

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**

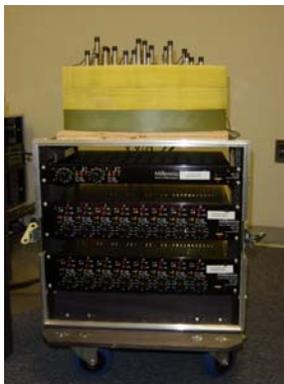
Introduction



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

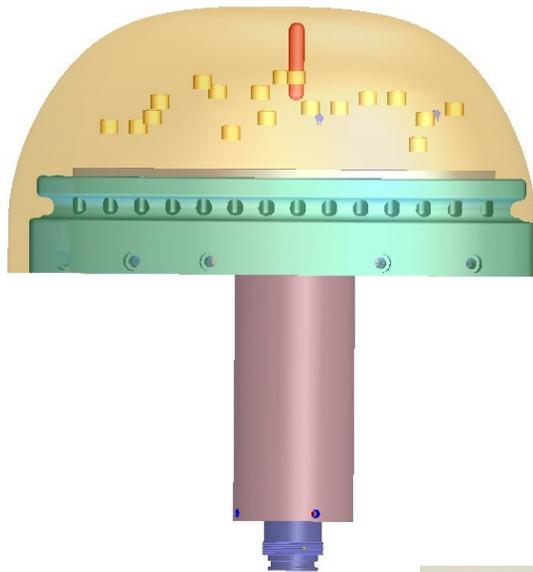
Introduction

- **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

Sparse Populated Volumetric Array (SPVA)

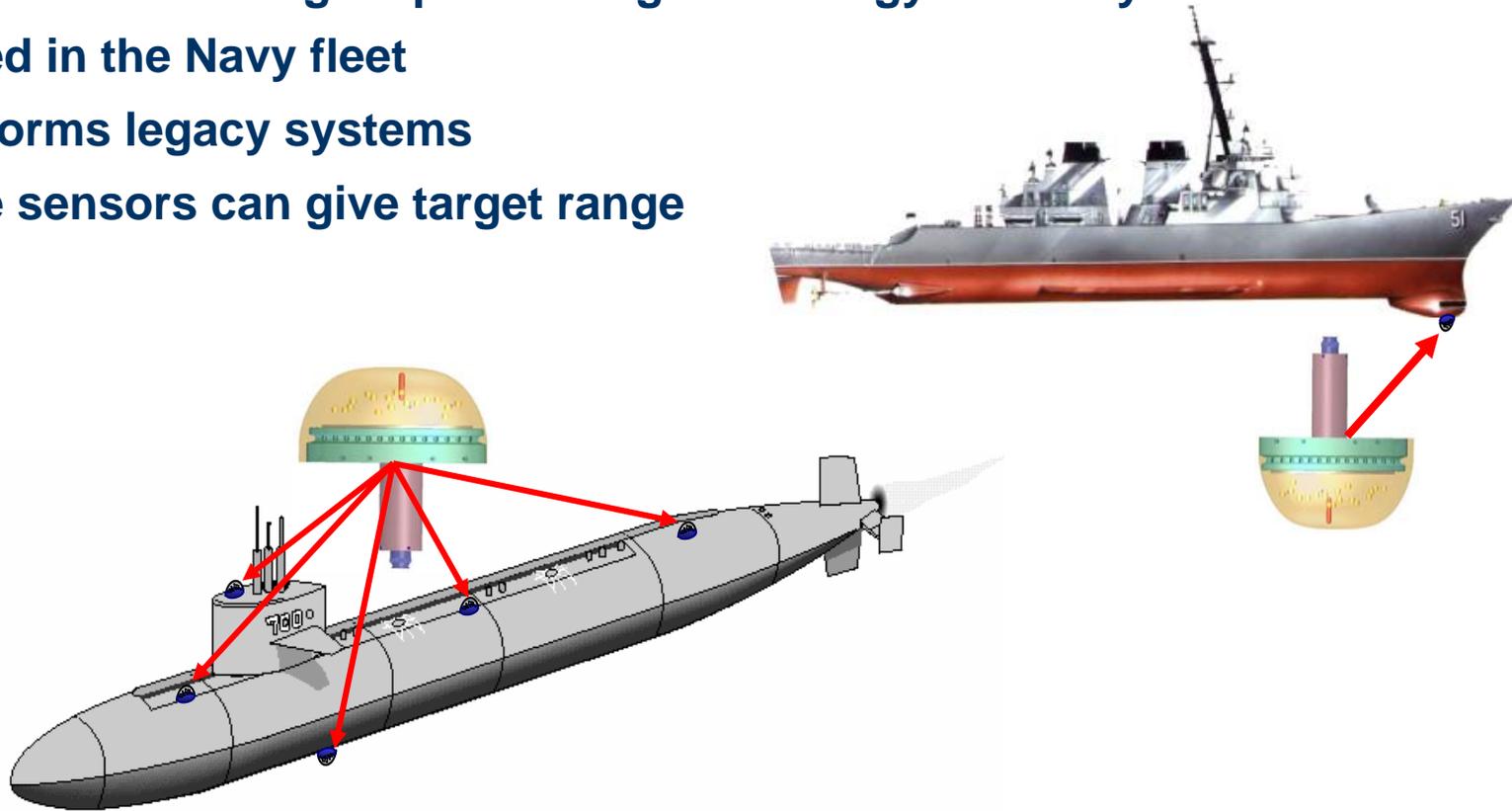


- 18 hydrophones embedded in polyurethane
- Provides 12.5 dB gain
- Covers very large frequency range
- 4π steradian coverage
- Real-time angle of arrival without beamforming
- Fractional degree angle accuracy
- Fiber optic telemetry

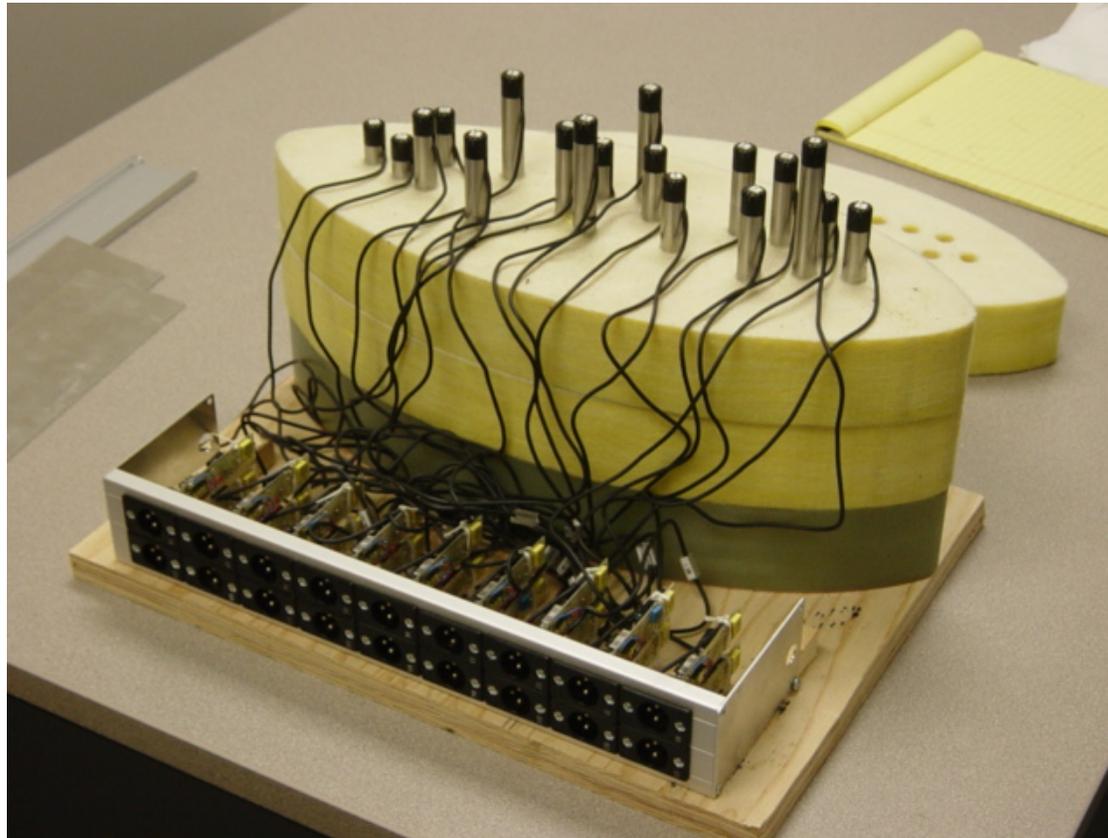


SPVA

- 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

Complete Acoustic Sensor System

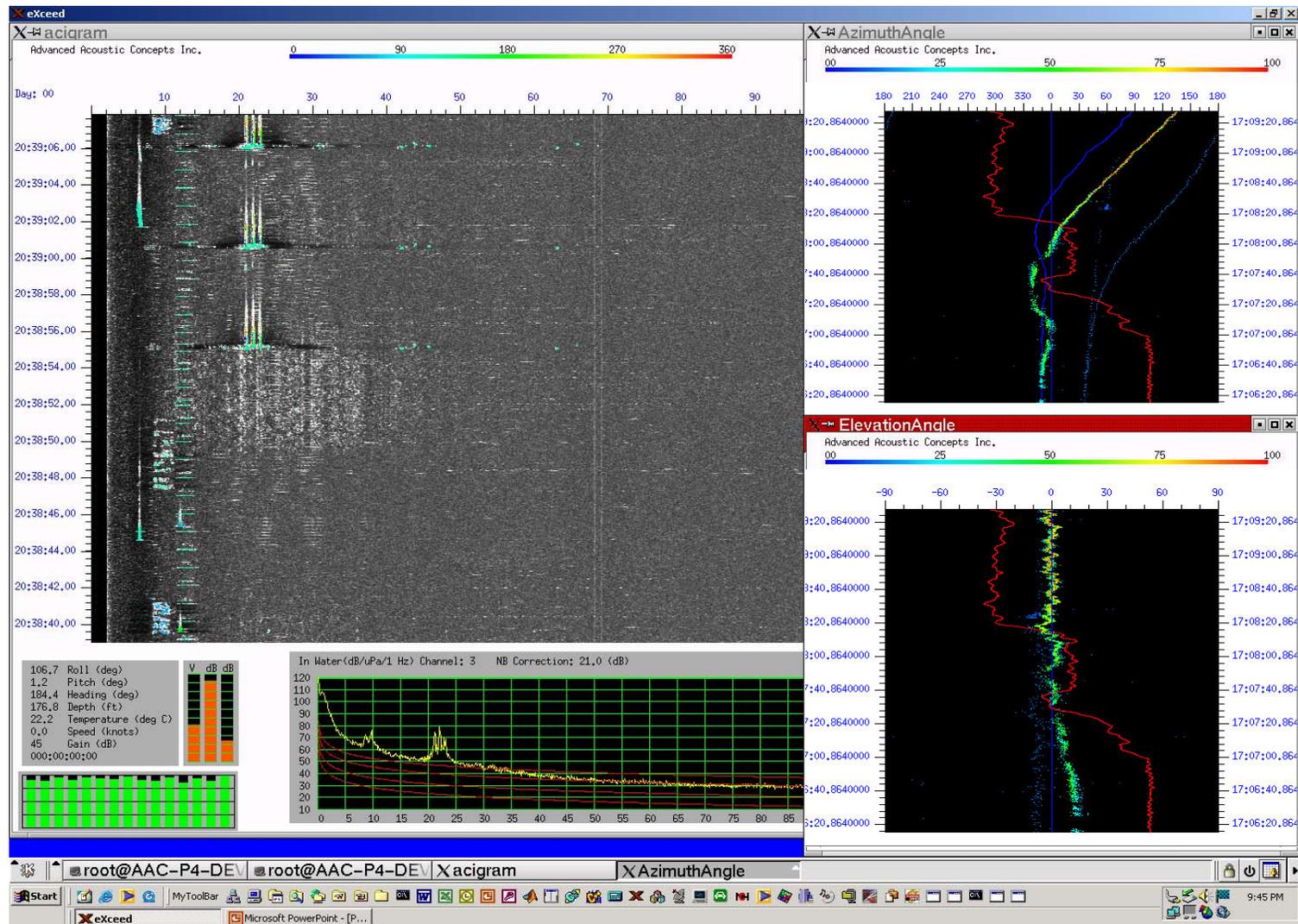


Air SPVA sensor
and pre-amplifiers

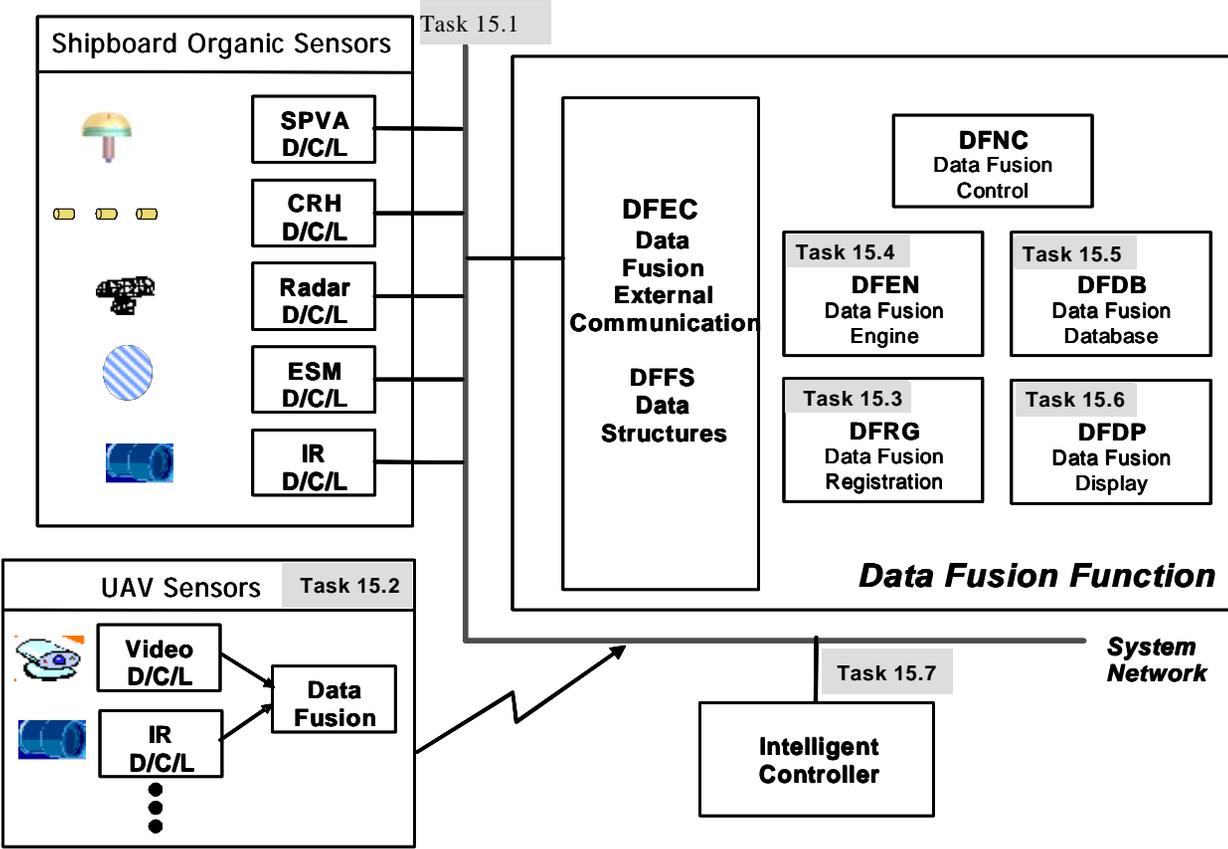
Digital recorder for offline signal
processing (production system will do
real-time signal processing)



SPVA Real-Time Displays

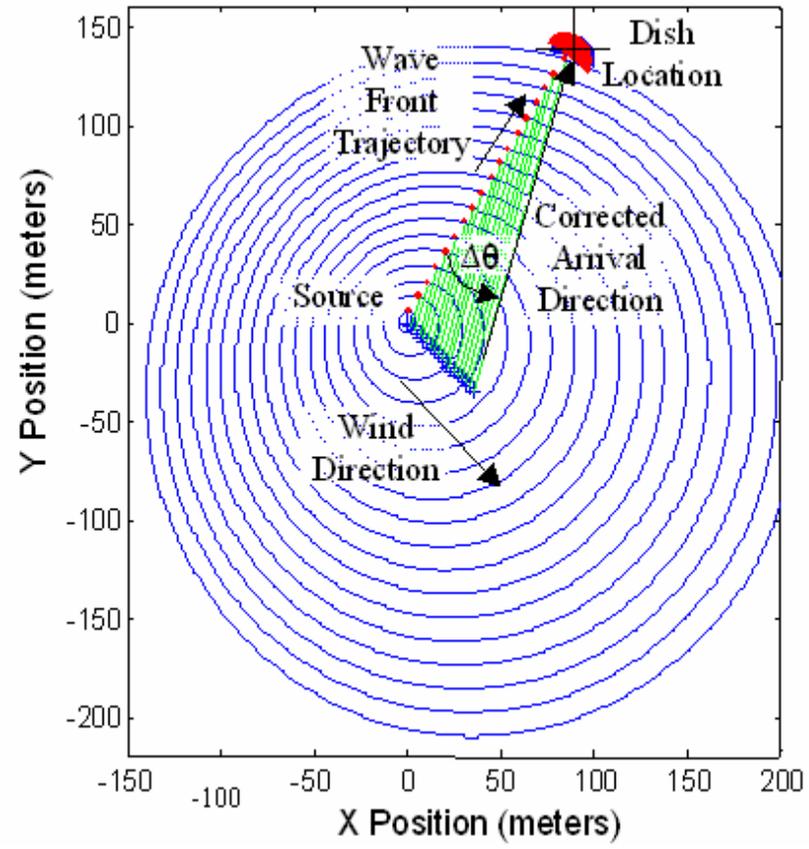


Data Fusion

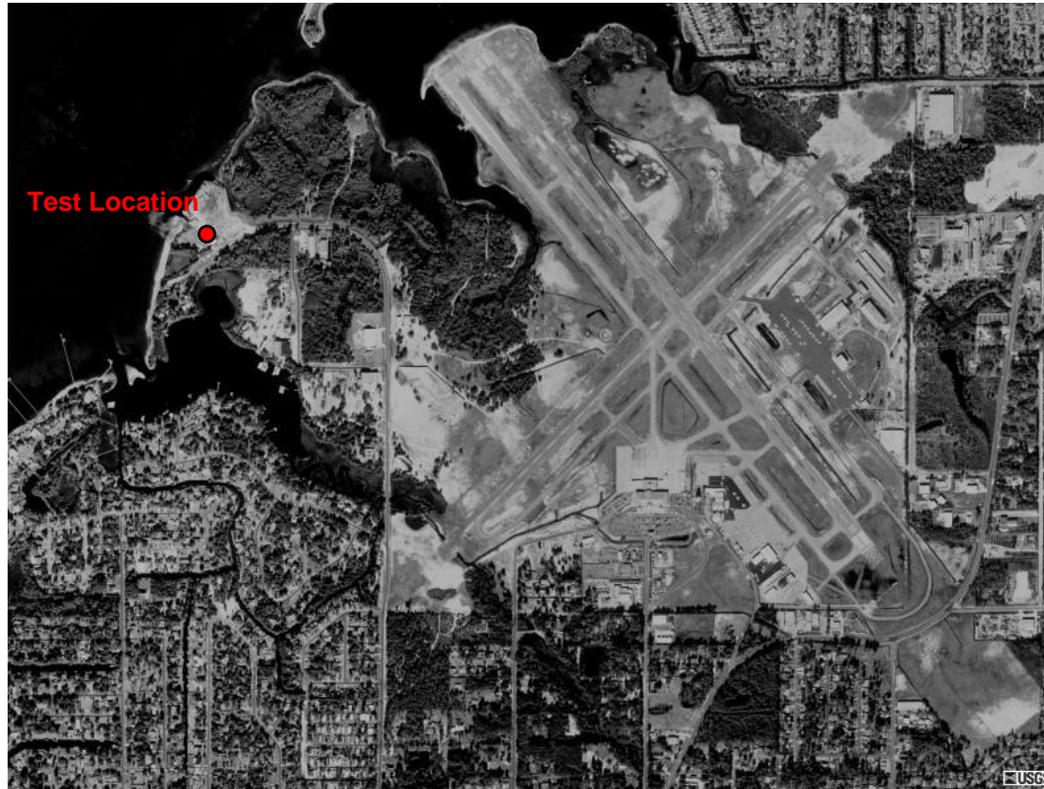


Atmospheric Compensation

- Wind speed
- Temperature
- Humidity



Field Test: PCBCIA

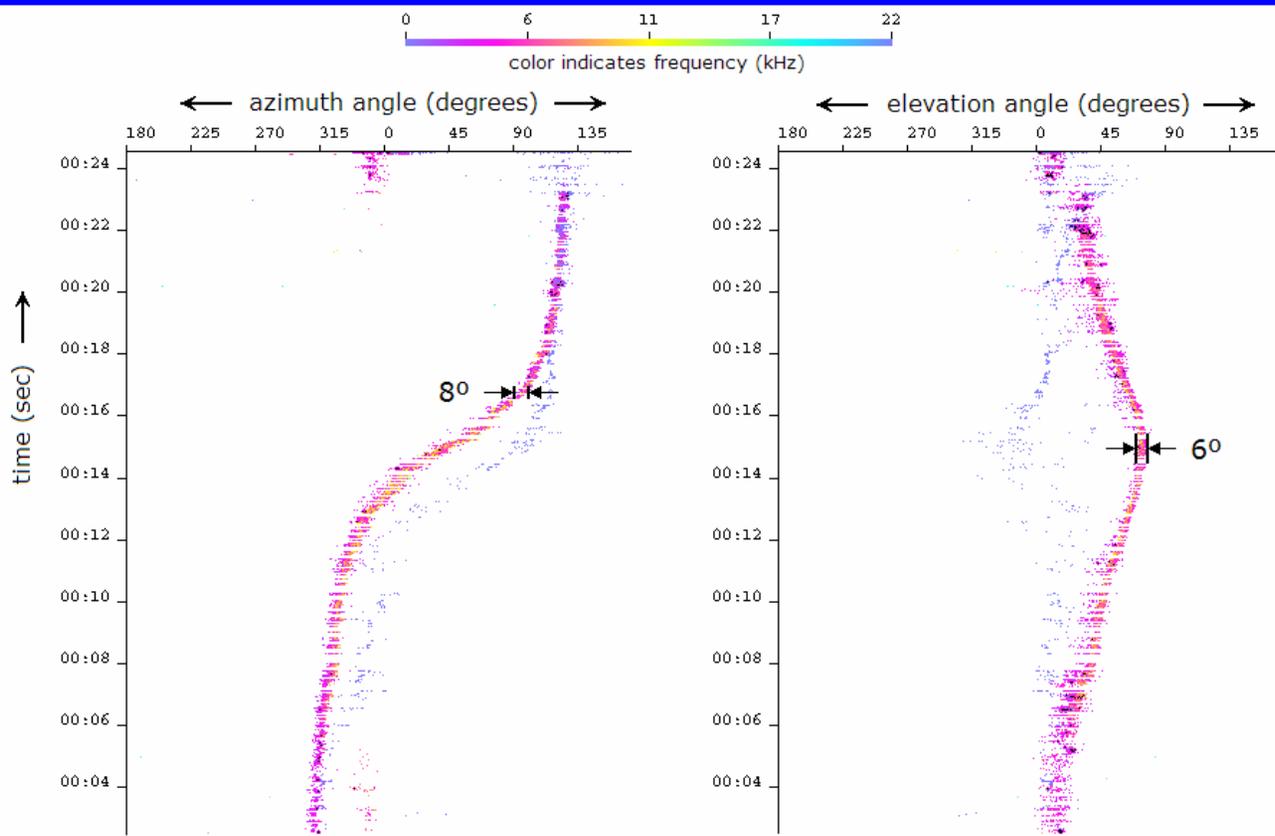


- Located in proximity to airport runway, trees, and water
- Test at beginning of Nov. to catch Fall migration

Field Test: PCBCIA



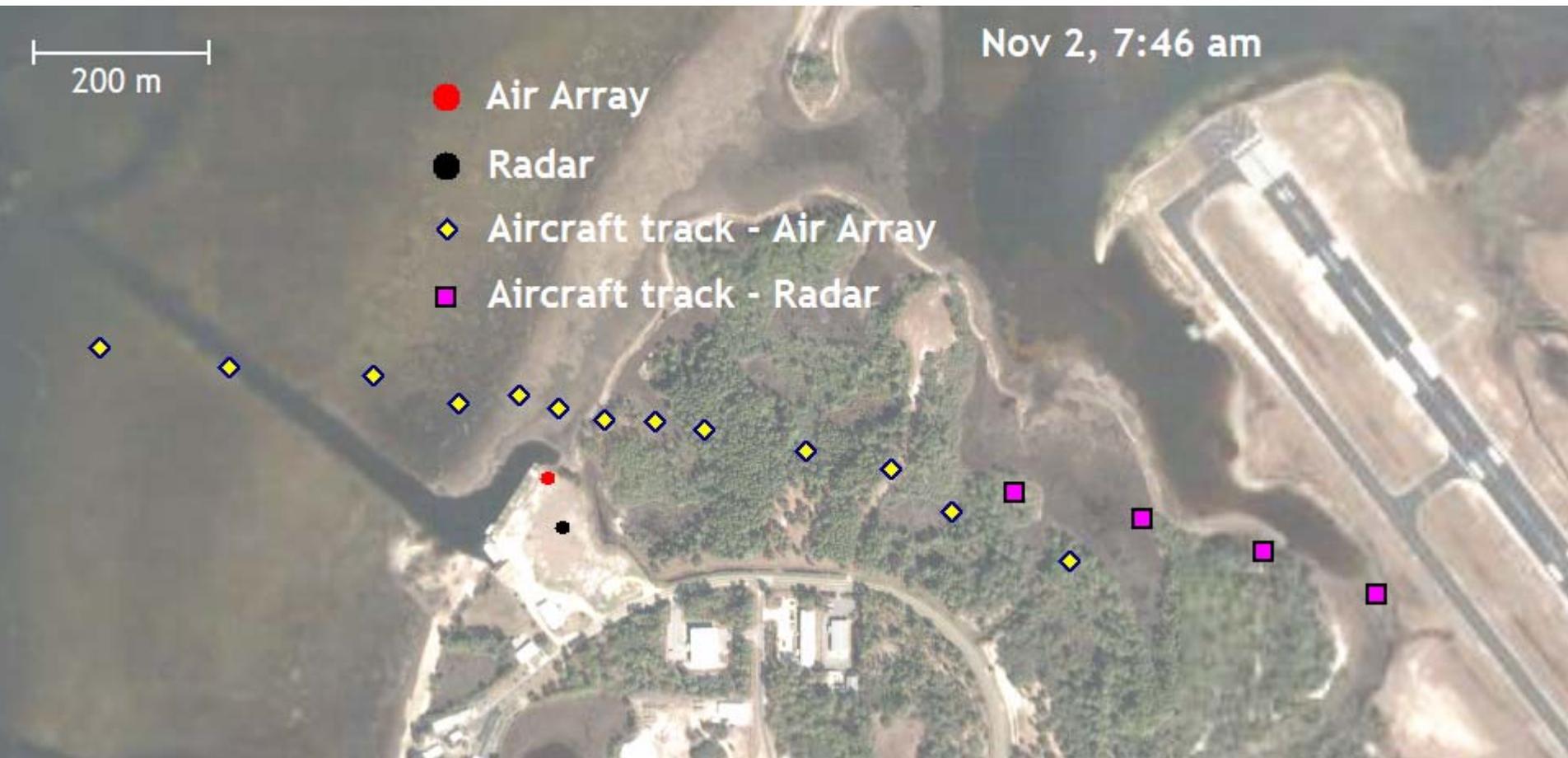
Aircraft Detection & Tracking



Nov 2 7:46:30 am plane flies directly overhead HD 1, Song 12

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

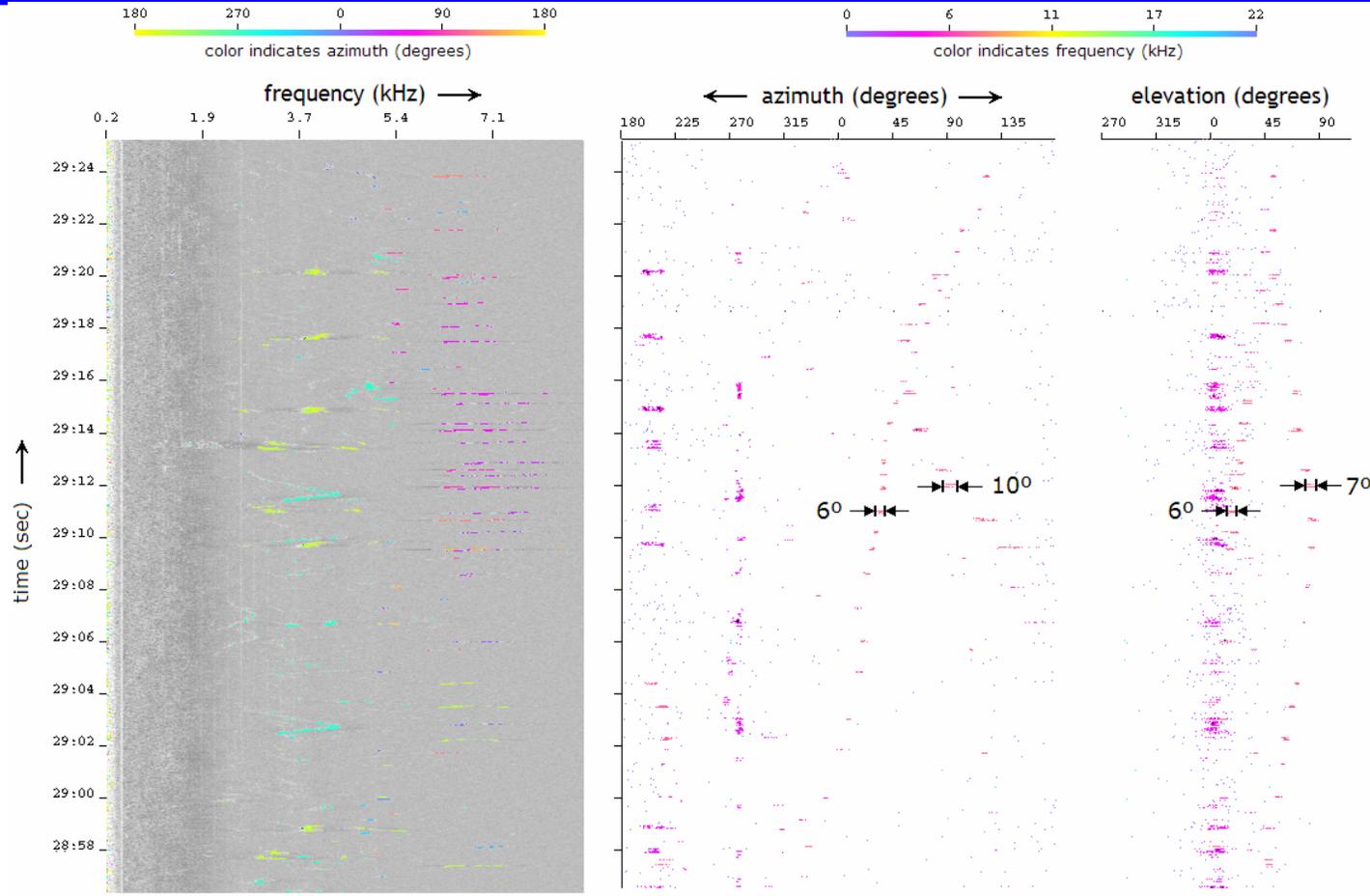
Aircraft Detection & Tracking: Radar Confirmation



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 from **non-threat** birds.

Morning Flight Calls



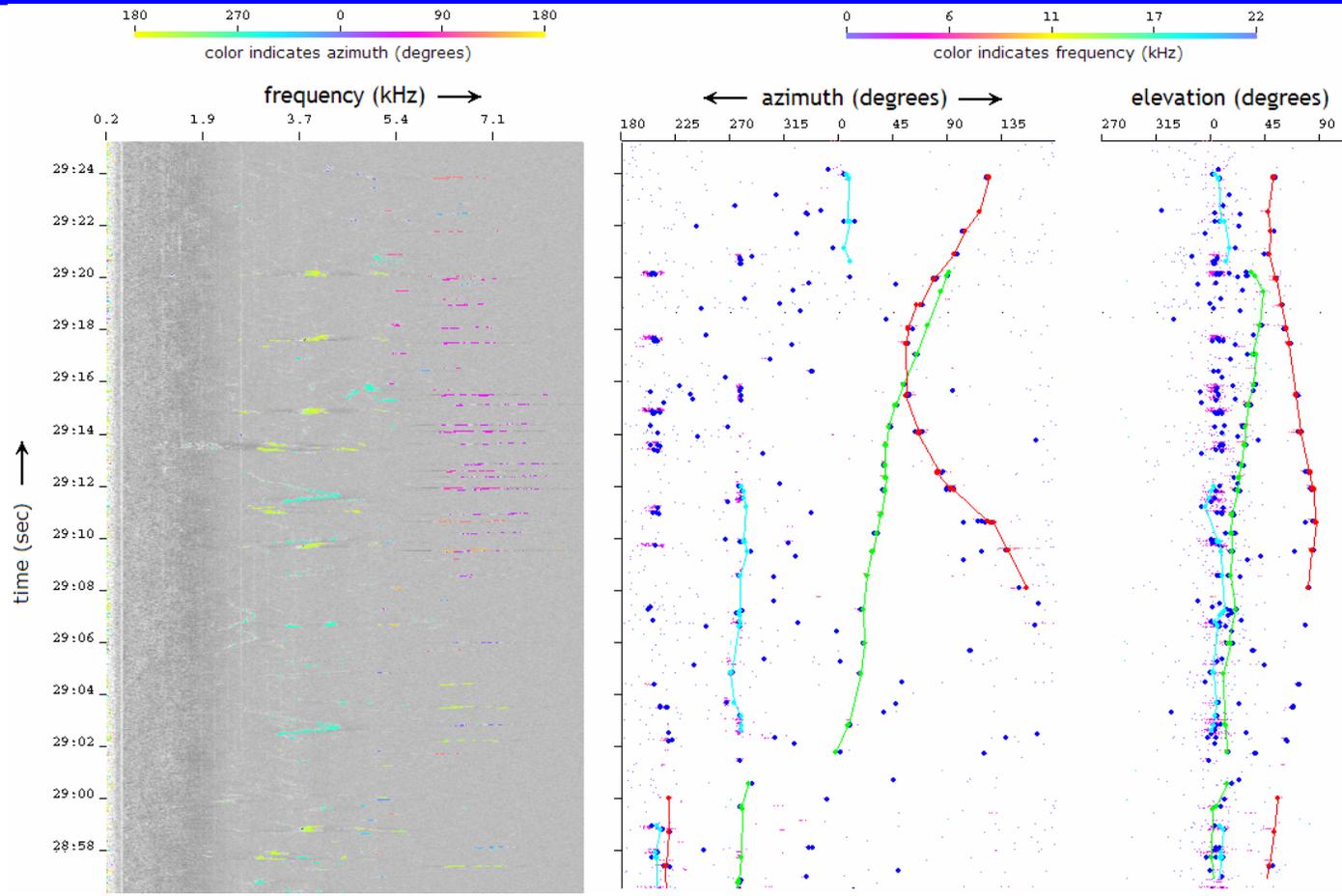
Nov 3 6:48:27-47 am

elevated bird call detections, two crossing tracks

HD 2, Song 17

Human interpreters will easily recognize tracks due to frequent and numerous calls.

Acoustic detection, localization, and tracking



Tracking software maintains integrity of overlapping tracks

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



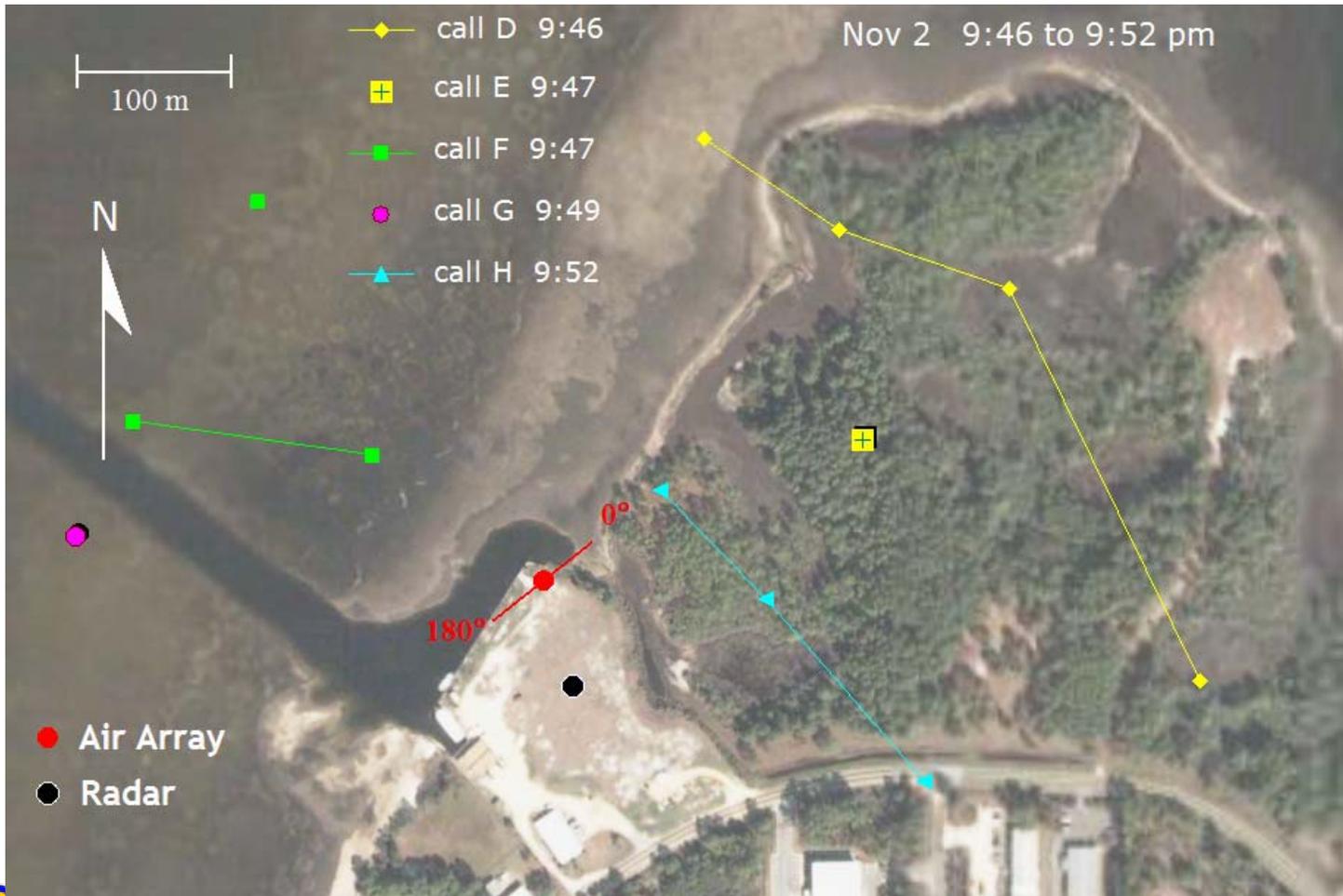
- Radar confirmation shows acoustic detections ranged up to 600 ft

Evening Flight Calls



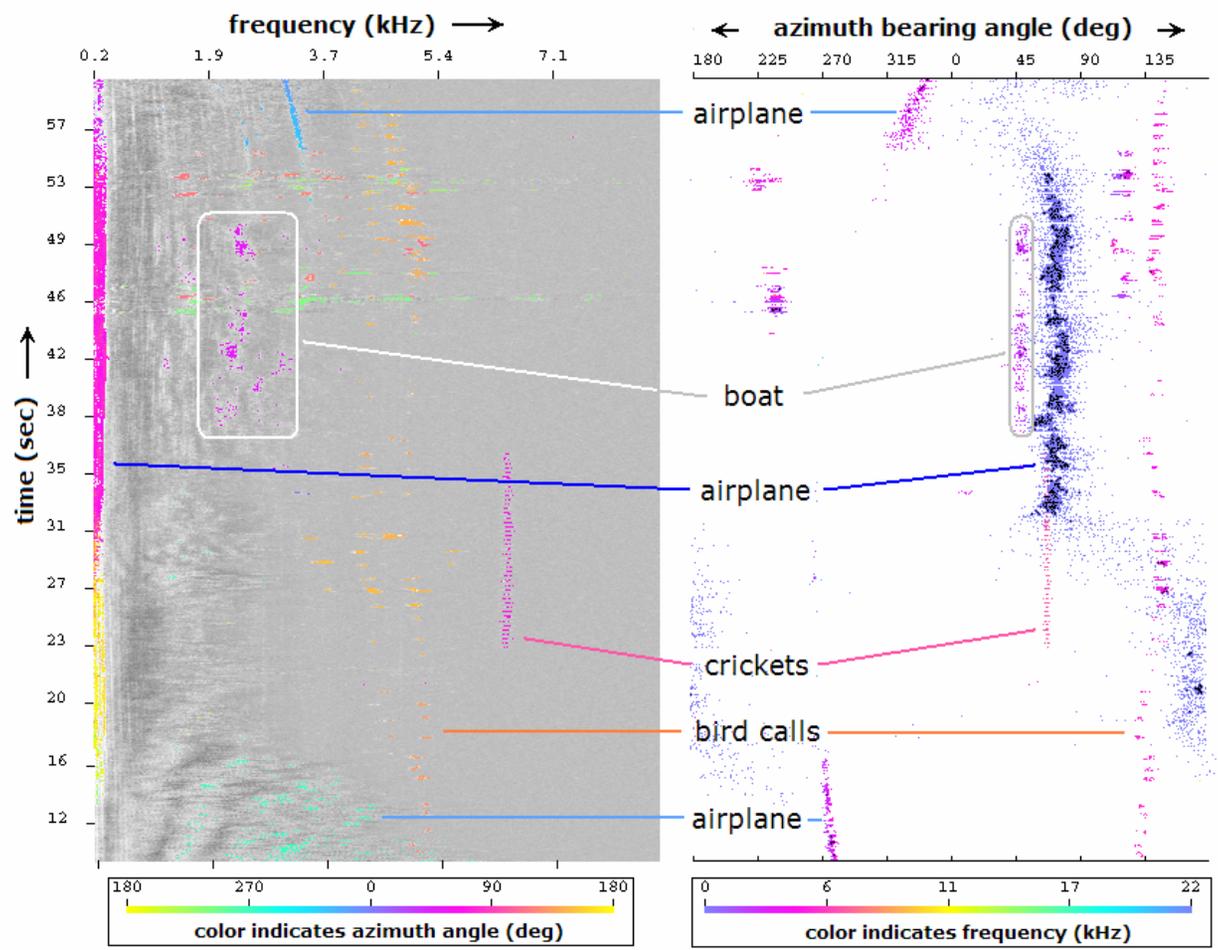
- During a typical 6-minute interval, 5 episodes of flight calls were detected.
- Interval between calls in one episode is typically 5 to 10 seconds.
- Each episode has very few calls, typically 1 to 4.
- Presumed migratory flight
- Calls were mostly from **non-threat** birds.

Evening Flight Calls



Acoustic detections ranged up to 1500 feet

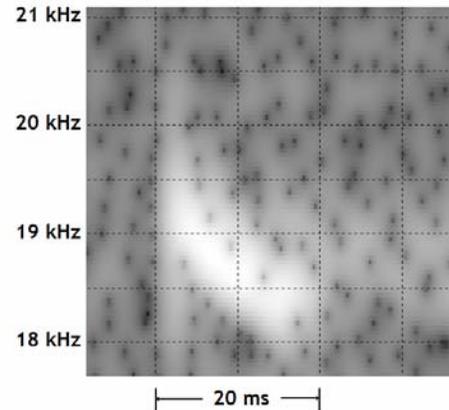
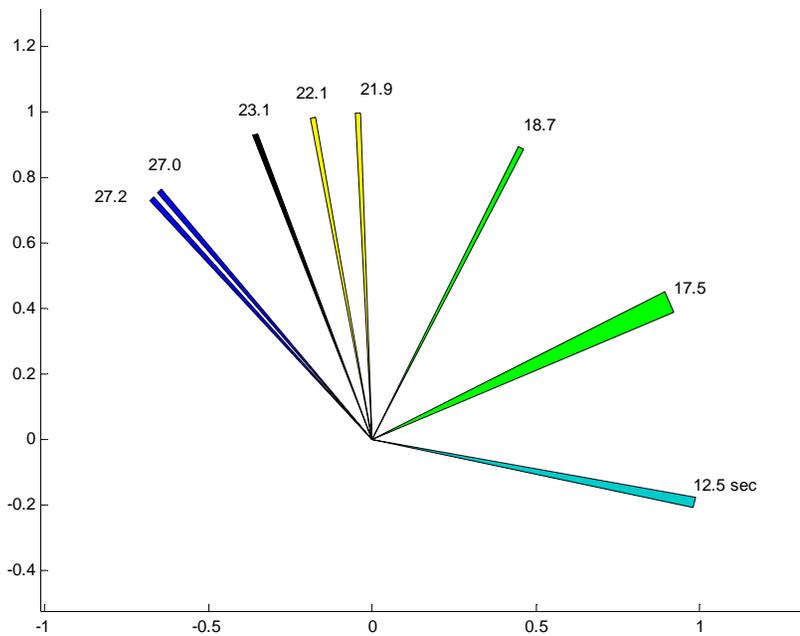
Multi-Source Detection



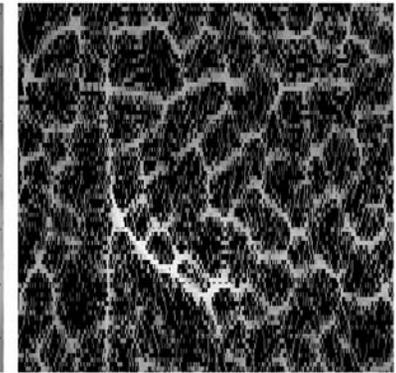
System can detect and track multiple targets simultaneously

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

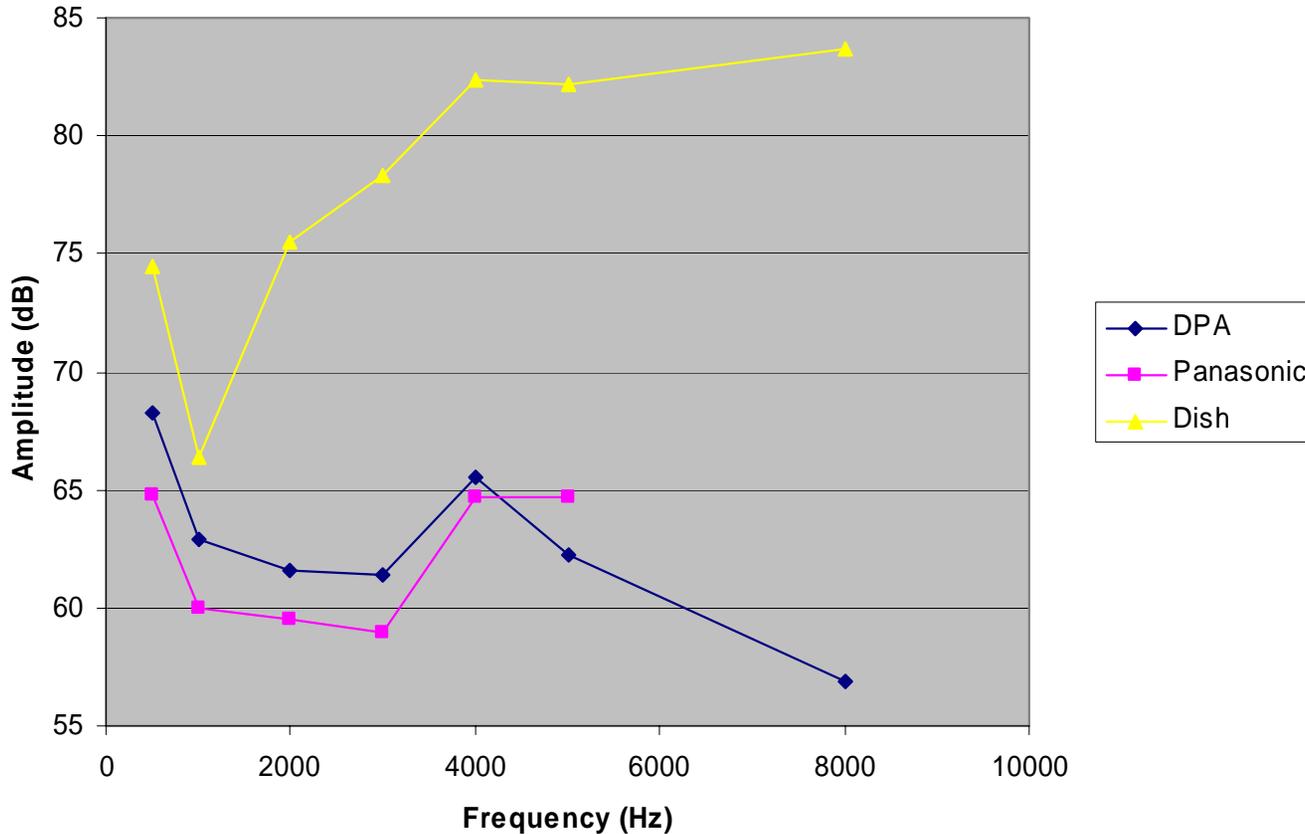
Parabolic Dish Microphone



- **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**



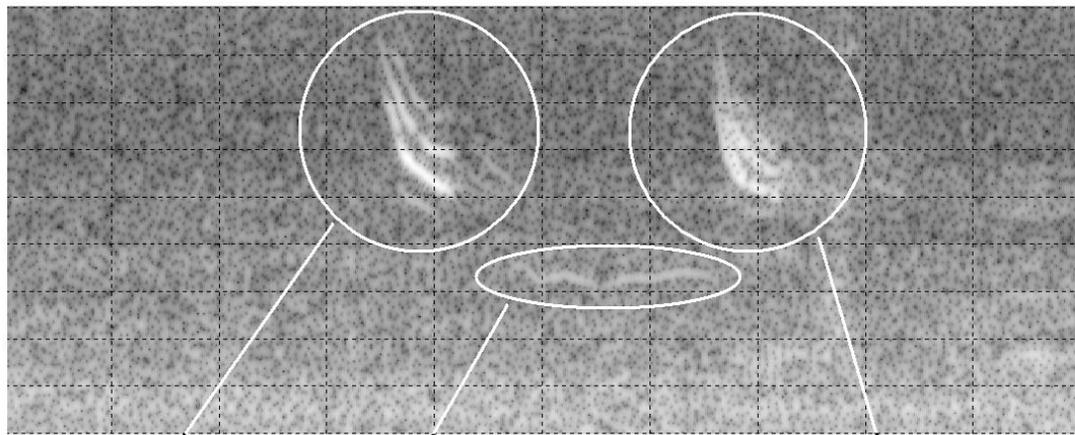
Parabolic Dish Performance



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

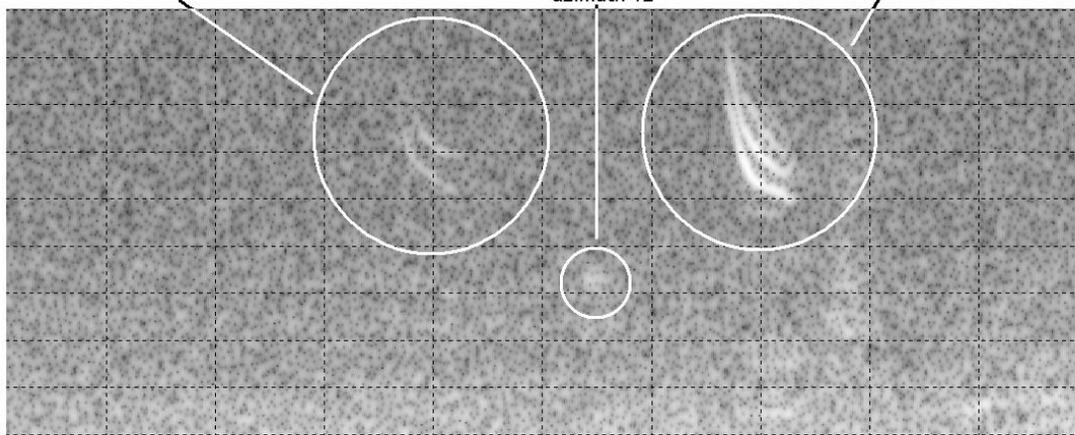
Parabolic Dish Performance

10 kHz
8 kHz
6 kHz
4 kHz



parabolic
dish
microphone

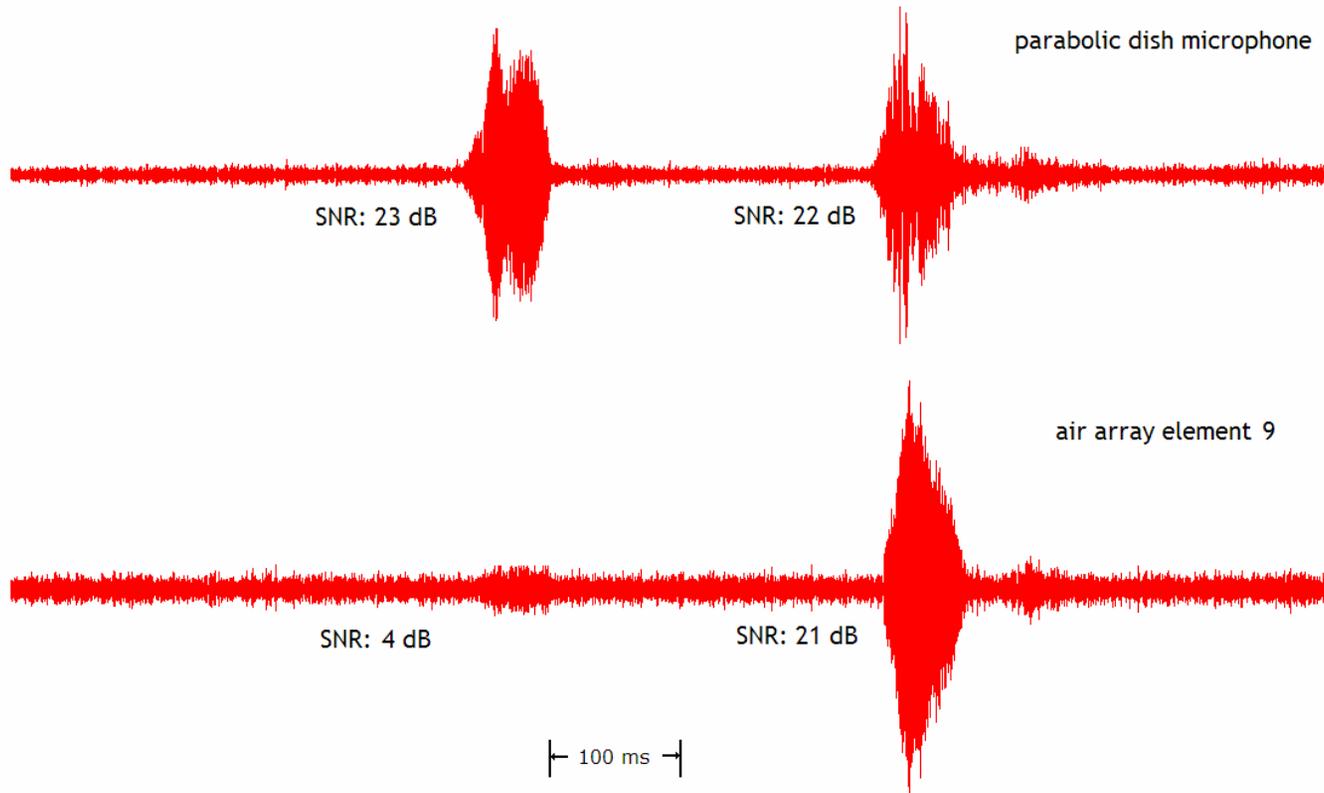
10 kHz
8 kHz
6 kHz
4 kHz



air array
element 9

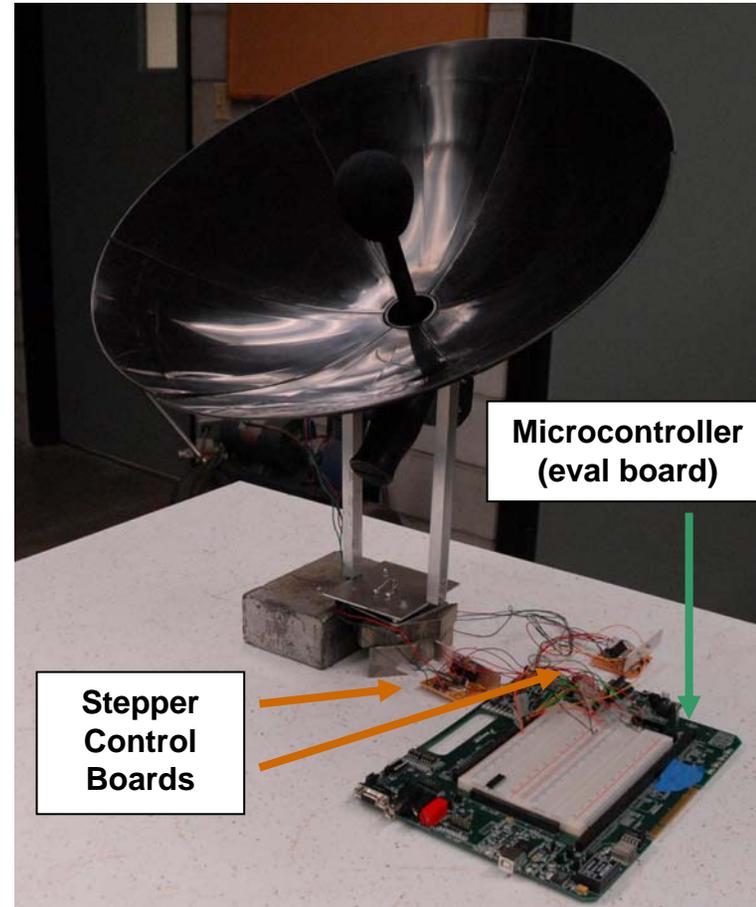
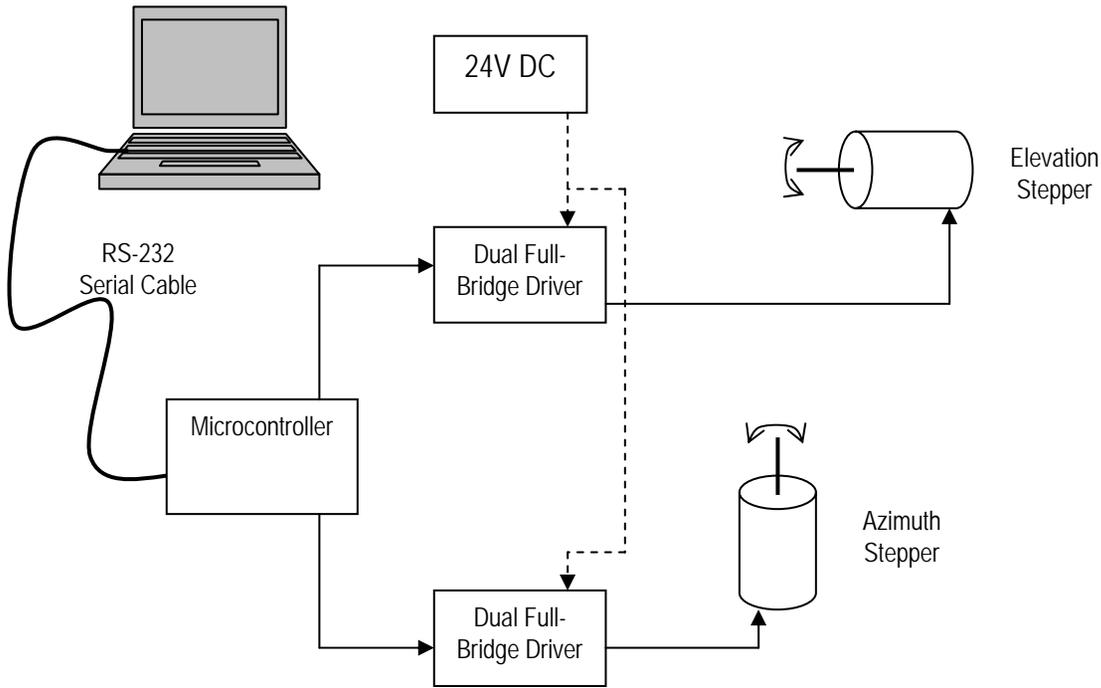
Two sparrow calls: the first is heard faintly by the air array, strongly with the dish.

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

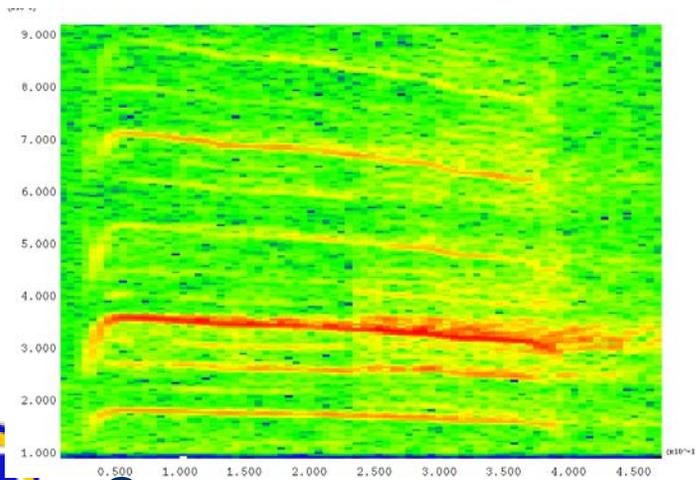
Classification Software



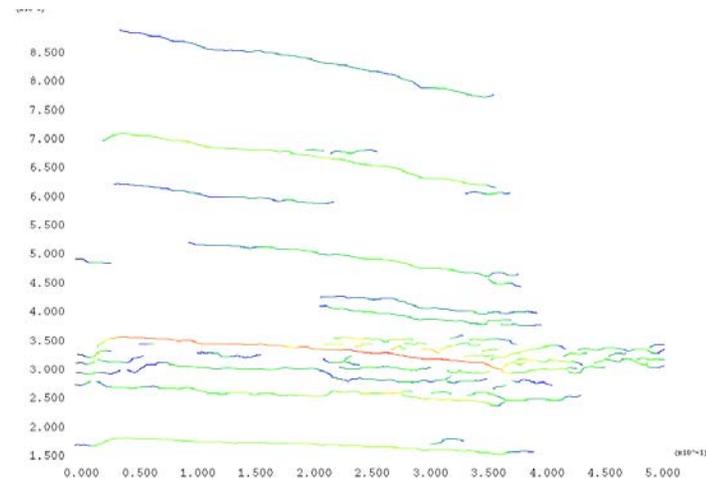
- **Frequency Track Analysis**
 - AAC
 - MSU
- **Cortical Processing Theory**
 - AAC & UMD
- **Composite Classifier**
 - MSU

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

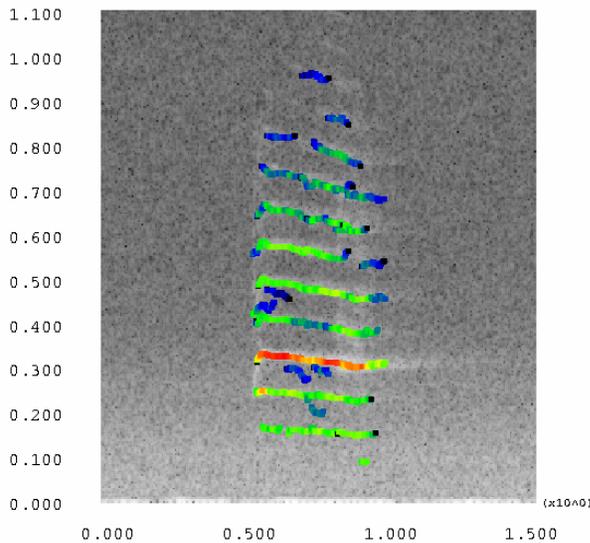


Frequency Tracks

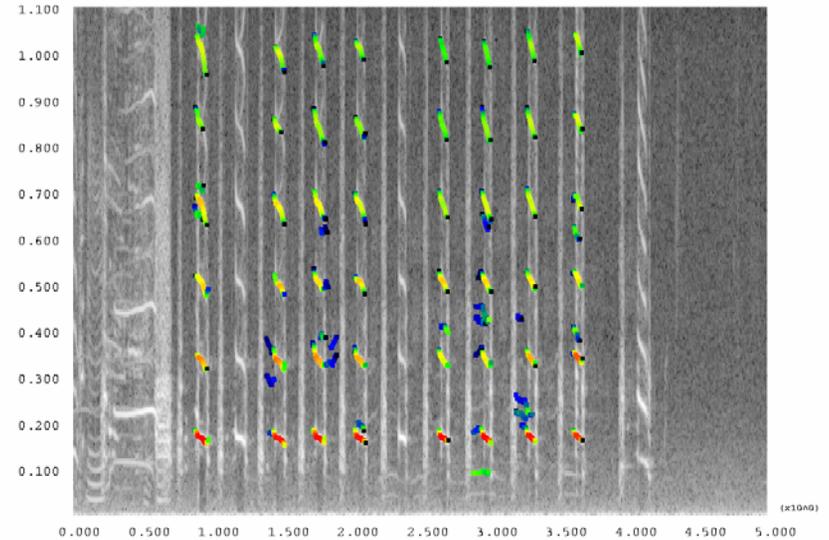
Blue Jay Call

Frequency track classifier results

Blue jay matching tracks

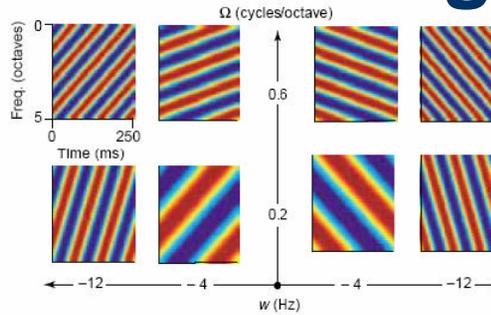


Herring gull syllable recognition



- 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)

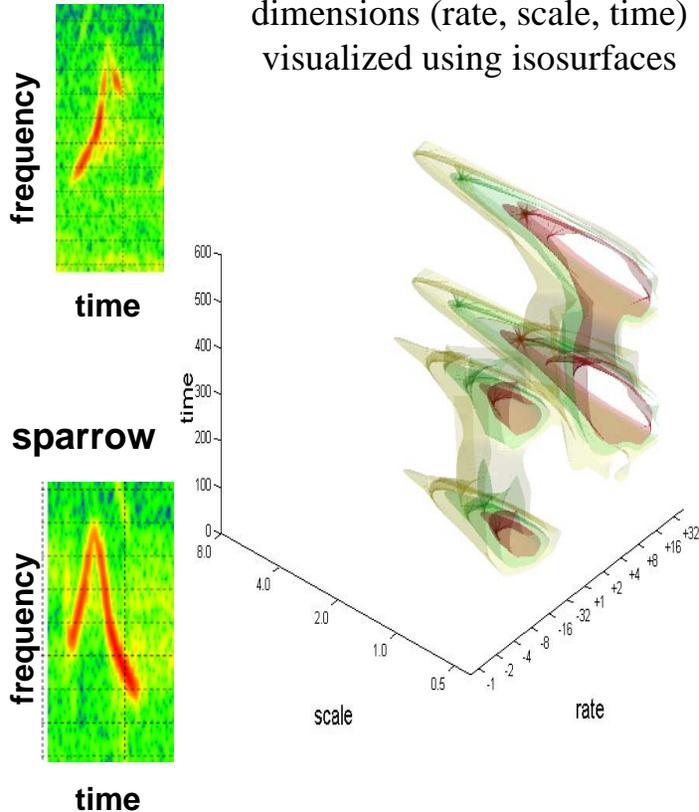
Cortical Processing Theory



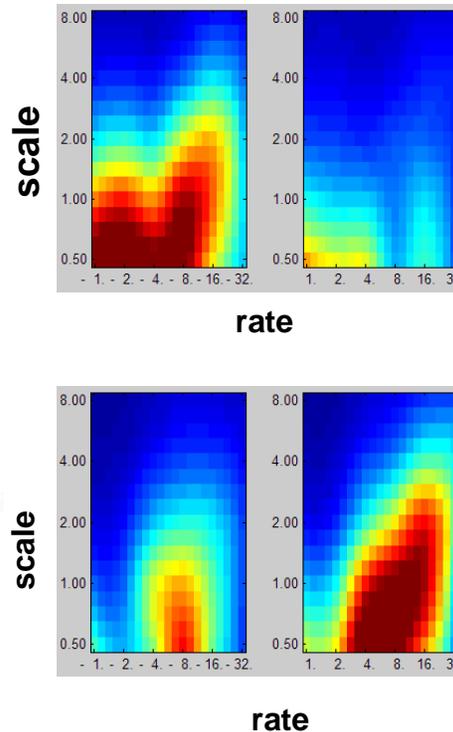
Prof. S. Shamma

wren

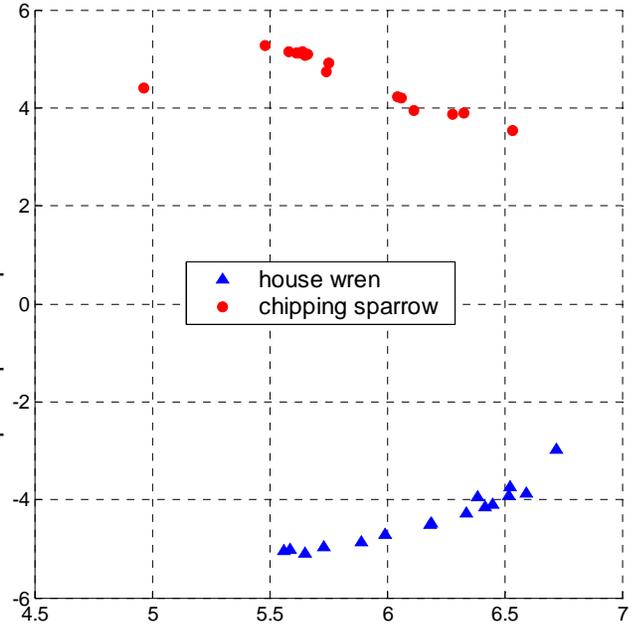
Response field in three dimensions (rate, scale, time) visualized using isosurfaces



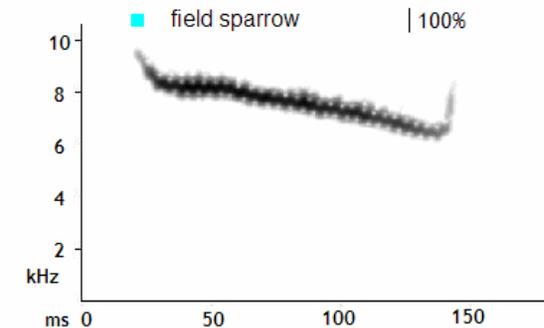
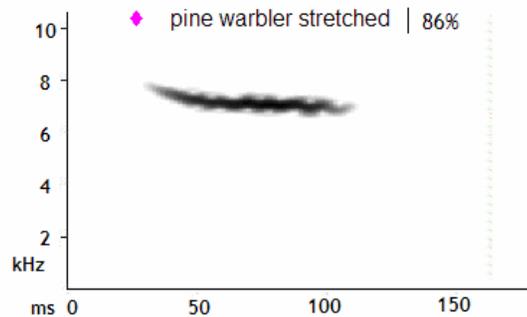
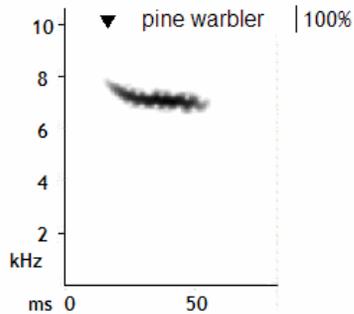
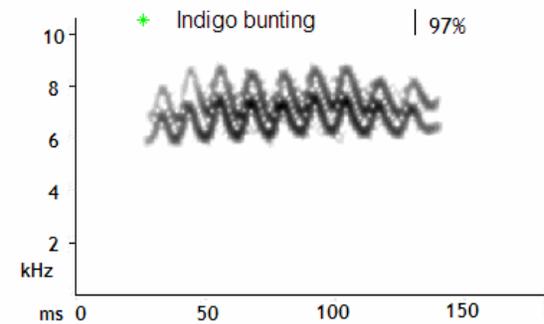
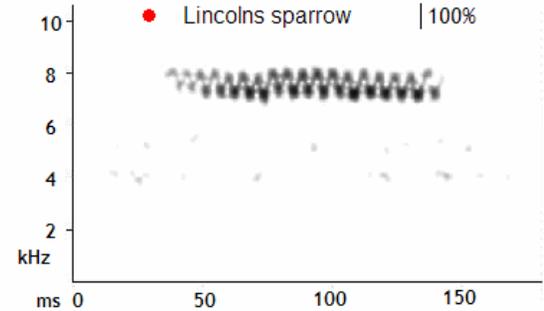
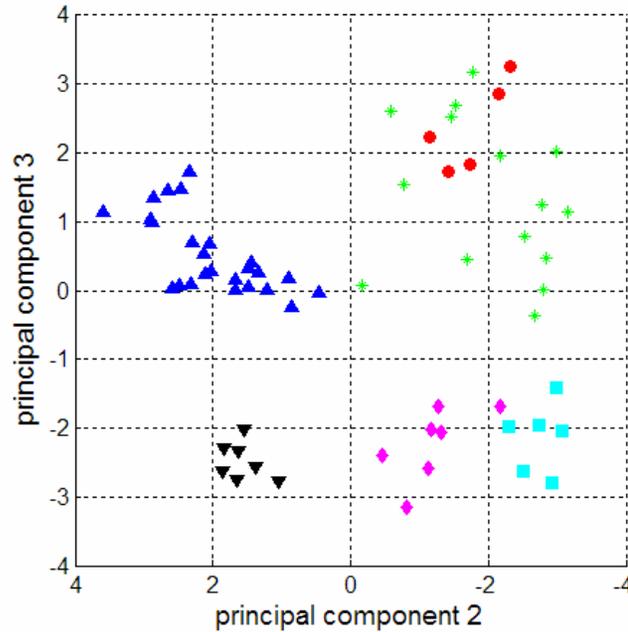
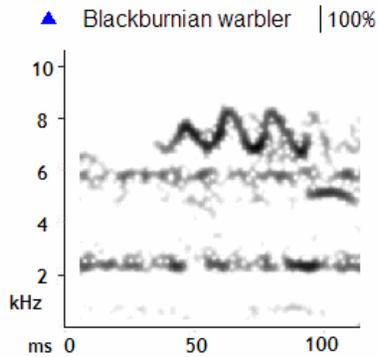
In-flight chip calls from house wren (top) and sparrow (bottom) are clearly distinguished and classified using rate-scale representation.



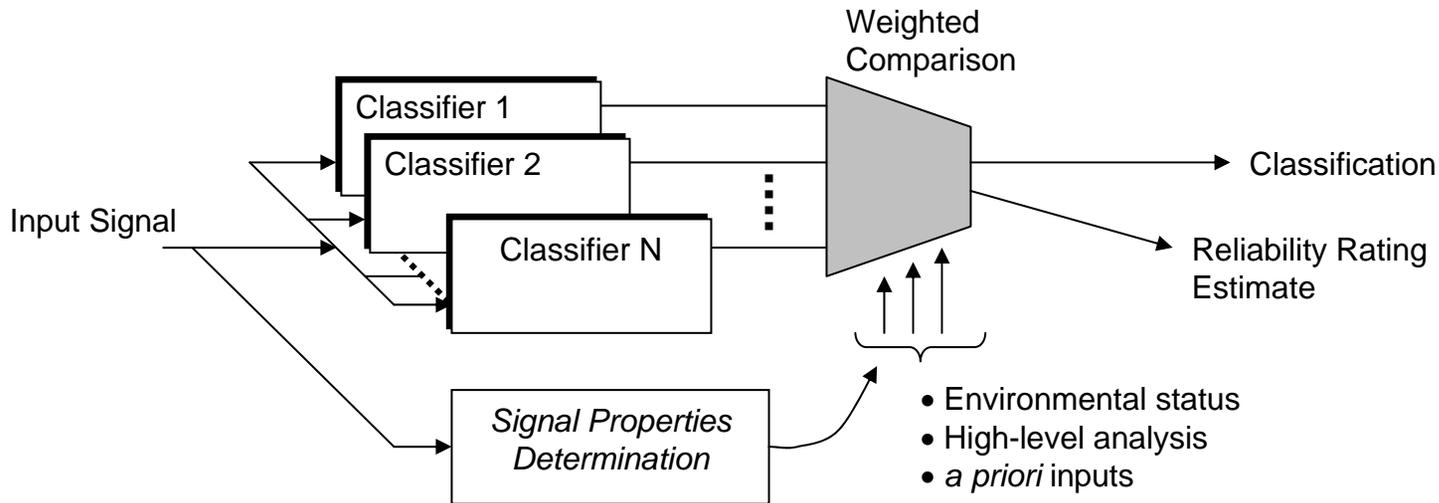
Principal Components of Rate-Scale Matrices



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