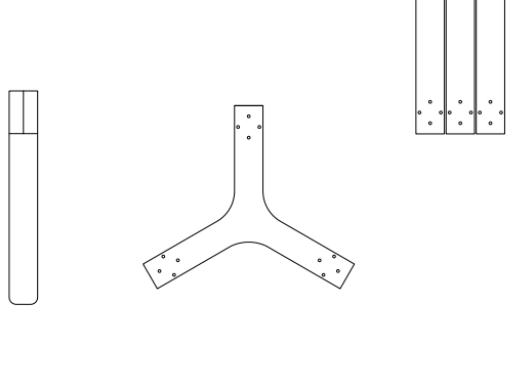
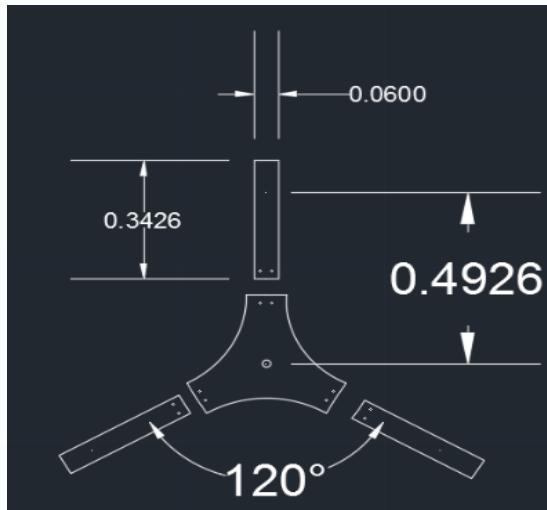
NODE (replicated 3x):

- (1) Tascam US4x4 4 channel A/D converter



(1) Ubiquity Networks Loco M900 900MHz wireless transceiver

(4) MOVO LV4 Omnidirectional Lavalier Microphone

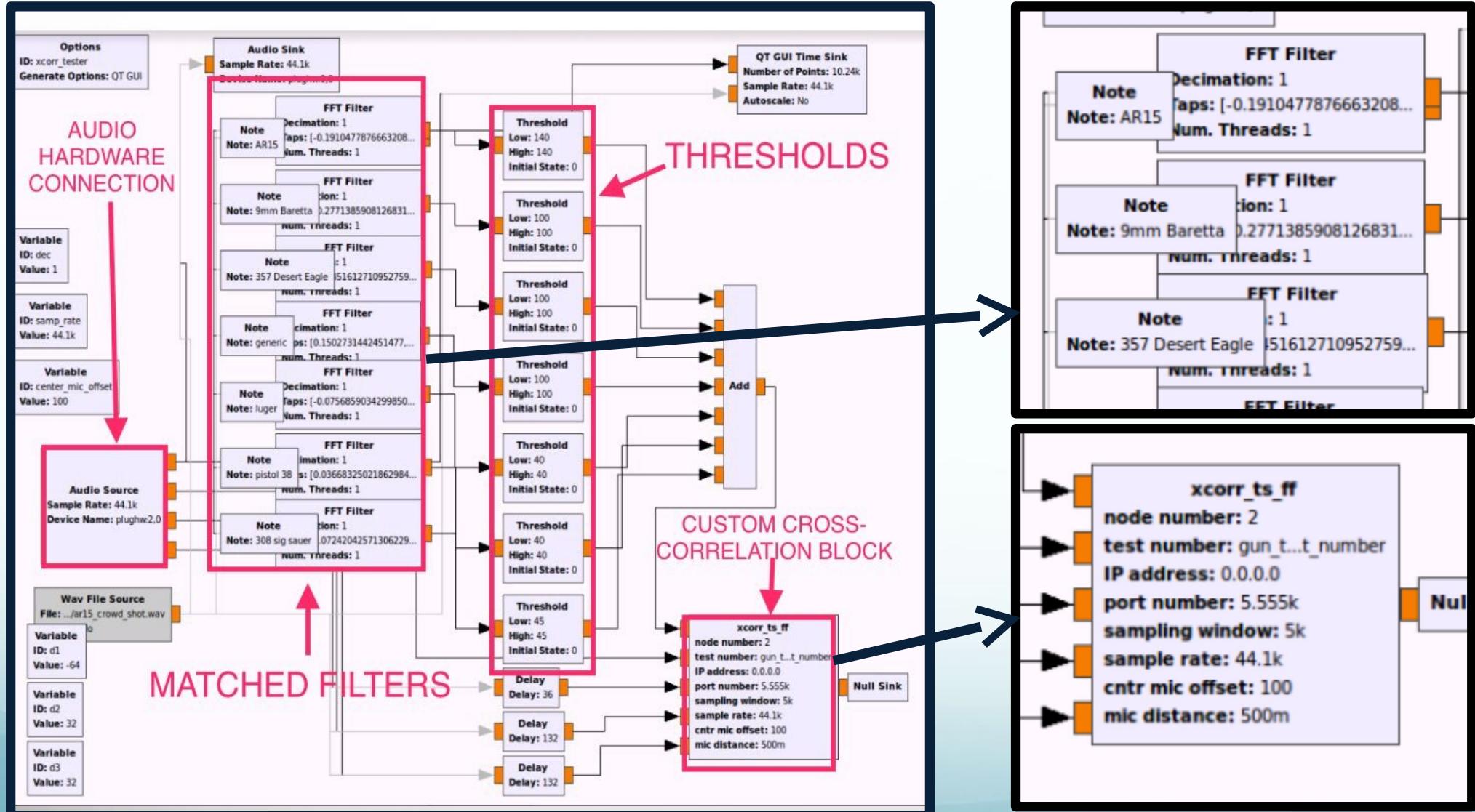
**AutoCAD****Physical implementation**

Why GNURadio?

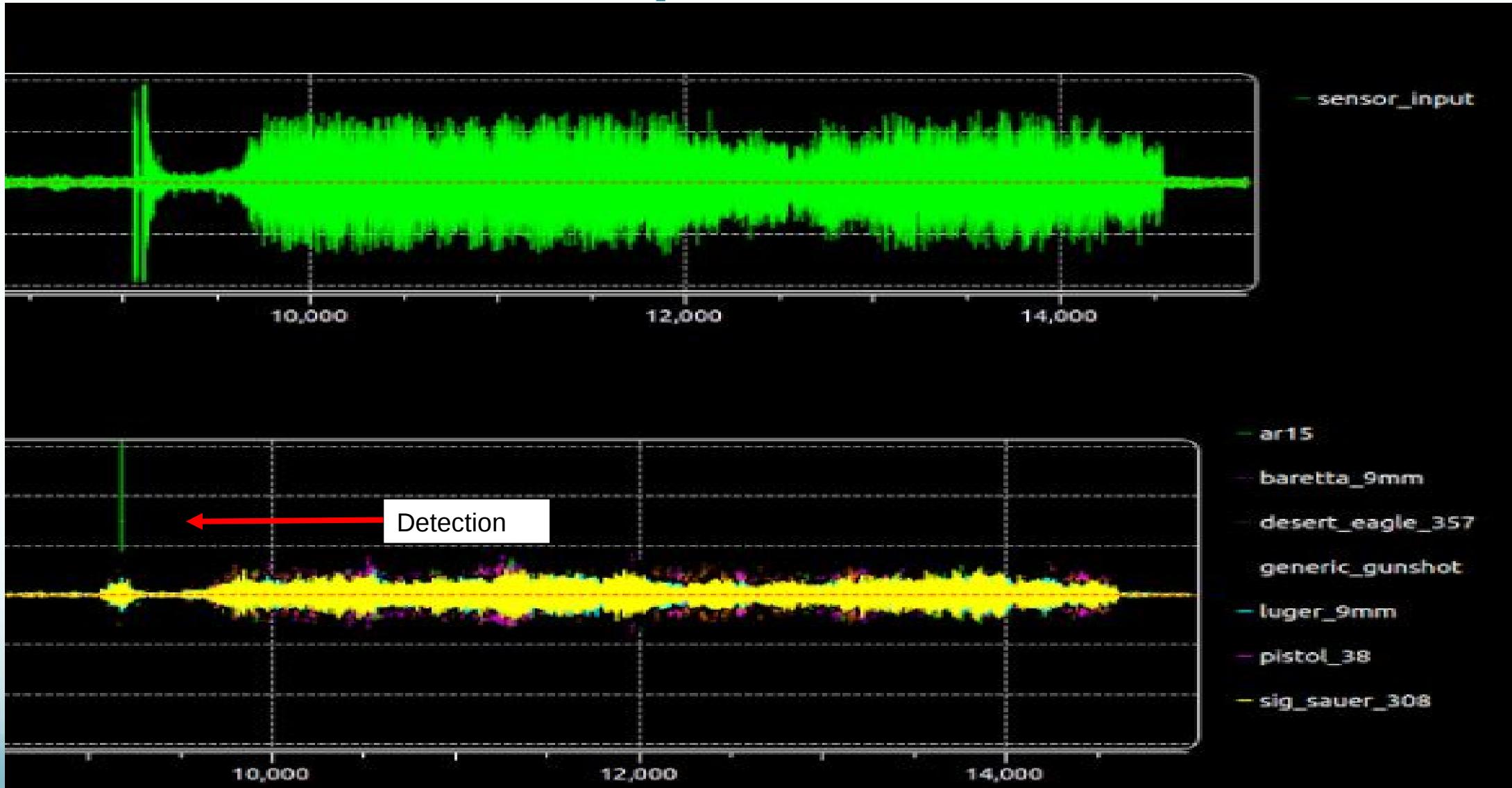
- IT'S "EASY"
 - Flowgraphs are easily manipulatable
 - Out-of-Tree Blocks meet custom needs
 - Visualizations give Quick Sanity Checks
- IT'S FREE
- IT'S "SUPPORTED"
 - Message boards
 - GNURadio Forum



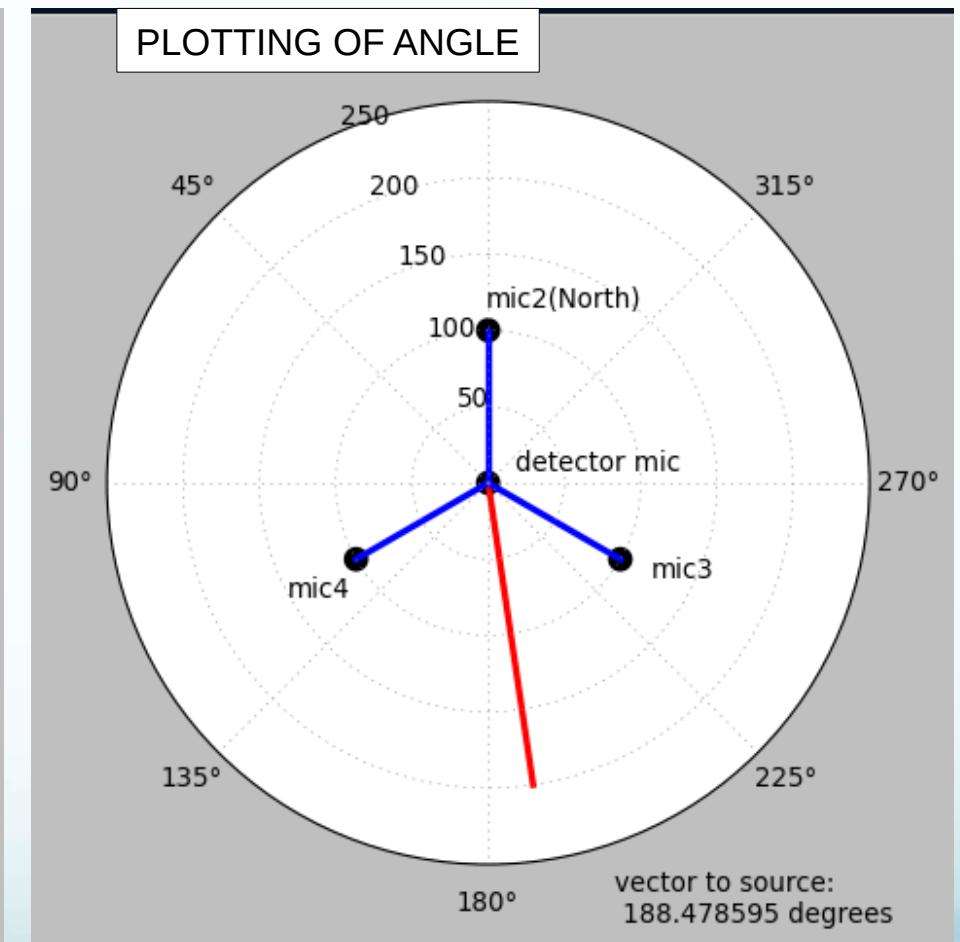
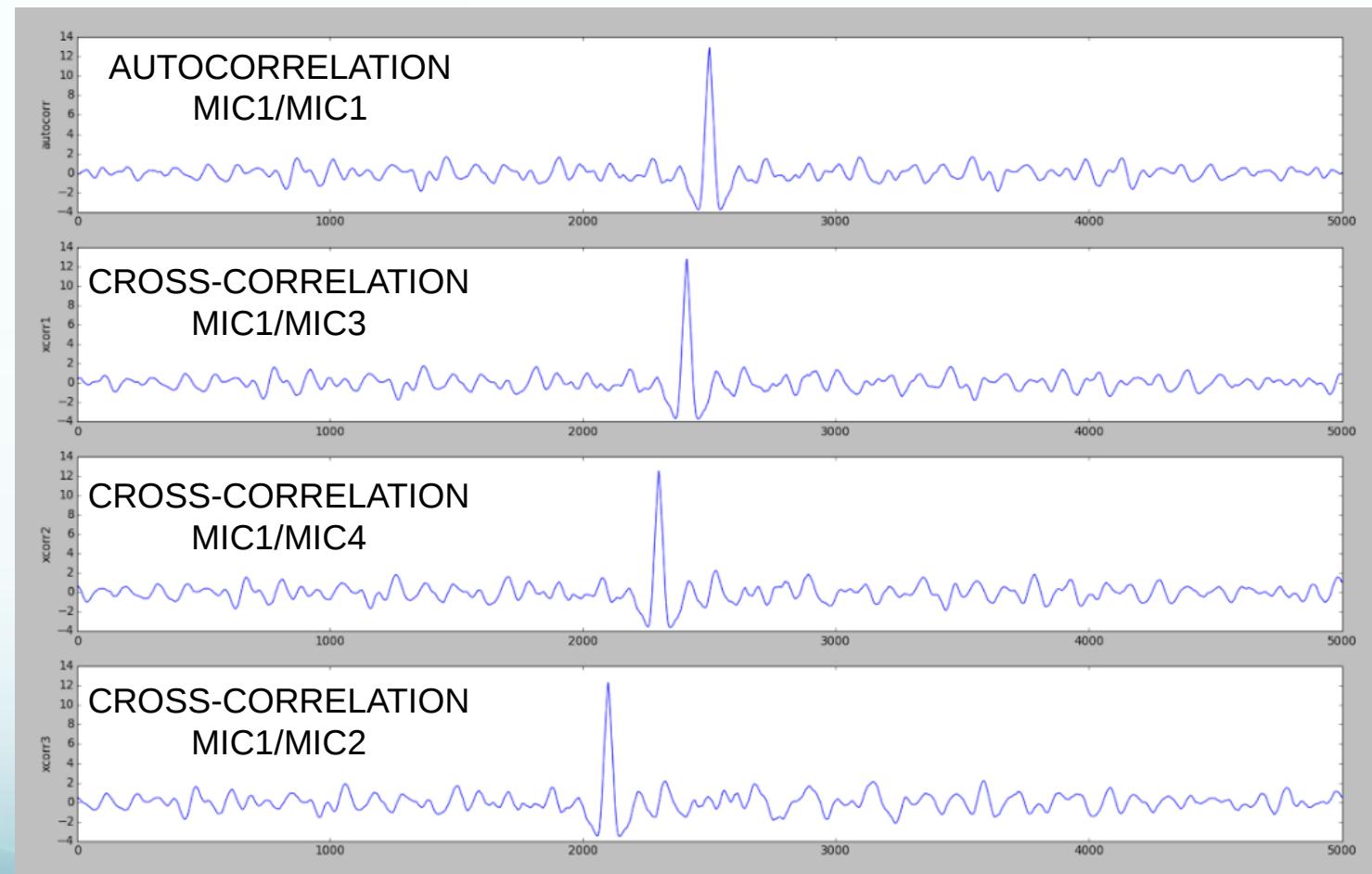
Benchtop Testing: single node implementation GNURadio Flowgraph



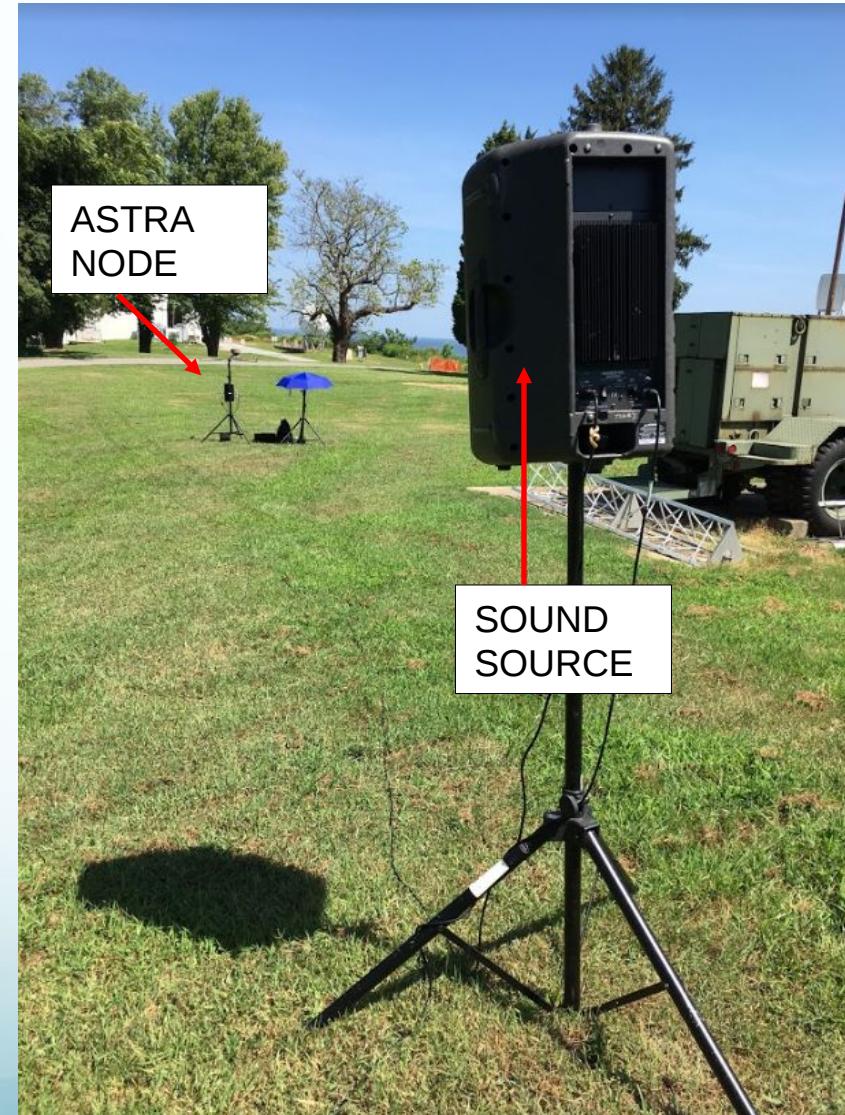
Matched Filter Outputs of Multiple Firearms



Benchtop Testing: single node Implementation plotting direction

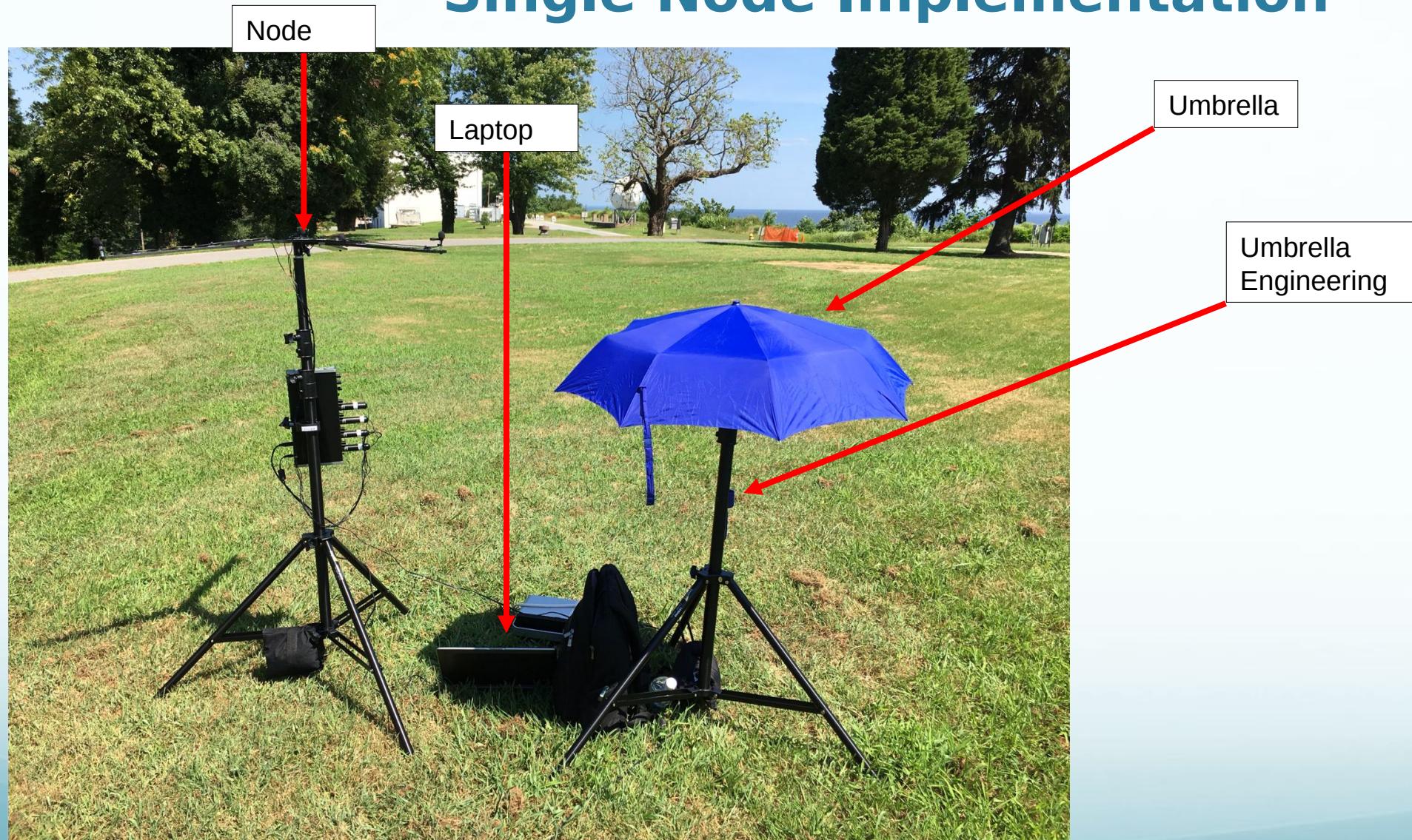


Speaker Testing: Single Node Implementation



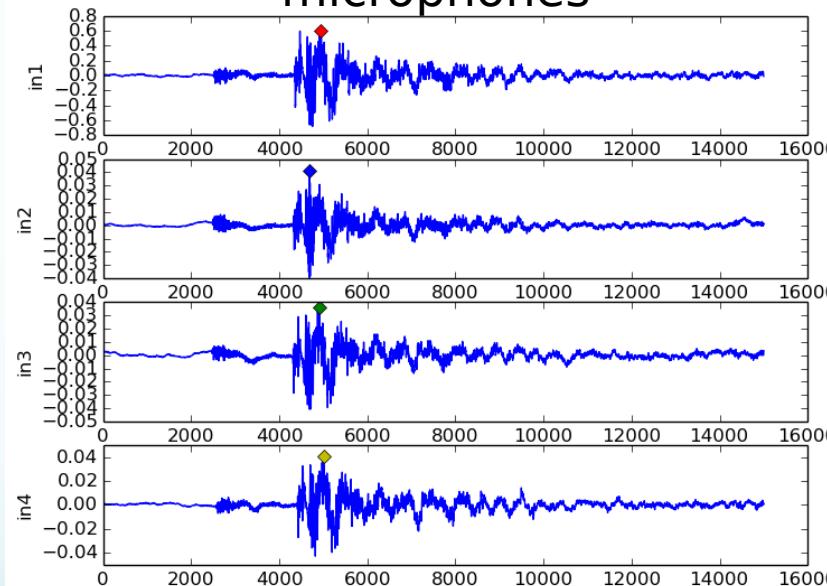
09/16/2017

Speaker Testing: Single Node Implementation

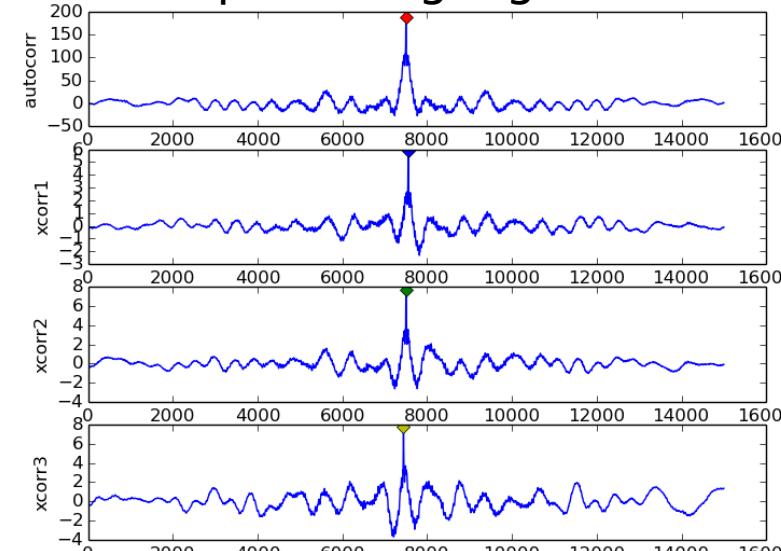


Speaker Testing: Single Node Implementation Results

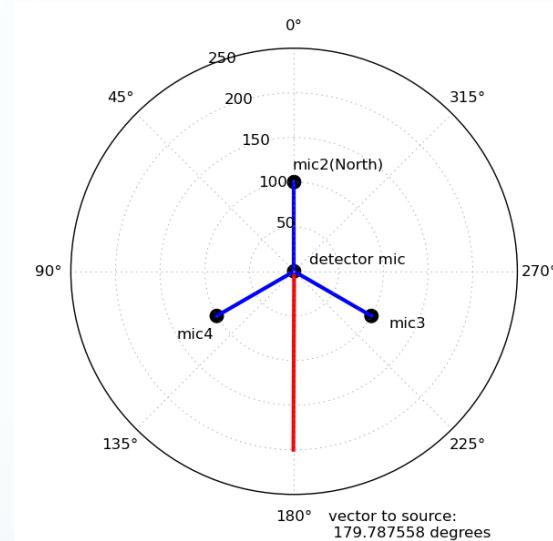
Raw audio streams from microphones



Cross-correlations with peaks highlighted



Accurately plotting location of sound source



Live Fire Single Node Testing and Matched Filter Data Collection



Live Fire Testing: Single Node Implementation

US ARMY INFANTRY SOLDIER FIRING VARIOUS FIREARMS DURING TEST



Live Fire Testing: Single Node Implementation

Sighting in Angles with
Lensatic Compass



Direction Finding Array
With shooter in background

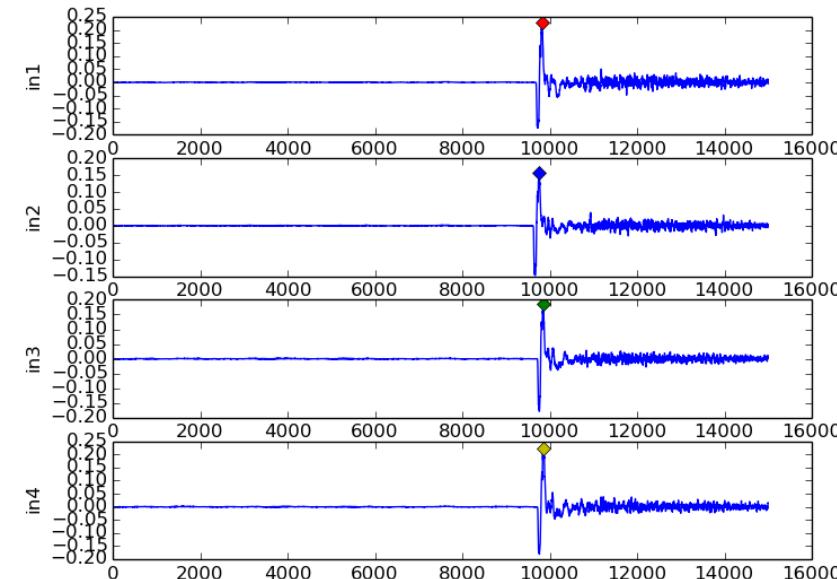


Collecting waveforms and
Observing system operation

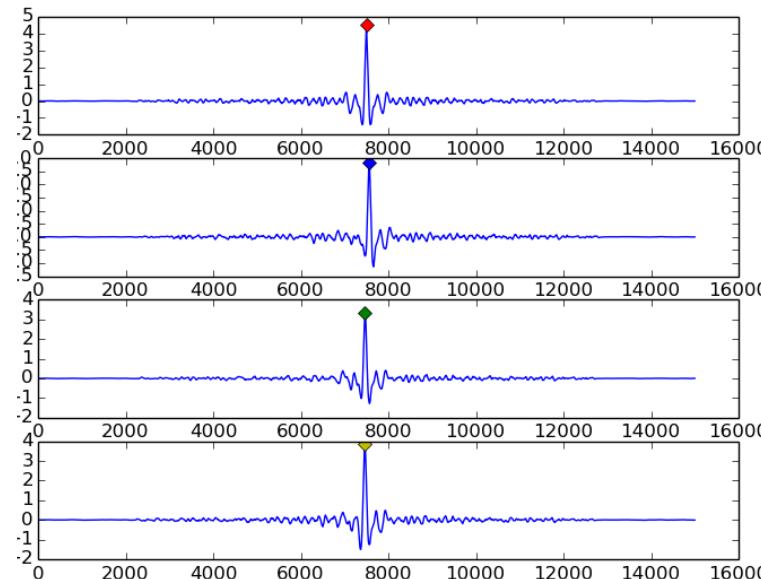


Live Fire Testing: Single Node Implementation

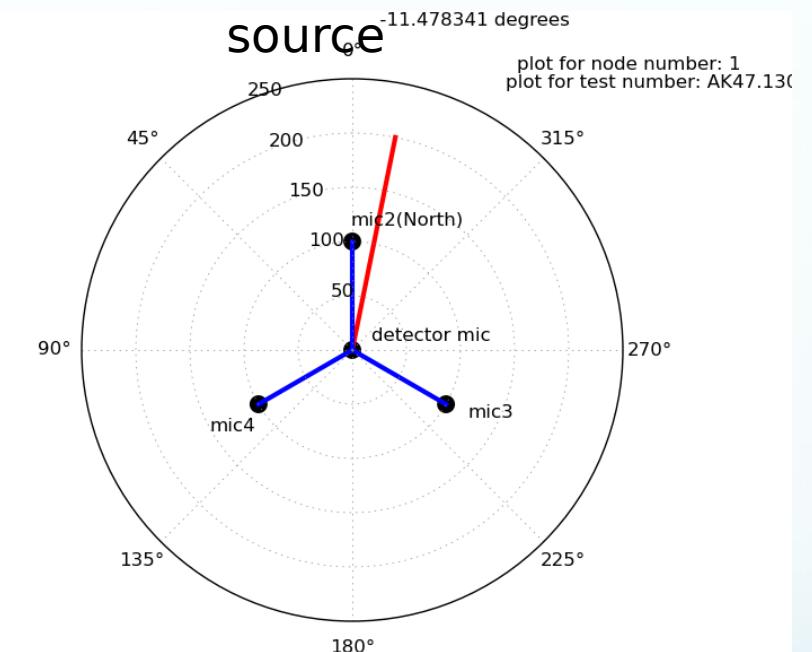
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Outdoor Shooting Range Test Layout



VIDEO

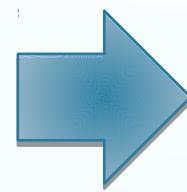
System Error Results

- Mean Angle Error (degrees)
- STDEV GPS Error (meters)
- Circular Error of Probability radius (meters)
- Combined Standard Deviation (meters)

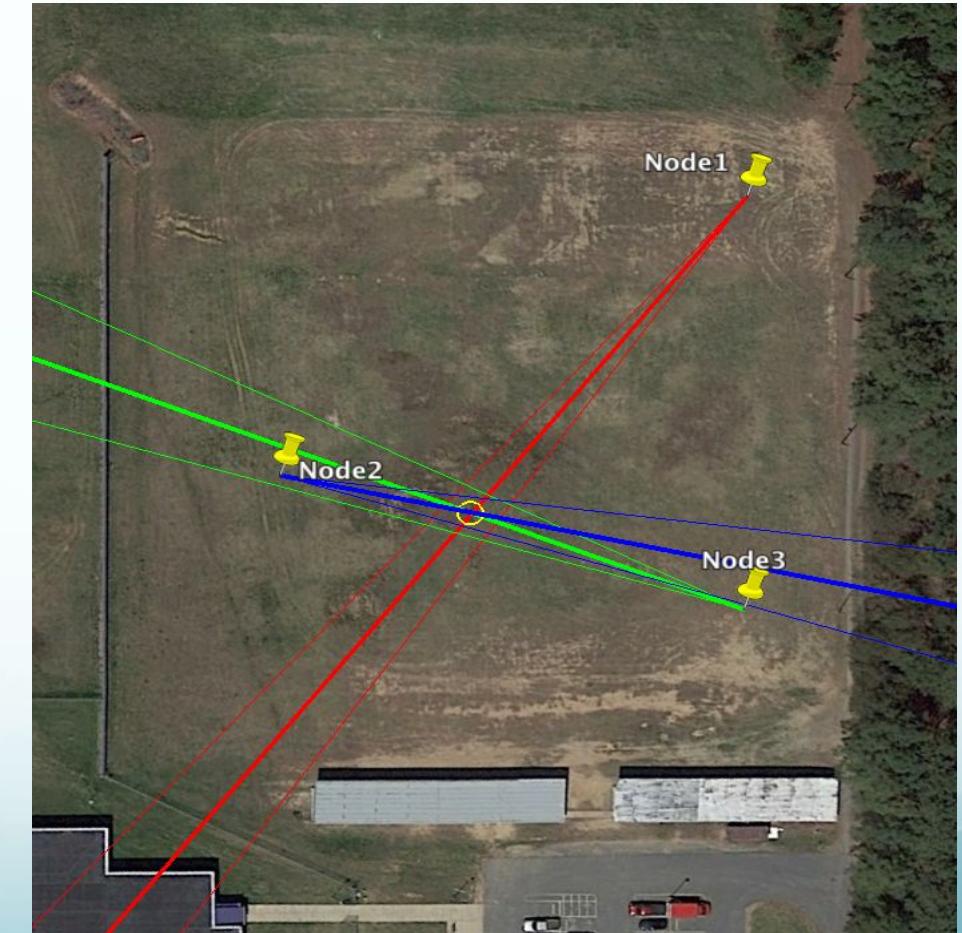
Node 1		Node 2		Node 3	
Node 1 Latitude	Node 1 Longitude	Node 2 Latitude	Node 2 Longitude	Node 3 Latitude	Node 3 Longitude
1.035	4.275	5.342			
CEP					
2.15					
CSD					
1.22					

CEP Shown in ASTRA User Terminal View

PRE-SHOT DISPLAY



POST-SHOT DISPLAY



Circular Error Probability (CEP) on ASTRA User Terminal

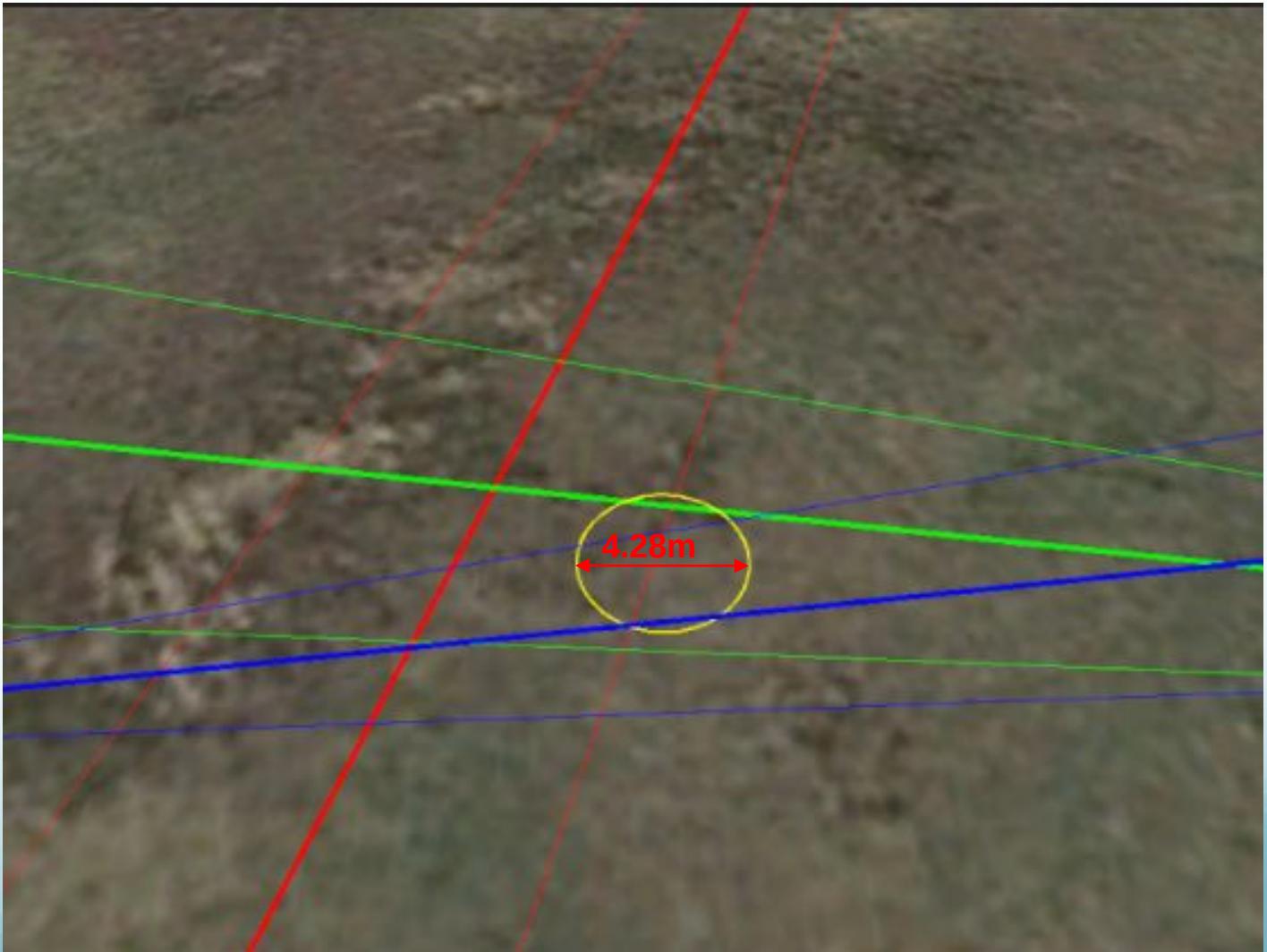
$$CEP = 0.62 \sigma_y + 0.56 \sigma_x$$

$$\sigma_y = 1.06 \text{ meters}$$

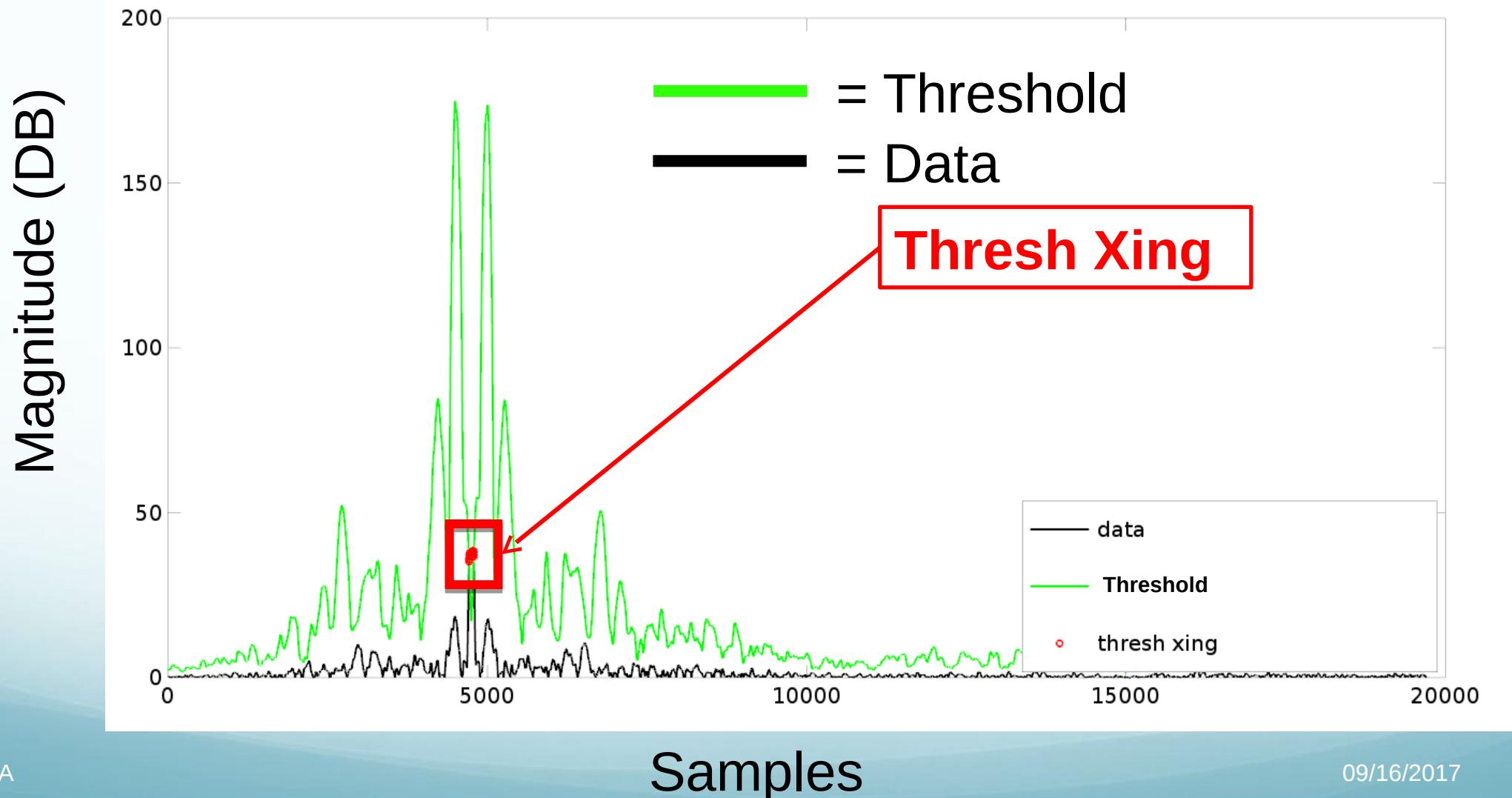
$$\sigma_x = 2.66 \text{ meters}$$

Novatel Study: APN-029 Rev 1, 3DEC2003

ASTRA



CA-CFAR Plot Using Recorded Gunshot Data



Team ASTRA

