An Acoustic / Radar System for Automated Detection, Localization, and Classification of Birds in the Vicinity of Airfields

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Outline

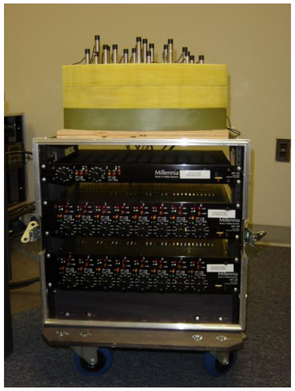
- Introduction
- Acoustic Sensor
- Acoustic Field Test Results
- Parabolic Dish Microphone Results
- Acoustic Classification Techniques

Introduction

- Hybrid Birdstrike Monitoring System:
  - Acoustic array
  - Radar
  - Parabolic dish microphone
- Data fusion
- Acoustic classification

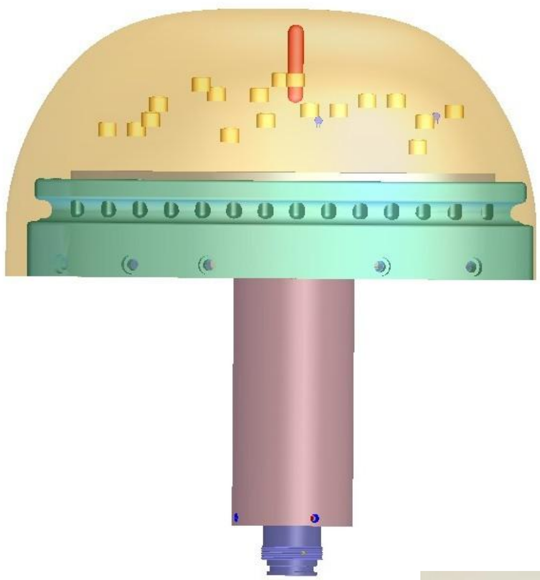
Introduction

- **Phase 2 STTR**
  - **Sponsor: Air Force Office of Scientific Research**
    Dr. Willard Larkin
  - **Team:**
    AAC – Project management, system integration, acoustic array, acoustic signal processing and classification
    DeTect, Inc. – Bird Detection Radar, signal processing, radar data analysis, PCBCIA field test, bird strike experts
    MSU – University partner, parabolic dish microphone, acoustic classification, atmospheric compensation model



Acoustic Sensor

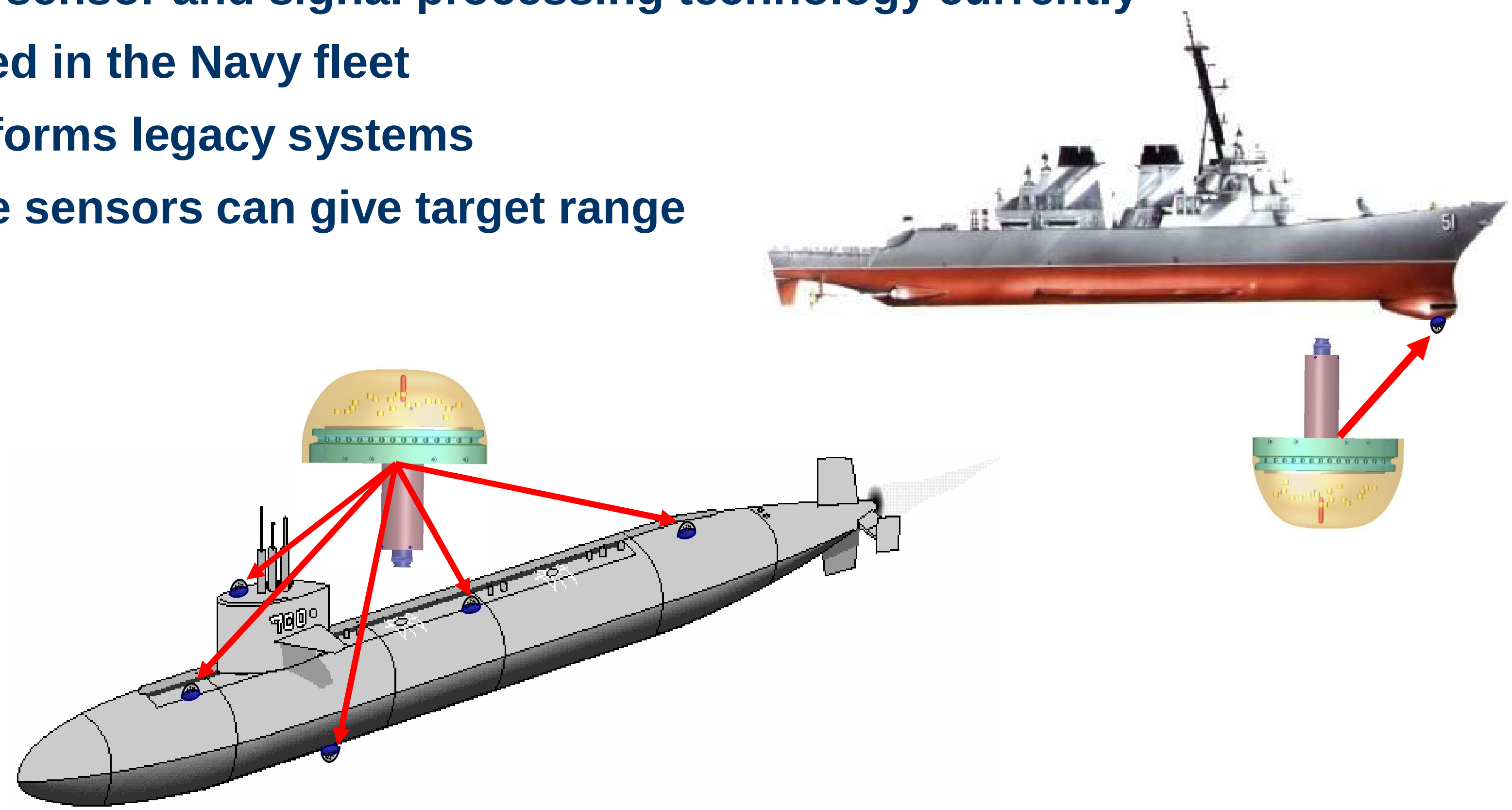
Sparsely Populated Volumetric Array (SPVA)



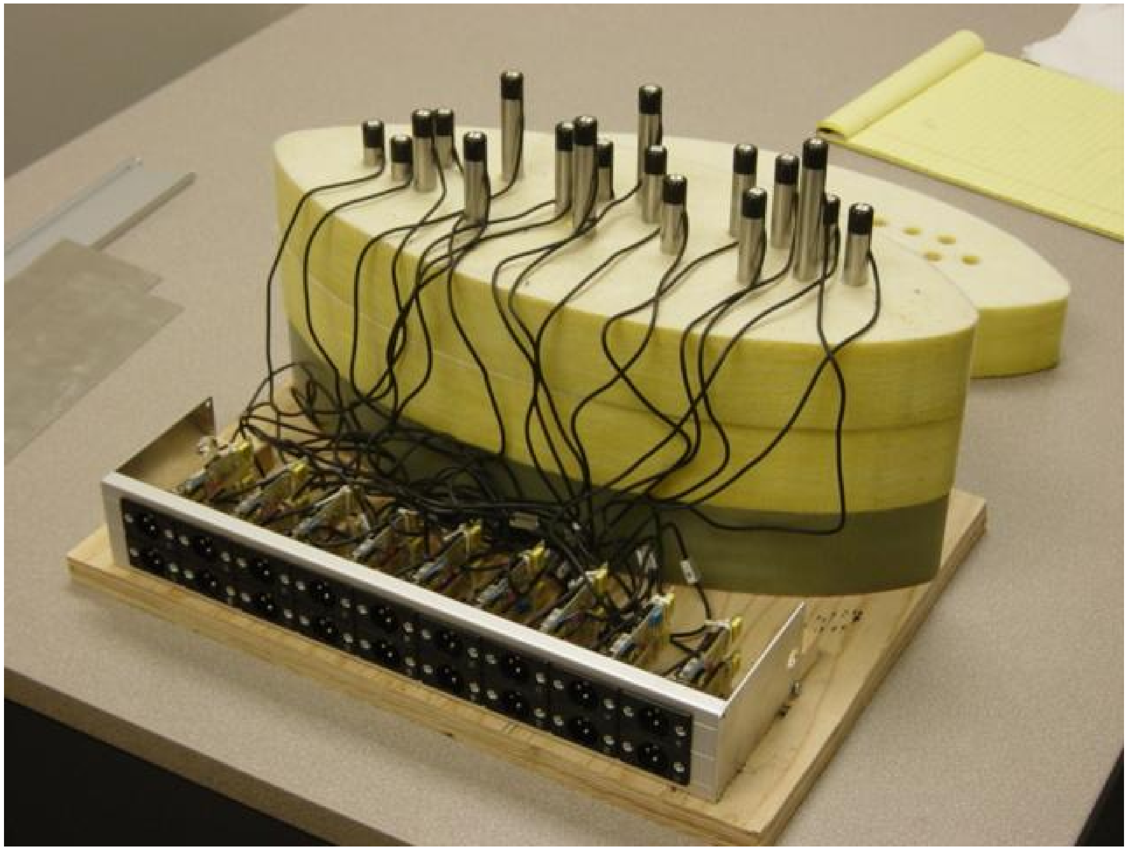
- 18 hydrophones embedded in polyurethane
- Provides 12.5 dB gain
- Covers very large frequency range
- 4π steradian coverage
- Real-time angle of arrival without beamforming
- Fractional degree angle accuracy
- Fiber optic telemetry

SPVA

- **Proven sensor and signal processing technology currently deployed in the Navy fleet**
- **Outperforms legacy systems**
- **Multiple sensors can give target range**



Air Acoustic Array



- **18 microphones mounted on rods**
- **Covers 0.2-20 kHz frequency range**
- **Sound absorber to mitigate reflections**

ADVANCED
ACOUSTIC
CONCEPTS

Complete Acoustic Sensor System

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
UNITED STATES AIR FORCE

Air SPVA sensor
and pre-amplifiers

Digital recorder for offline signal processing (production system will do real-time signal processing)

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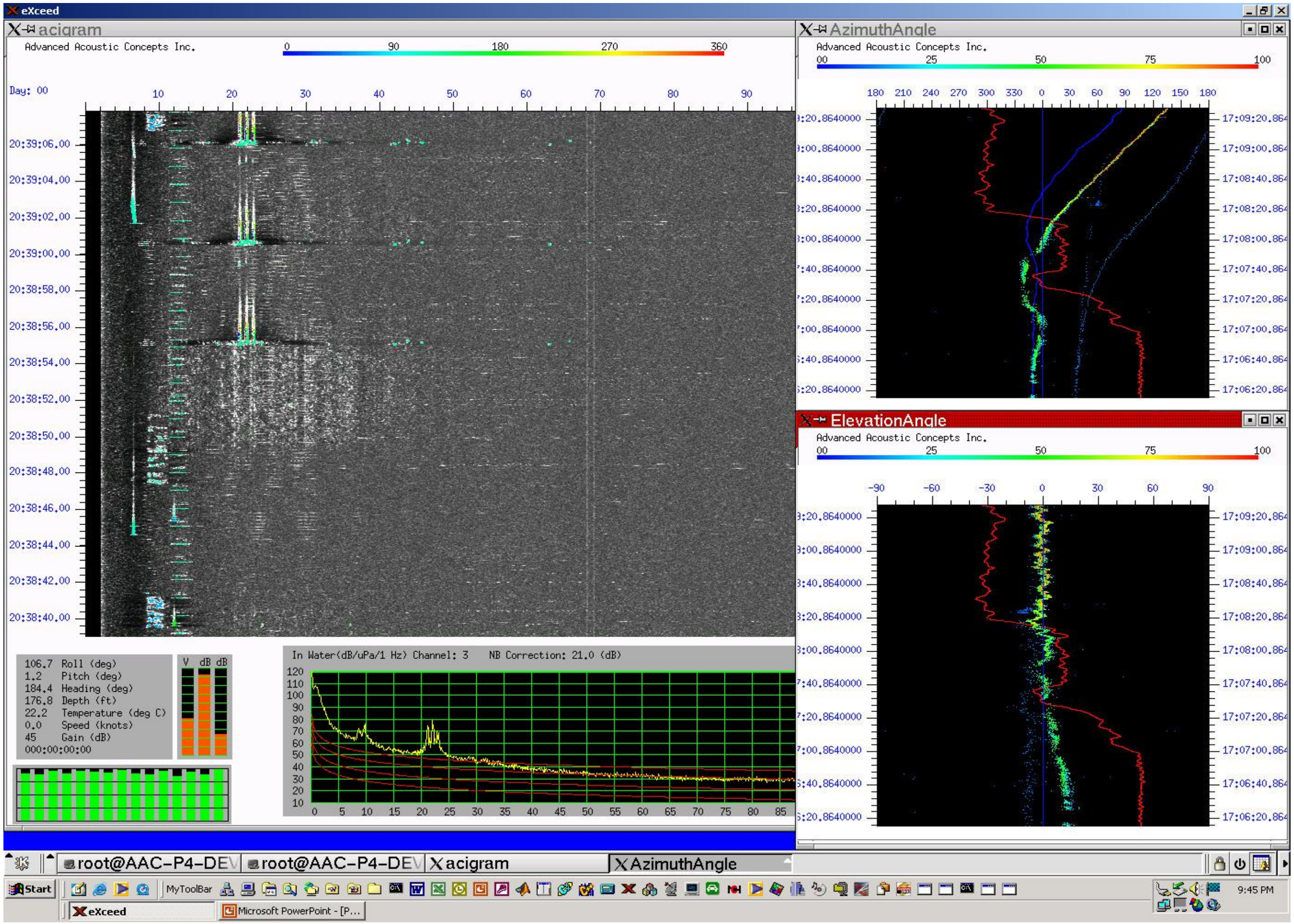
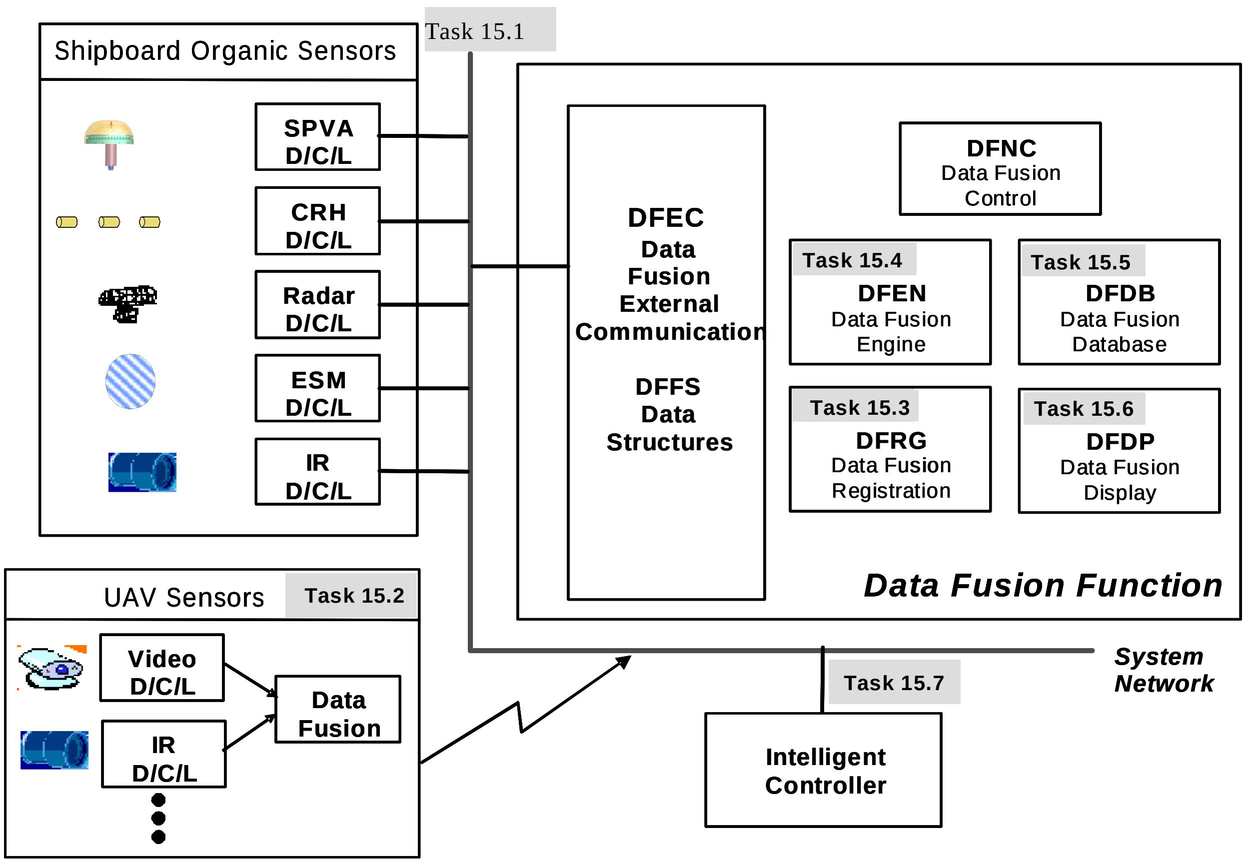
SPVA Real-Time Displays



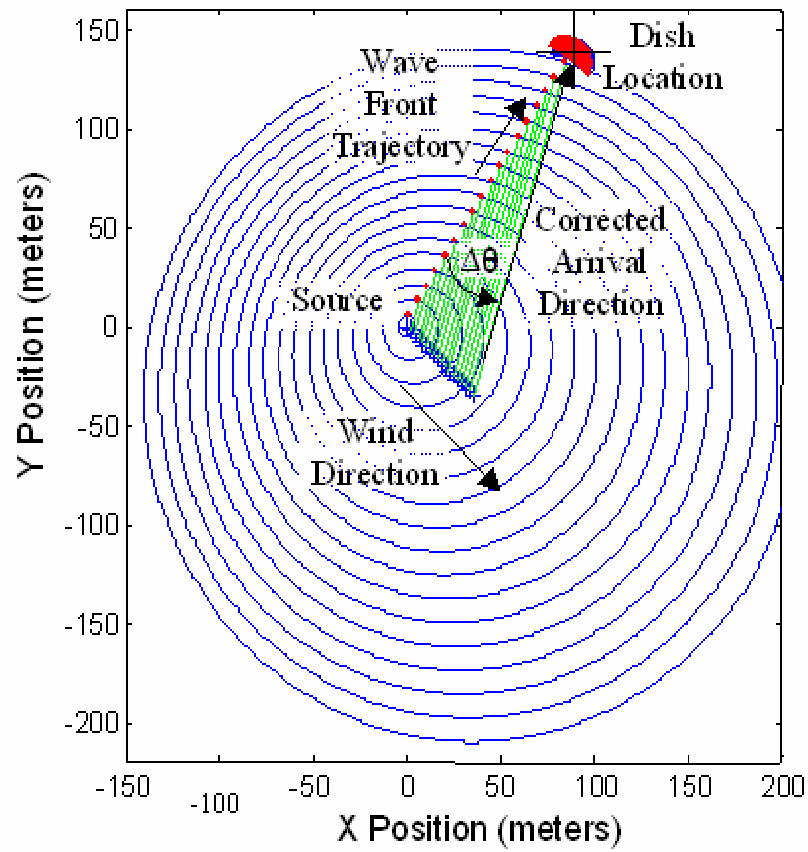
Data Fusion



Shipboard Organic Sensors
Task 15.1
SPVA D/C/L
CRH D/C/L
Radar D/C/L
ESM D/C/L
IR D/C/L
DFEC Data Fusion External Communication
DFFS Data Structures
DFNC Data Fusion Control
Task 15.4
DFEN Data Fusion Engine
Task 15.5
DFDB Data Fusion Database
Task 15.3
DFRG Data Fusion Registration
Task 15.6
DFDP Data Fusion Display
Data Fusion Function
UAV Sensors
Task 15.2
Video D/C/L
IR D/C/L
Data Fusion
System Network
Task 15.7
Intelligent Controller

Atmospheric Compensation

- **Wind speed**
- **Temperature**
- **Humidity**

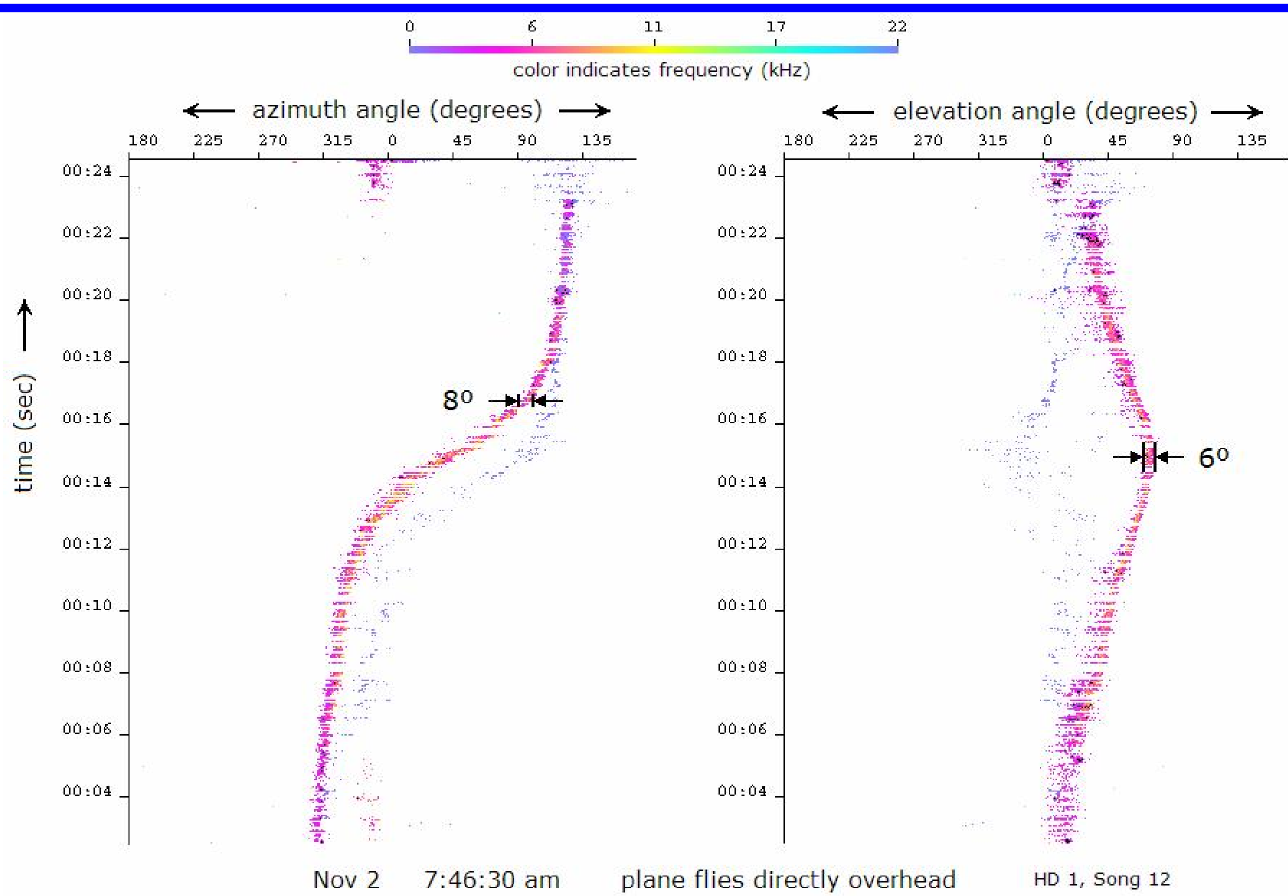


Field Test: PCBCIA

- Located in proximity to airport runway, trees, and water
- Test at beginning of Nov. to catch Fall migration

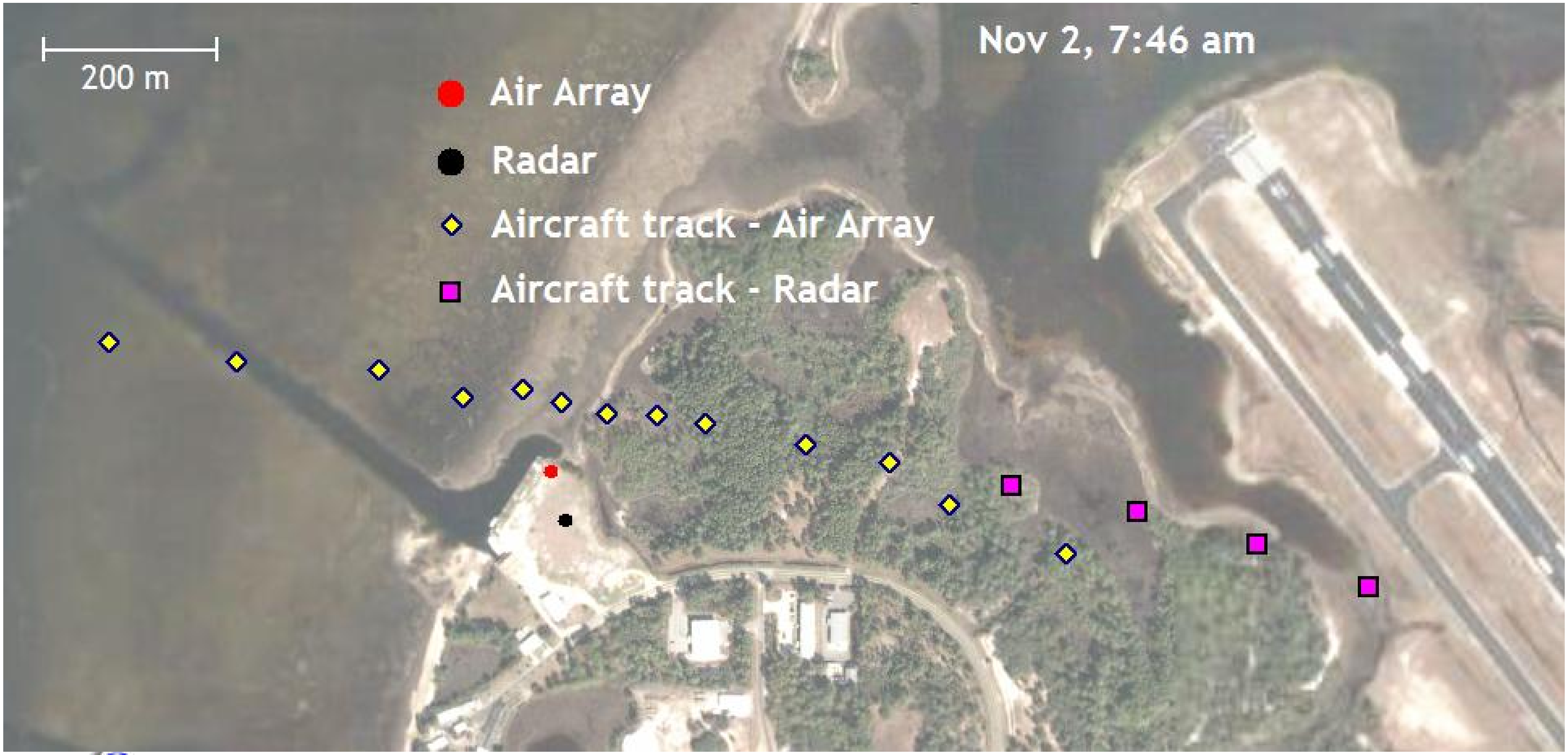
Field Test: PCBCIA

Aircraft Detection & Tracking



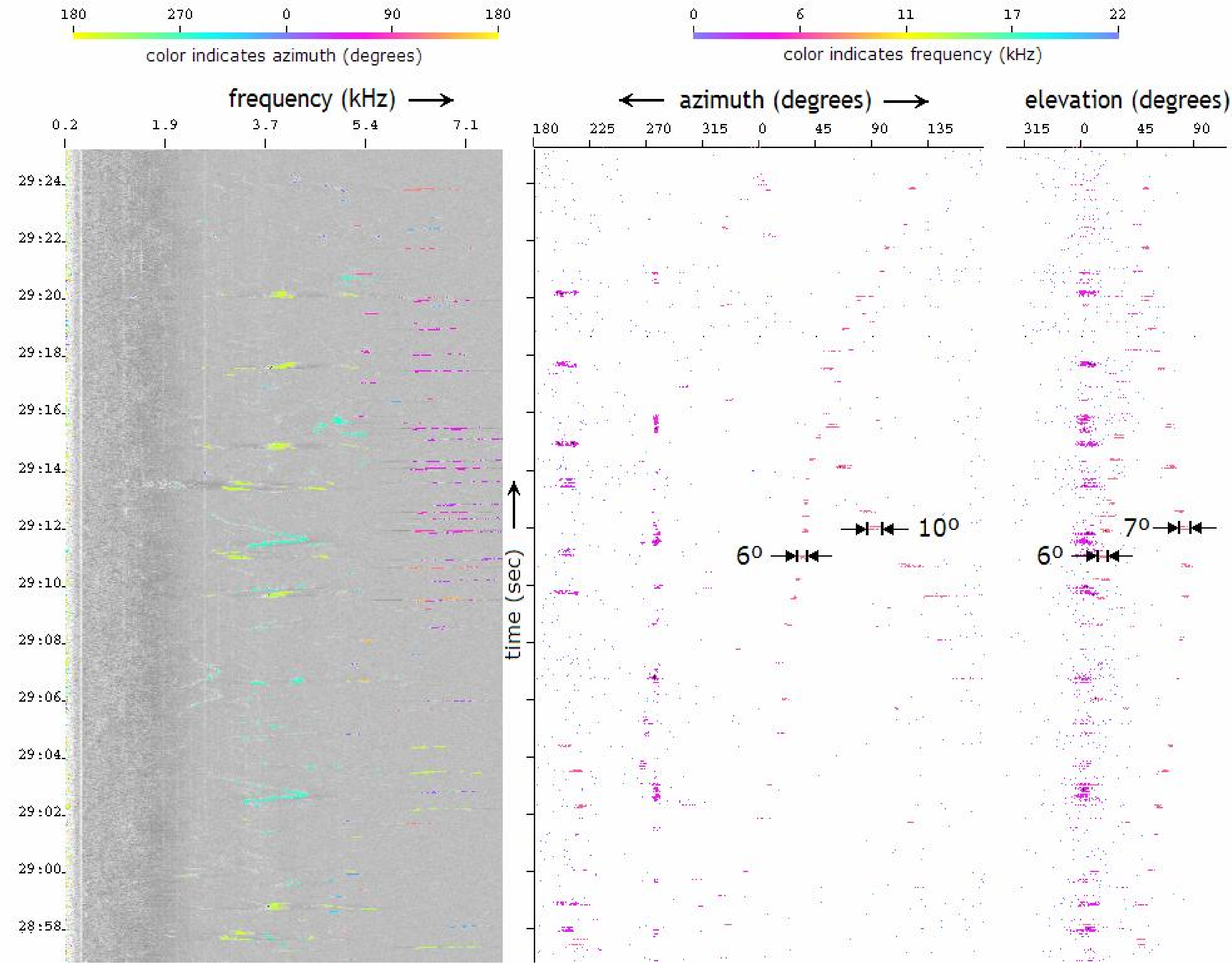
- **Track of small aircraft passing nearly directly overhead proves system capability**
- **Angle accuracy is < 10 deg**

Aircraft Detection & Tracking: Radar Confirmation



Morning Flight Calls

- In a typical 30 minute time interval, at least 30 episodes of flight calls were detected.
- Calls from a single bird were frequent, every 1 to 3 seconds.
- Each episode consisted of many calls, typically 4 to 30.
- Presumed local, not migratory flight
- Calls were mostly at higher frequencies, indicating small, low-threat birds.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0 6 11 17 22
color indicates frequency (kHz)
frequency (kHz)
0.2 1.9 3.7 5.4 7.1
azimuth (degrees)
180 225 270 315 0 45 90 135
elevation (degrees)
315 0 45 90
29:24
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29:18
29:16
29:14
29:12
29:10
29:08
29:06
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29:02
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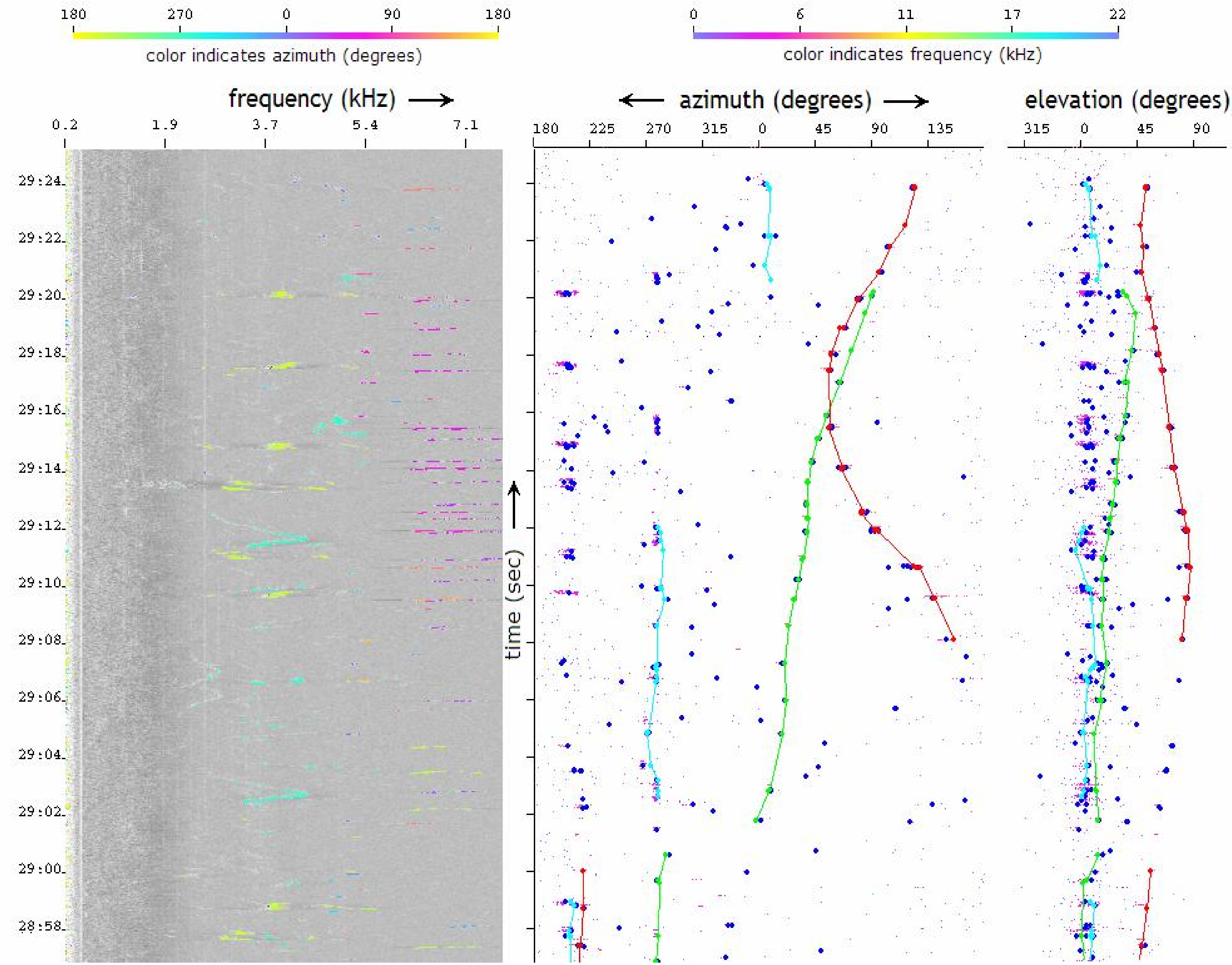
28:58
time (sec)
6°
10°
6°
7°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29:14
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29:10
29:08
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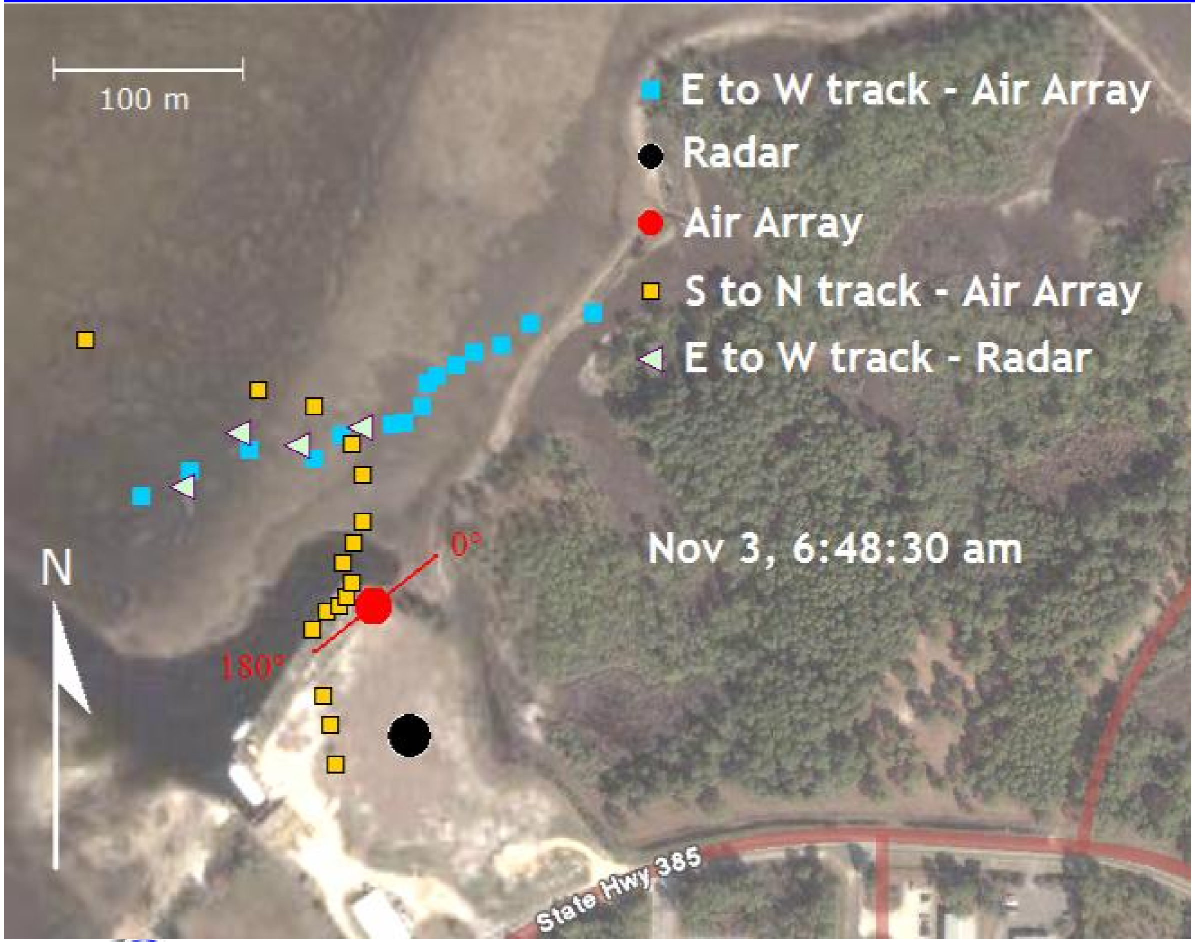
29:04
29:02
29:00
28:58

Morning Flight Calls

- Test setup has a single SPVA, so range is not known.
- (Relative) ranges are estimated from amplitudes of calls.
- There is one free parameter, to be fixed from radar data.

Morning Flight Calls: Radar Confirmation



- **Radar confirmation shows acoustic detections ranged up to 600 ft**

ADVANCED ACOUSTIC CONCEPTS

Evening Flight Calls

- Ø During a typical 6-minute interval, 5 episodes of flight calls were detected.
- Ø Interval between calls in one episode is typically 5 to 10 seconds.
- Ø Each episode has very few calls, typically 1 to 4.
- Ø Presumed **migratory** flight
- Ø Calls were mostly at higher frequencies, indicating small, low-threat birds.

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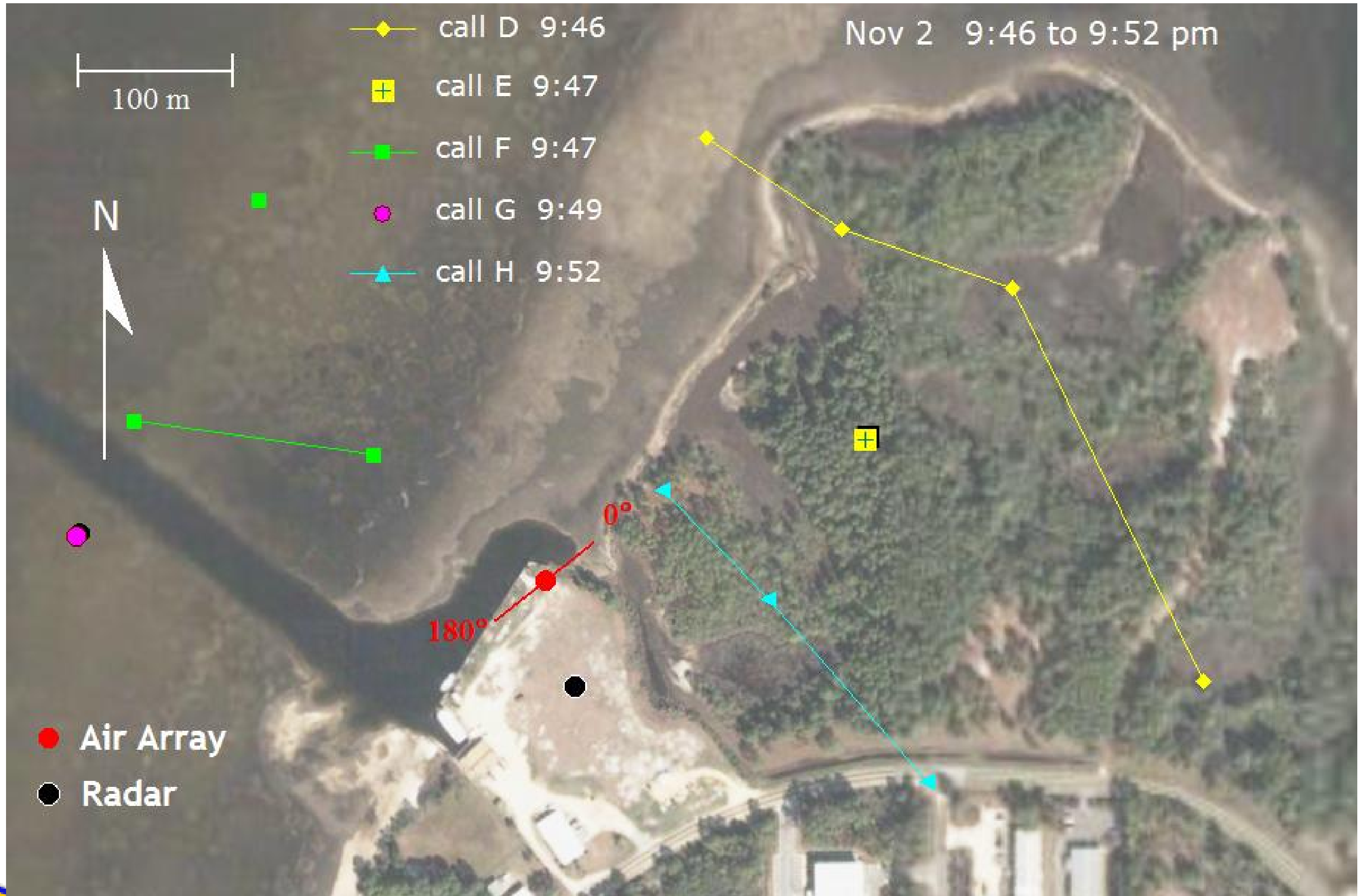
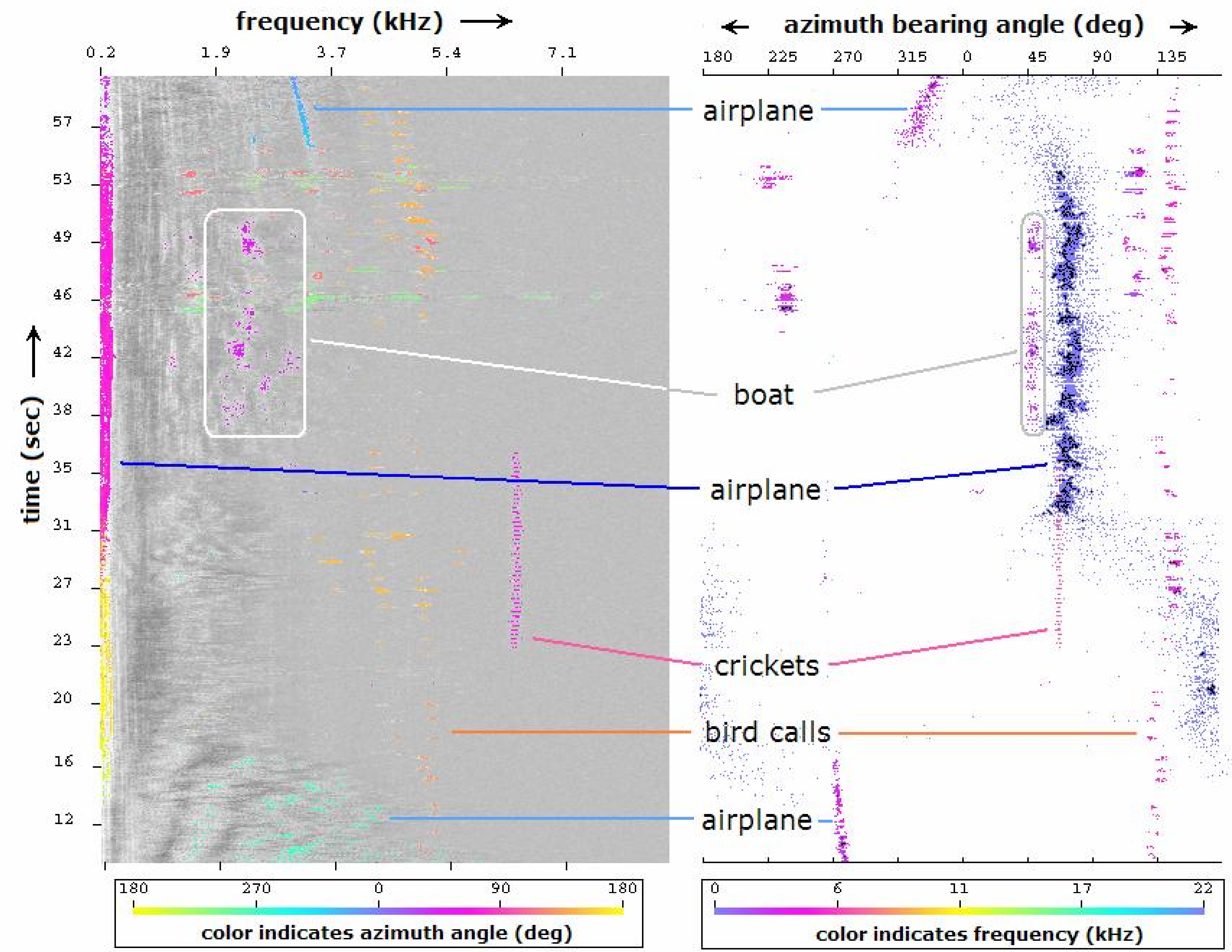
Evening Flight Calls



Acoustic detections ranged up to 1500 feet

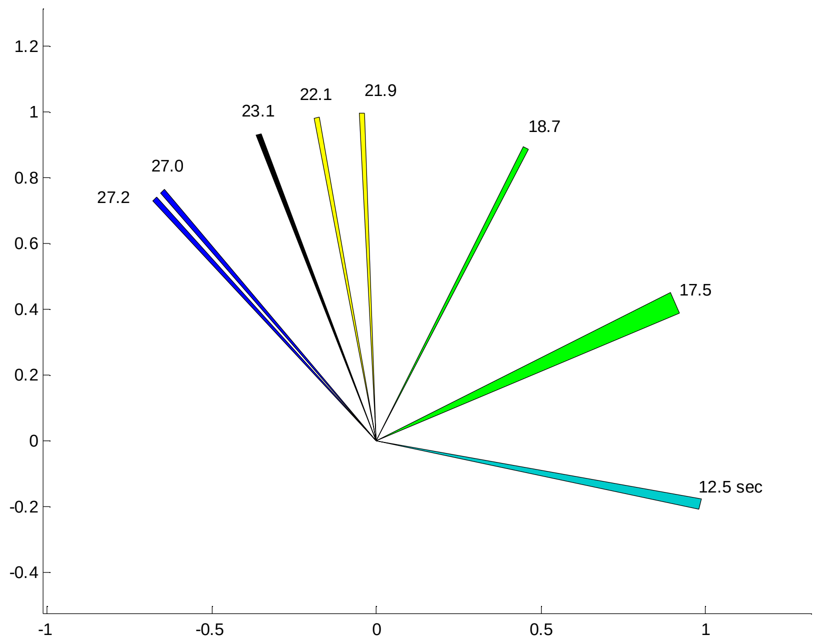
System can detect and track multiple targets simultaneously

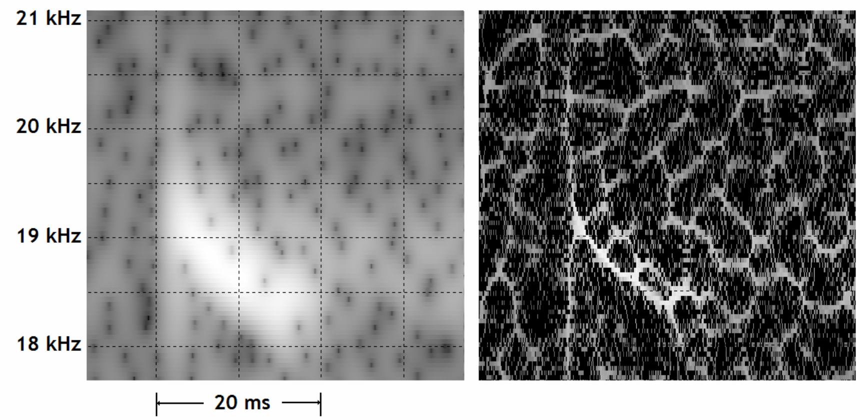


ADVANCED ACOUSTIC CONCEPTS

Bat Detection

Azimuth bearings with detection times, indicating an erratic flight path





conventional spectrogram

complex reassigned spectrogram

- **Results of a bat detection event consisting of 8 calls**
- **Calls are at the upper end of the detection band**

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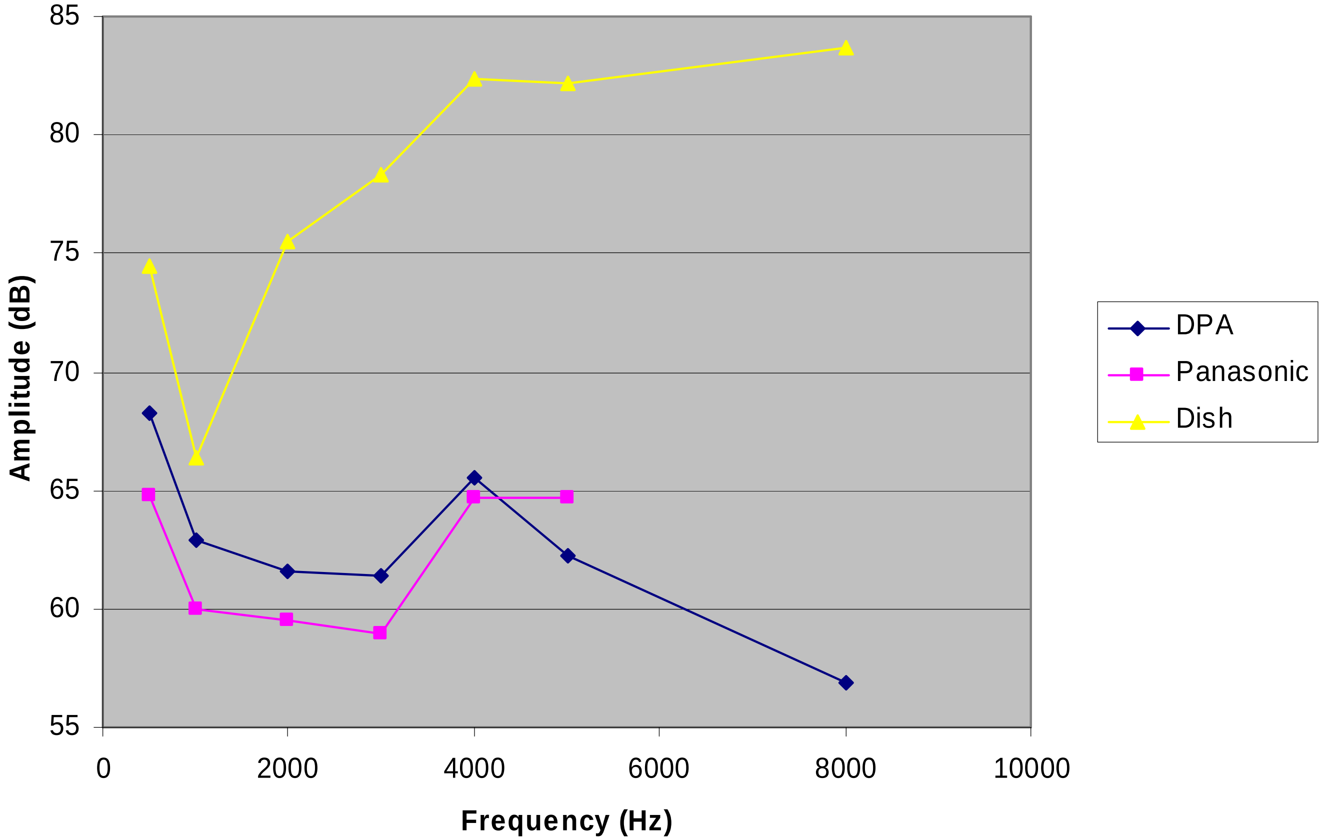
Parabolic Dish Microphone

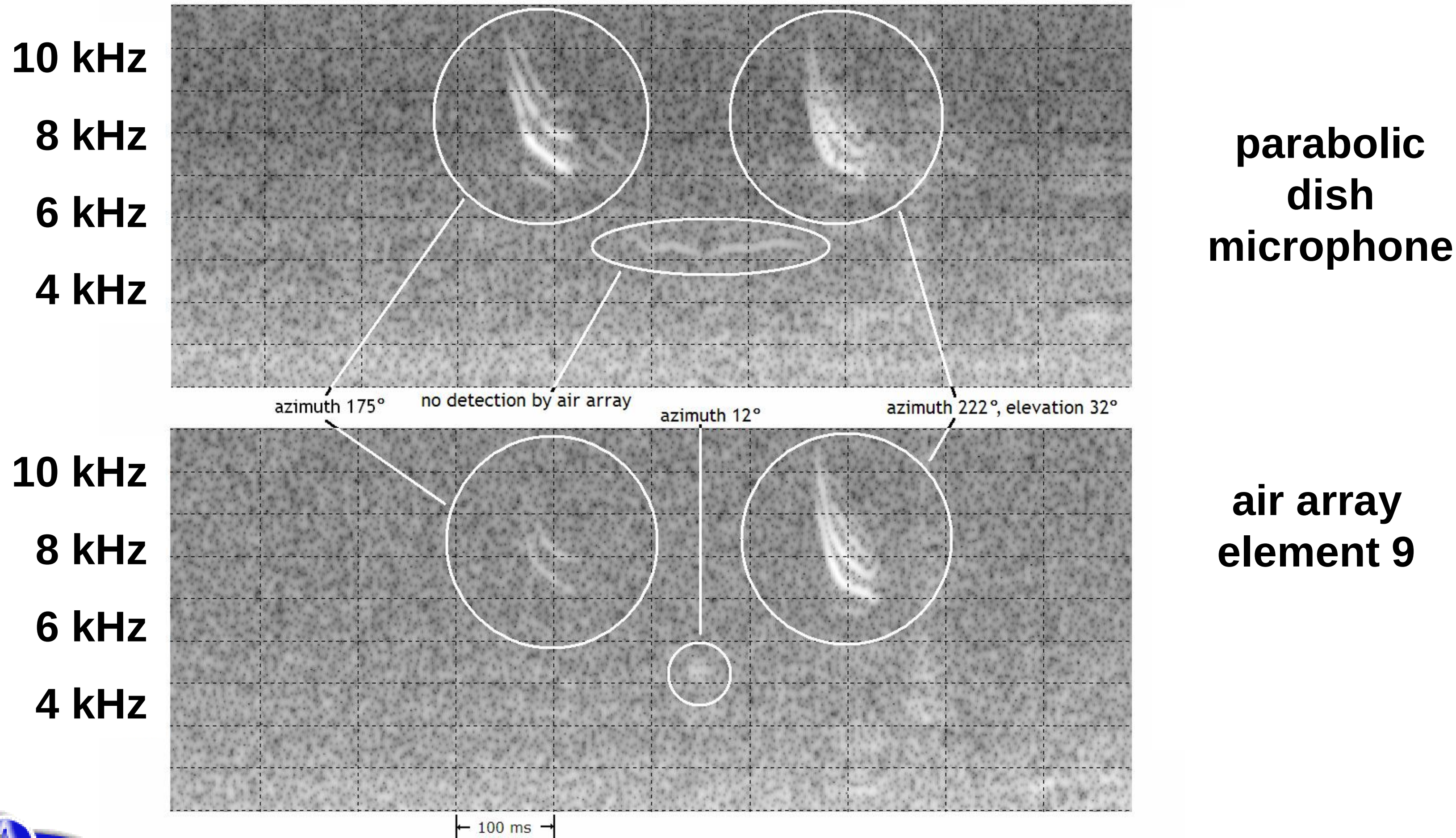
- Classification requires high S/N data
- Lots of competing background noise at airfield
- Need directional, high-gain microphone
- Large electronically steered arrays expensive
- Solution:
  - Commercially available dish microphone
  - Mounted on two-axis servo
  - Mechanically steered by:
    - radar track data
    - acoustic bearing data
  - Provides signal isolation and gain

Parabolic Dish Performance



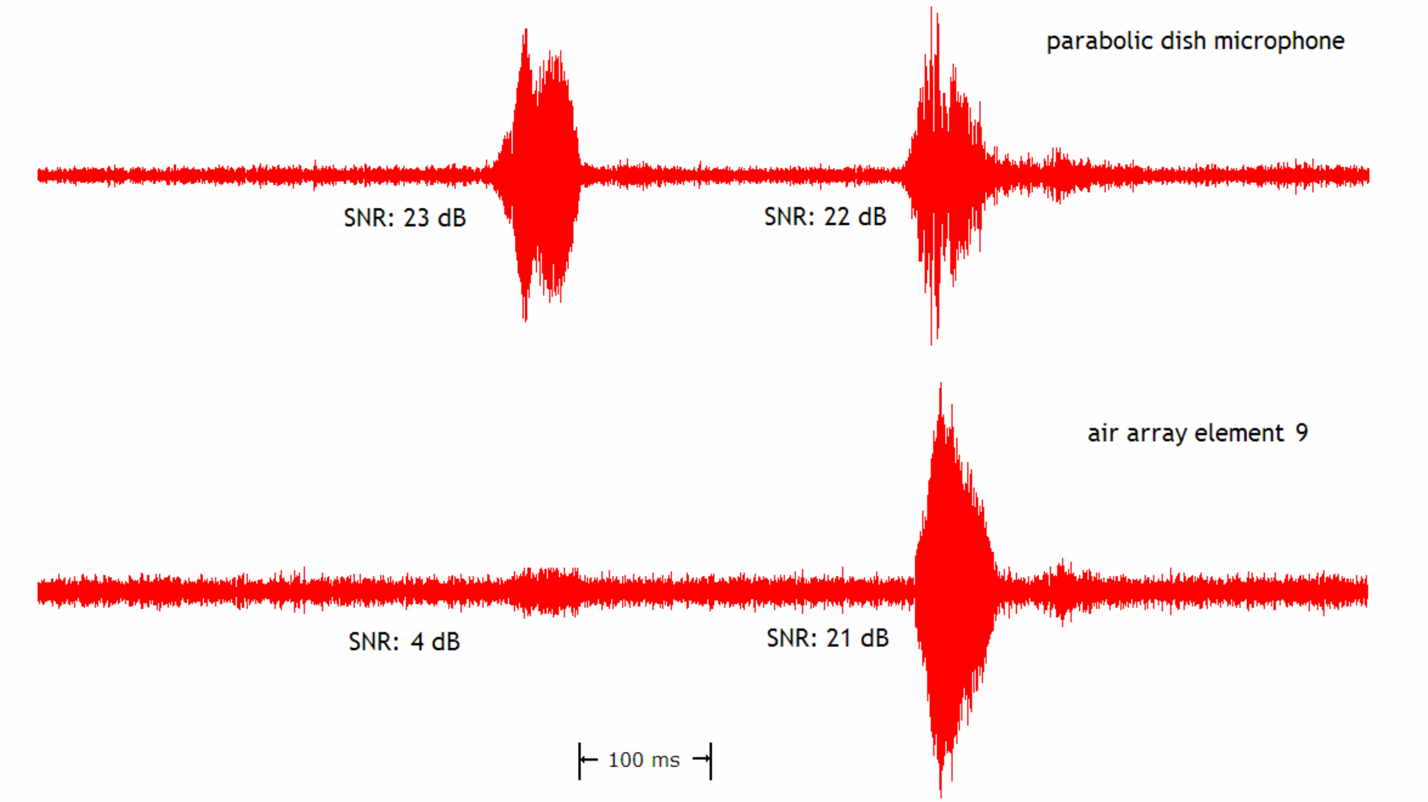
- **Plot shows parabolic dish performance improvement over simple microphones**
- **As much as 25 dB gain in laboratory tests**

Parabolic Dish Performance



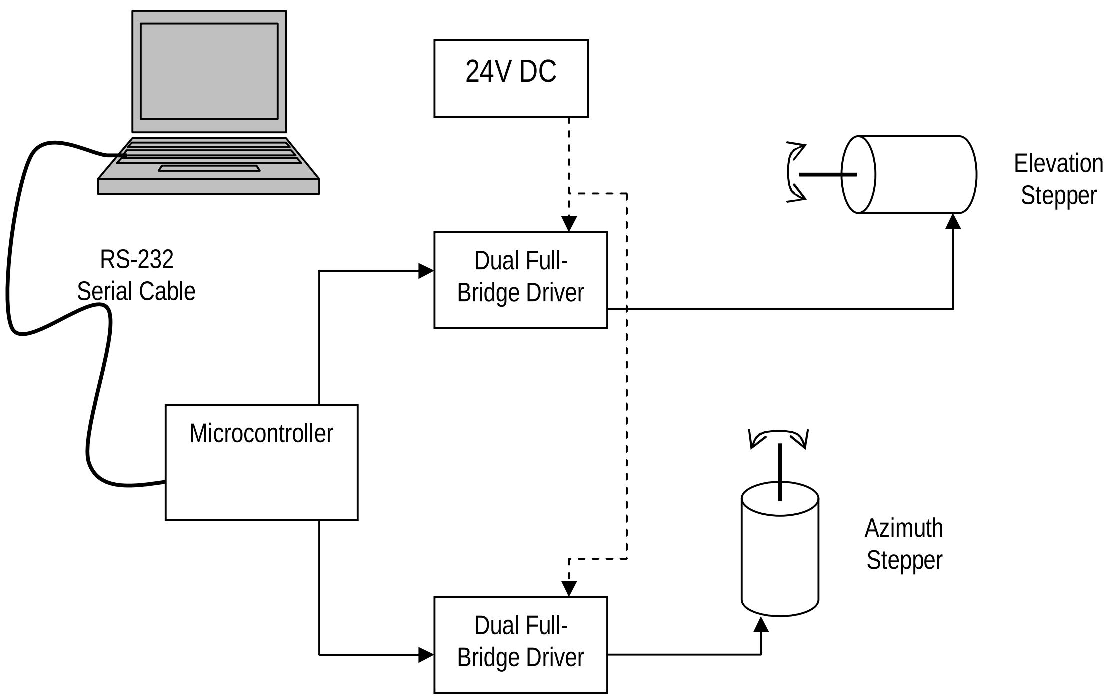
Two sparrow calls: the first is heard faintly by the air array, strongly with the dish.

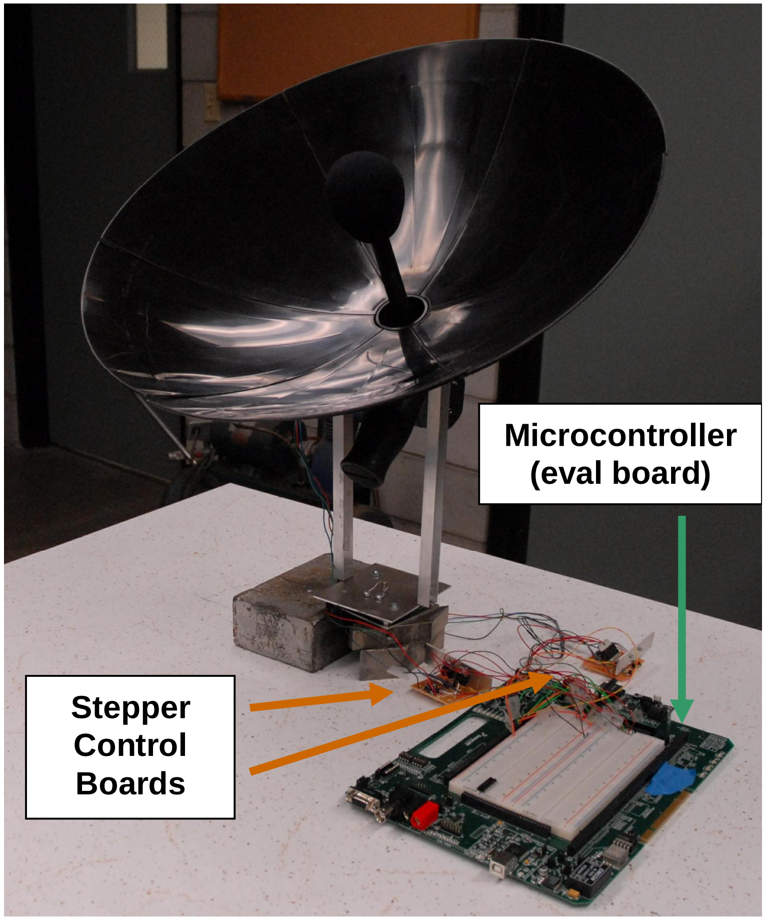
Parabolic Dish Performance



Parabolic dish provides 19 dB gain for bird calls

Parabolic Dish Steering





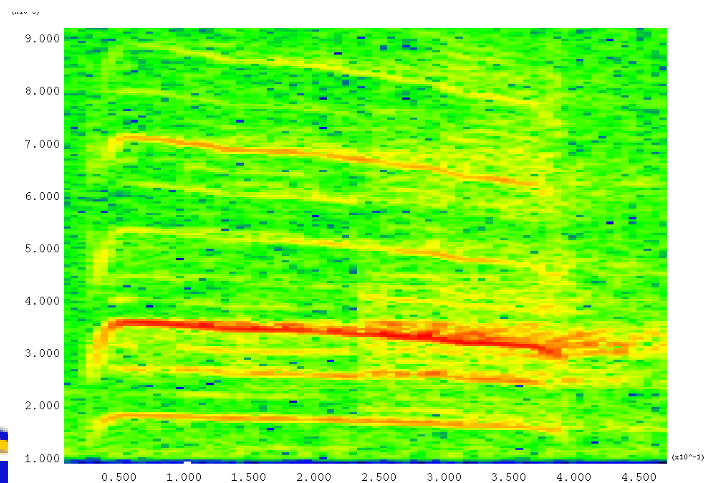
Microcontroller circuit directs the dish to bearings from air array signal processing

Classification Software

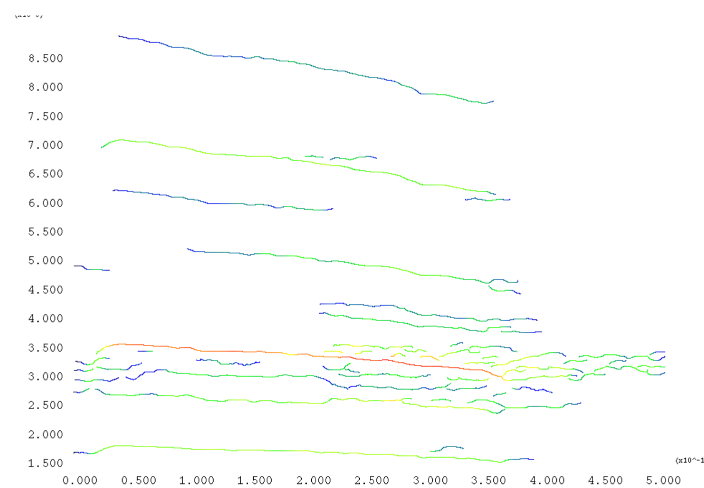
- **Frequency Track Analysis**
  - AAC
  - MSU
- **Cortical Processing Theory**
  - AAC & UMD
- **Composite Classifier**
  - MSU

Frequency Track Analysis

- Compute spectrogram and smooth
- Find local maxima at each time and connect (peak tracks)
- Remove short and weak tracks
- Compute features (min, max, and mean frequency, length, slope, …)
- Compare features statistically with training set



Spectrogram

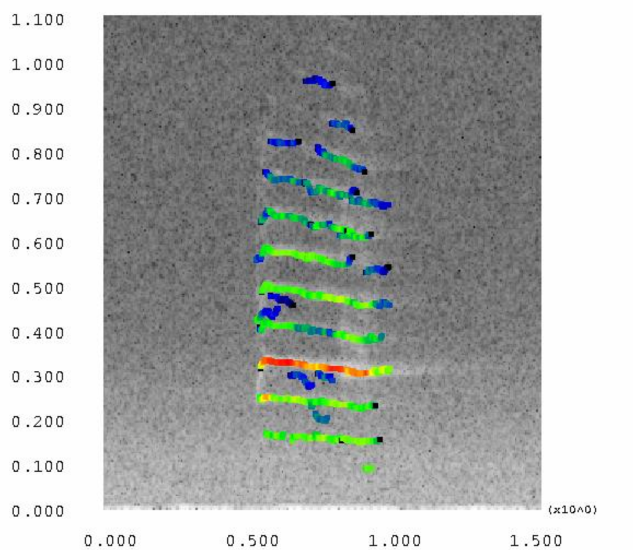


Frequency Tracks

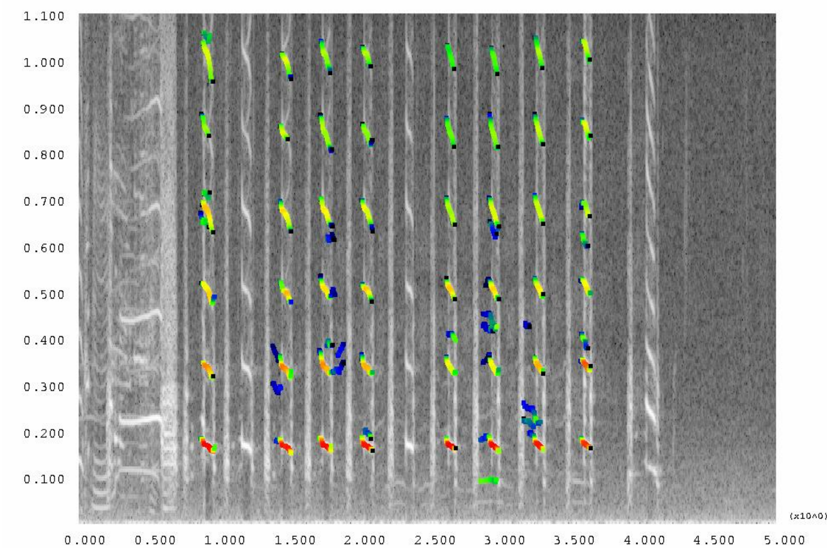
Blue Jay Call

Frequency track classifier results

Blue jay matching tracks



Herring gull syllable recognition



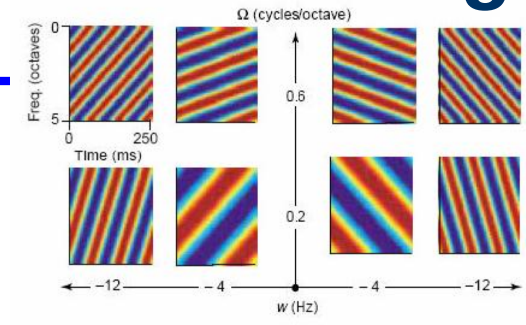
- **MSU: 12 species and 16 synthesized sounds, 99% success with 12 db SNR added noise**
- **AAC: 4 species trained, 10 species tested with 0 false positives (except blue jay)**

ADVANCED ACOUSTIC CONCEPTS

Cortical Processing Theory

UNIVERSITY OF MARYLAND

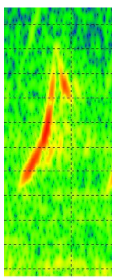
Center for Auditory and Acoustic Research



Prof. S. Shamma

wren

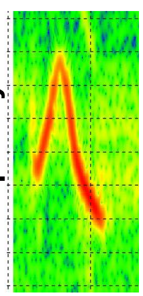
frequency



time

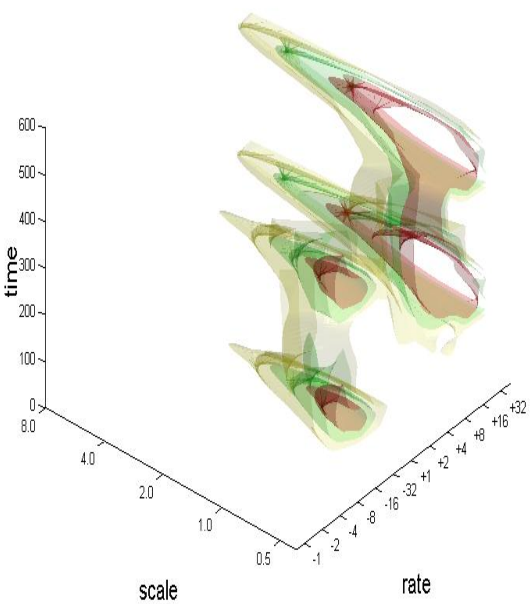
sparrow

frequency

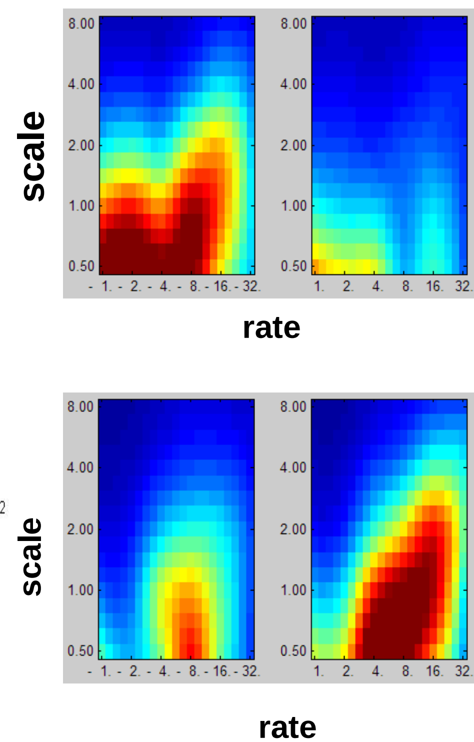


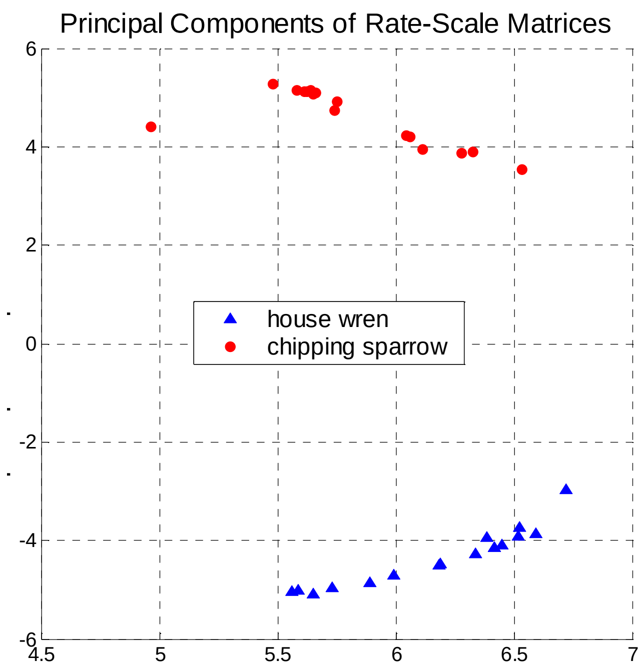
time

Response field in three dimensions (rate, scale, time) visualized using isosurfaces



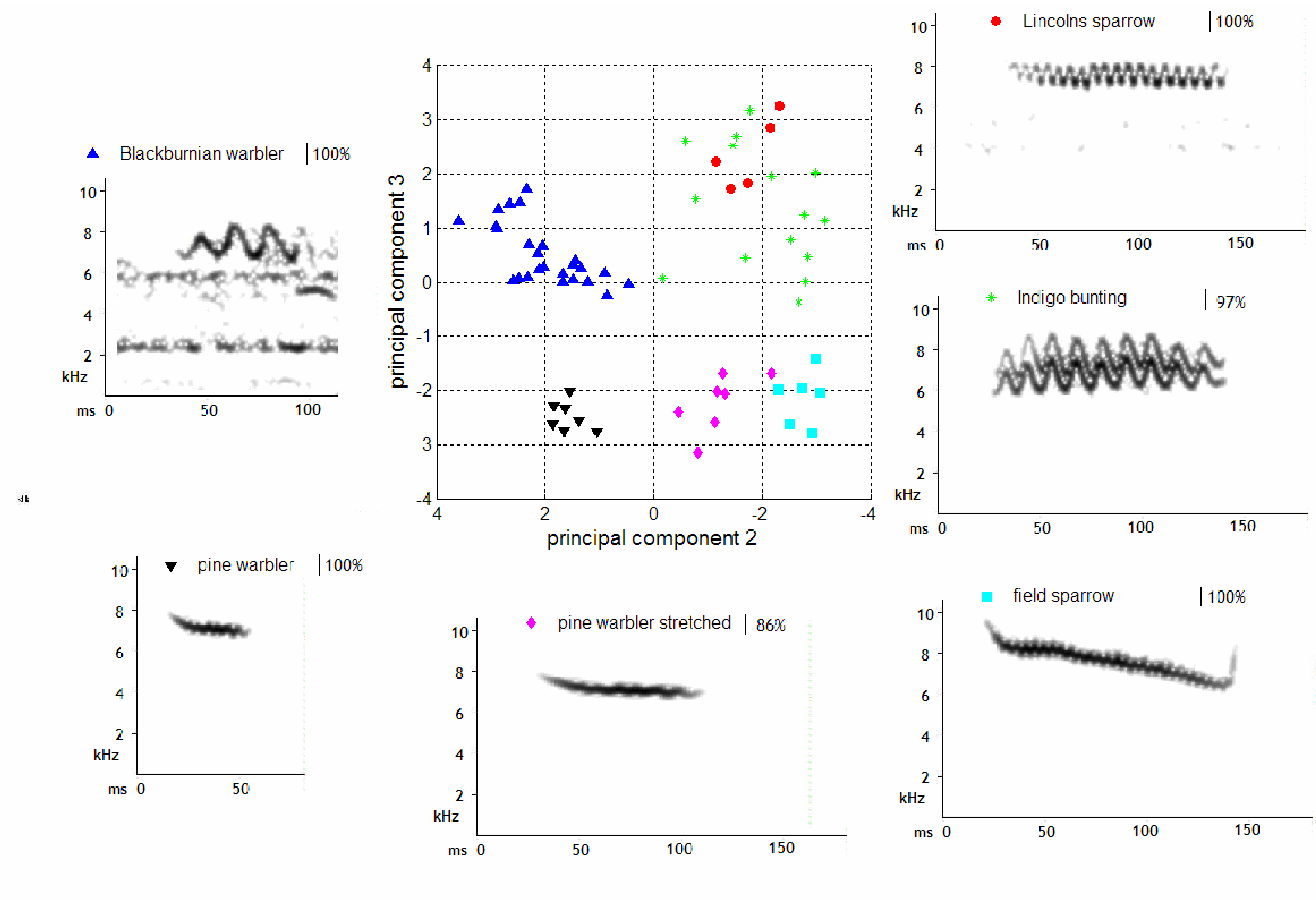
In-flight chip calls from house wren (top) and sparrow (bottom) are clearly distinguished and classified using rate-scale representation.



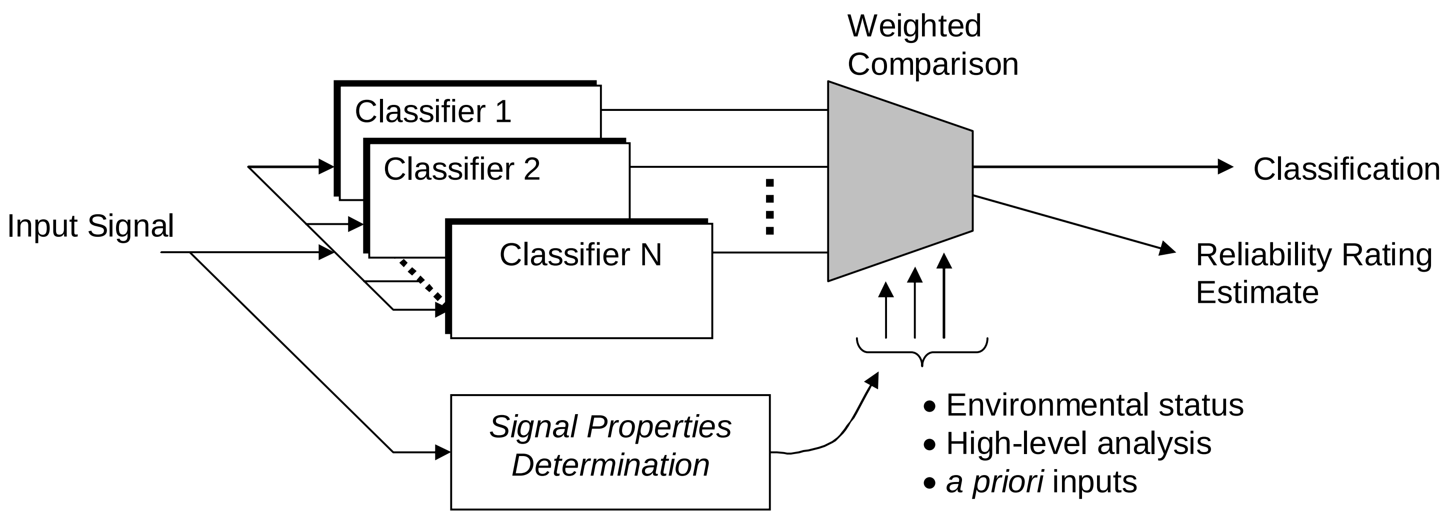


ADVANCED ACOUSTIC CONCEPTS

Bird call recognition from rate-scale matrix



MSU Compound Classifier



- **Auditory cortex ripple-based**
- **Frequency track analysis**
- **Other candidate methods**
- **Weighted comparison of all will give optimal result**

Conclusions

- AAC's highly successful underwater acoustic array sensor has been transitioned to an air sensor
- Field testing has proven its capability to detect a variety of acoustic sources at significant distances
- Testing alongside radar has shown that the two systems are highly complementary
- Parabolic dish provides significant gain over array
- Combined system of array, radar, and dish is a robust solution to monitoring bird activity at airfields
- System can be used to detect, track, and classify other activity as well:
  - vehicles, watercraft, aircraft, people, bats
  - Potential Homeland Security applications – perimeter security, border security