# EcoEARS
# Ecological & Environmental Acoustic Remote Sensor Application for Long-Term Monitoring and Assessment of Wildlife

Technical Symposium & Workshop Threatened, Endangered, and At-Risk Species on DoD and Adjacent Lands

June 7-9, 2005


- Stuart H Gage – Michigan State University
- Rob Maher – Montana State University
- Gonzalo Sanchez – Sanchez Industrial Design Inc.

# Areas of Collaboration

Stuart H Gage

Monitoring and Interpretation of Environmental Acoustics

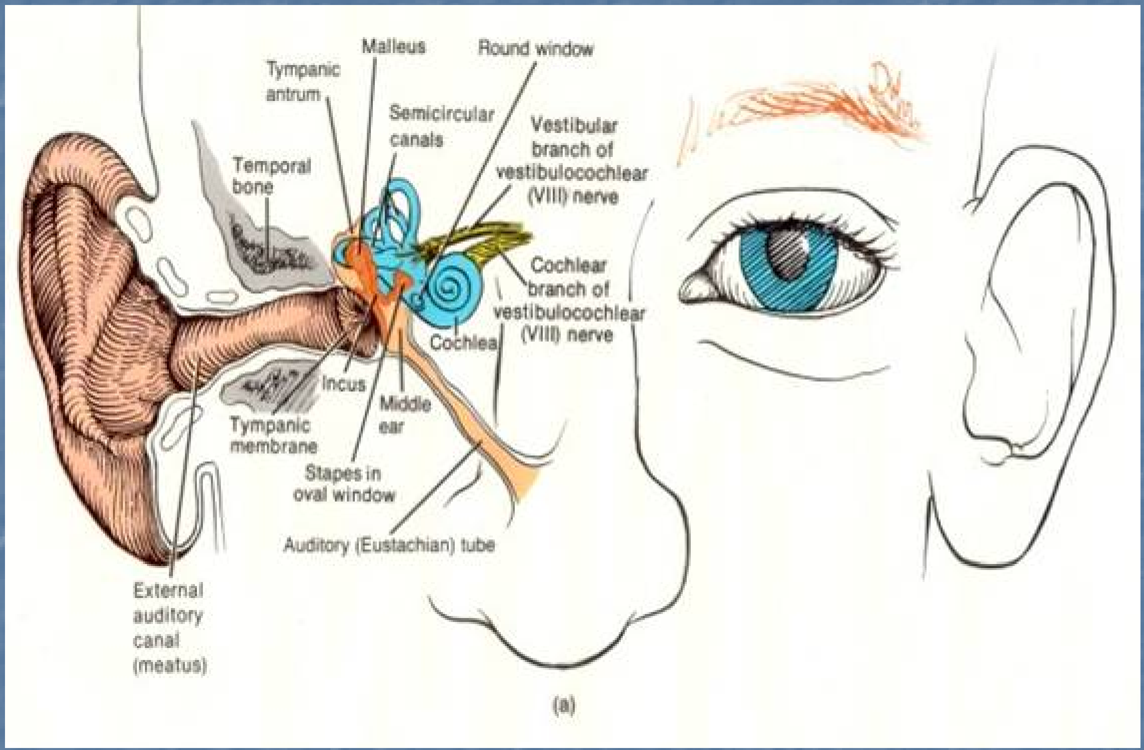
Rob Maher

Acoustical Detection of Birds on Airport Environments

Gonzalo Sanchez

Design and Implementation of Real-Time Data Acquisition Hardware

# The Ear as an Environmental Sensor




The ability to hear and to interpret sound is one of our basic senses. Acoustic signals produced by the environment is an untapped resource to assess the dynamics and health of the Earth's ecosystems within which we live and extract resources.

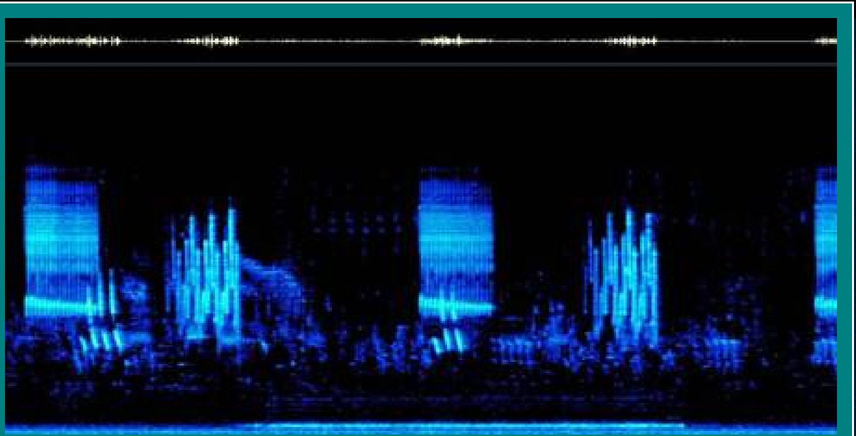
# Sound as an Ecological Indicator and a Stressor

*Ecological Indicator*

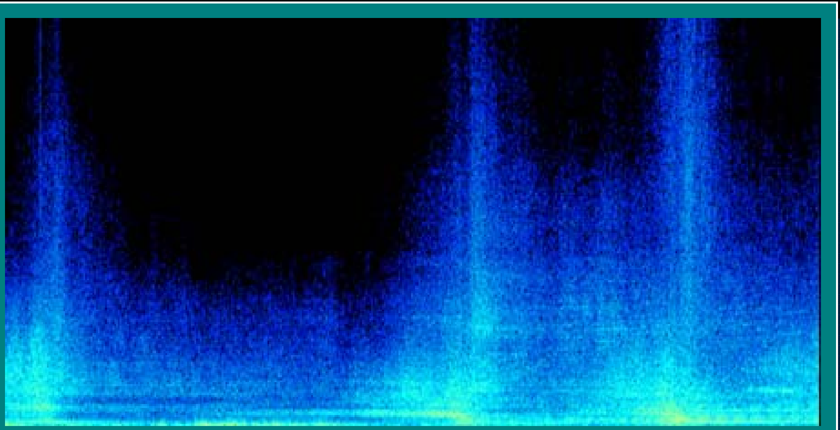
*Biophony*

*Stressor*

*Anthrophony*

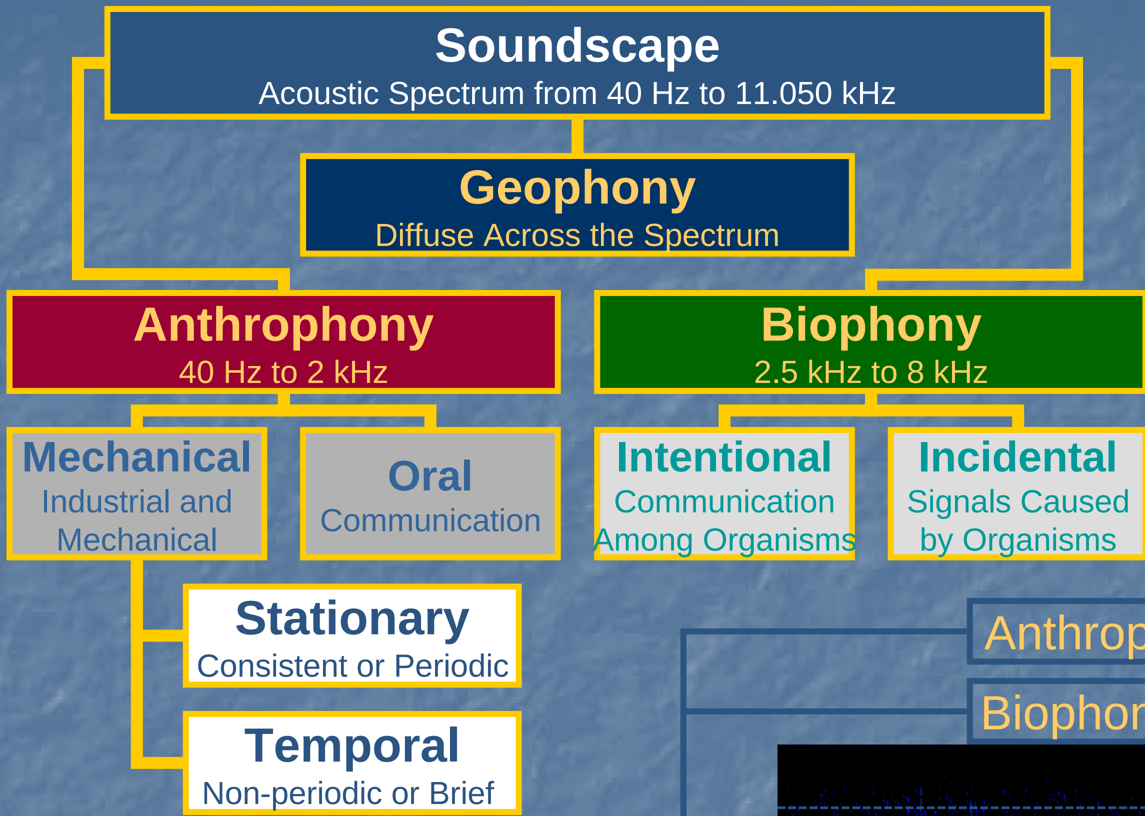


Hay Marsh, MI
05/22/2002
10:50 am

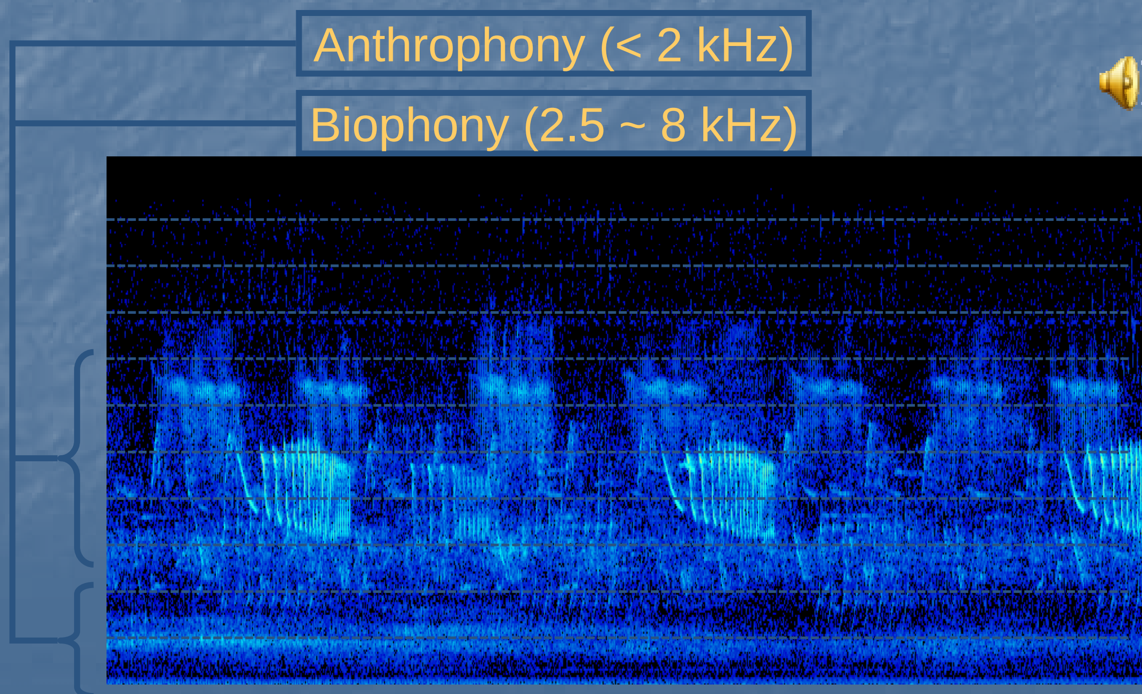


Chippewa River, MI
07/01/2002
10:55 am

# Soundscape Taxonomy and Spectrogram




Spectrogram Slicing

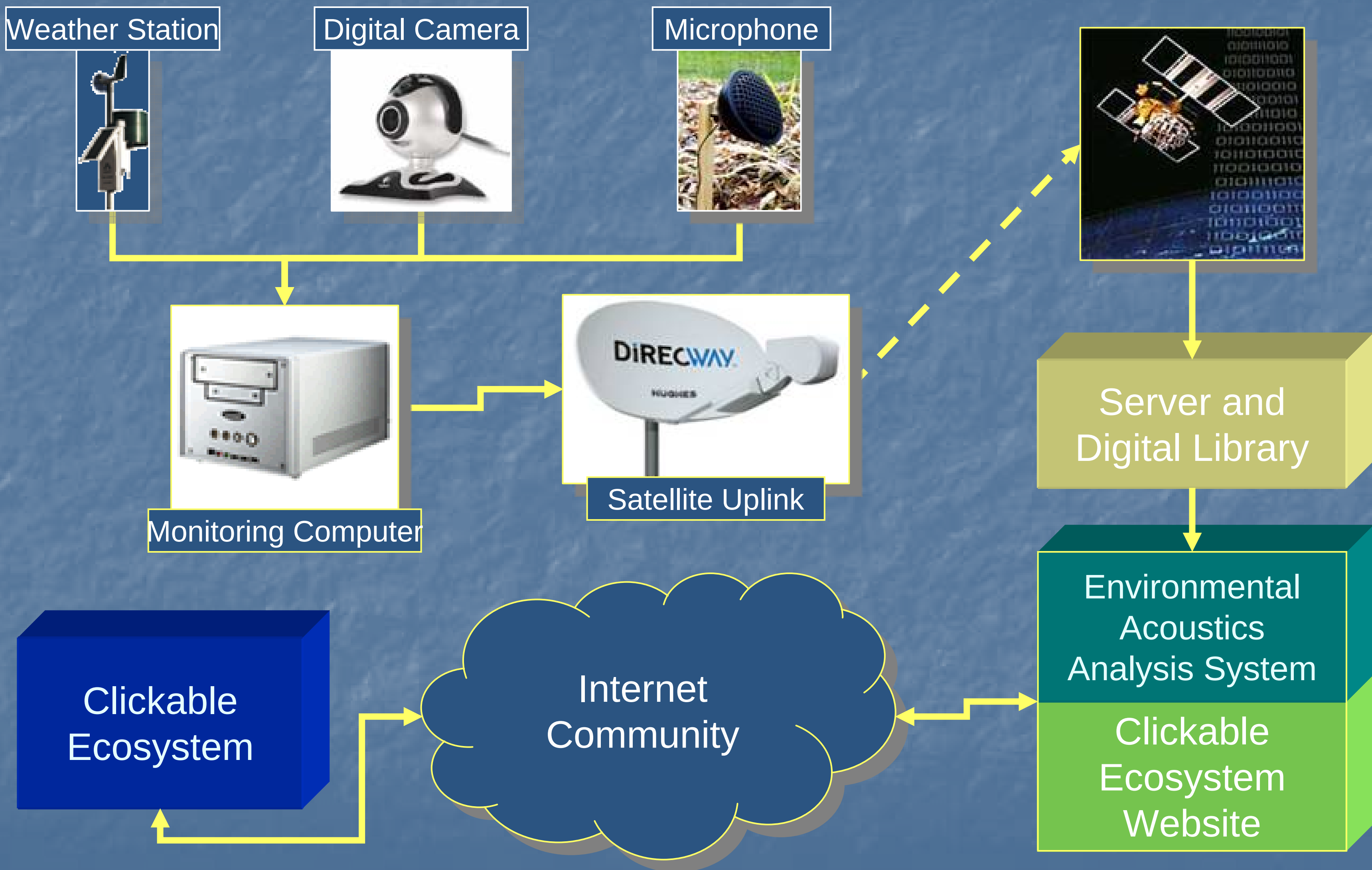


# Spectral Analysis

These formulae are mathematical derivations of the acoustic activity within the three primary spectral regions. The variables are used in analyses. The automation system rapidly calculates the values necessary to derive these variables for multiple samples.

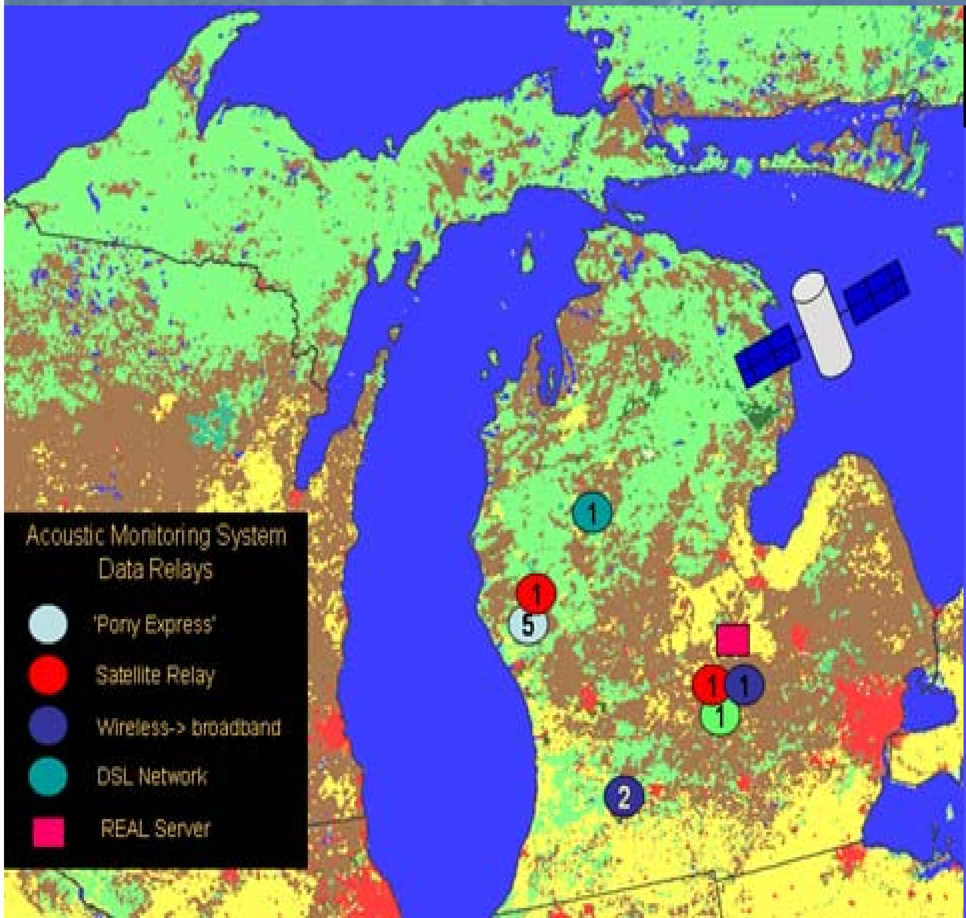
| Index | Ratio | Percentage |
|---|---|---|
| *Anthrophony* | $\alpha_r = \left(\frac{\alpha}{\sigma}\right)$<br>$\alpha$ = Mean from 0 to 2 kHz<br>$\alpha_r$ = Ratio of anthropogenic activity mean to grand mean | $\alpha_p = \left(\frac{(L1+L2)}{\sum 11 Levels}\right) \times 100$<br>$\alpha_p$ = Percentage of activity in the anthrophony band |
| *Biophony* | $\beta_r = \left(\frac{\beta}{\sigma}\right)$<br>$\beta$ = Mean from 2 to 11 kHz<br>$\beta_r$ = Ratio of biological activity mean to grand mean | $\beta_p = \left(\frac{\sum L3 to L11}{\sum 11 Levels}\right) \times 100$<br>$\beta_p$ = Percentage of activity in the biophony band |
| *Geophony* | $\gamma_r = \left(\frac{\gamma}{\sigma}\right)$<br>$\gamma$ = Mean from 8 to 11 kHz<br>$\gamma_r$ = Ratio of geological activity mean to grand mean | $\gamma_p = \left(\frac{\sum L8 to L11}{\sum 11 Levels}\right) \times 100$<br>$\gamma_p$ = Percentage of activity in the geophony band |
| *Activity* | $\rho = \left(\frac{\beta}{\alpha}\right)$<br>$\rho$ = Ratio of biological to anthropogenic activity | **Global Variables**<br>L = 1 kHz level<br>$\sigma$ = Mean value of entire signal (Grand Mean) |

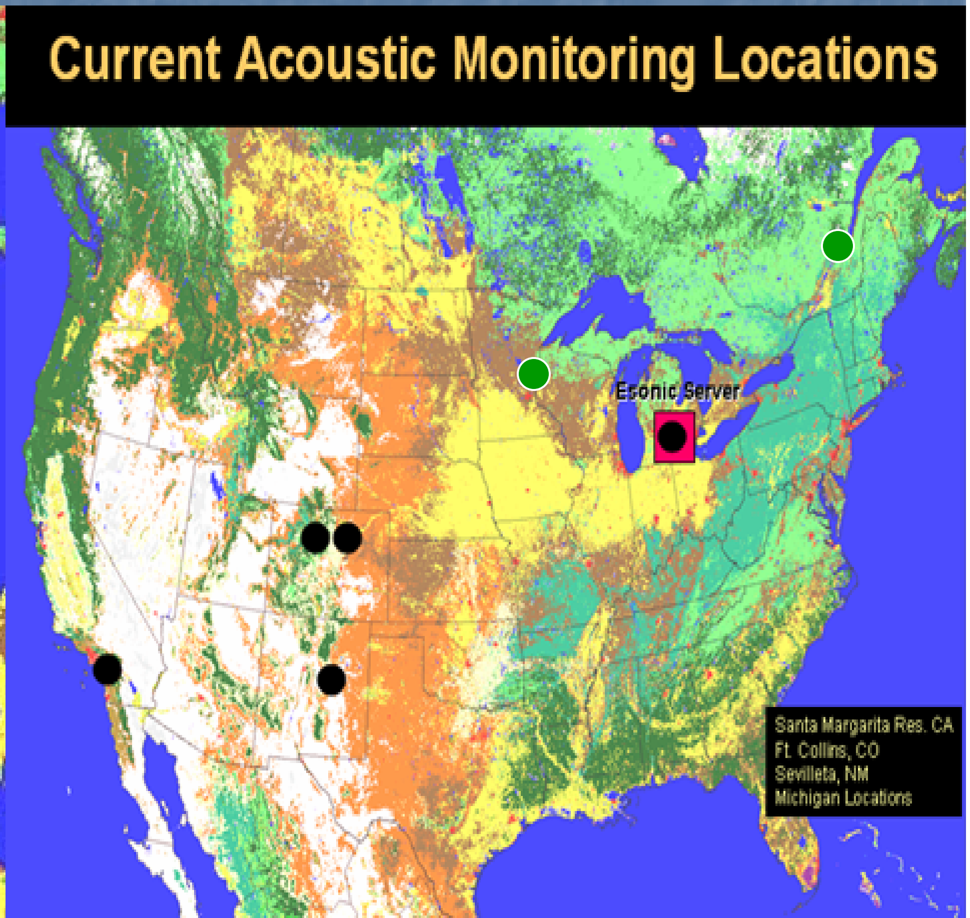
# Framework for Environmental Acoustic Monitoring

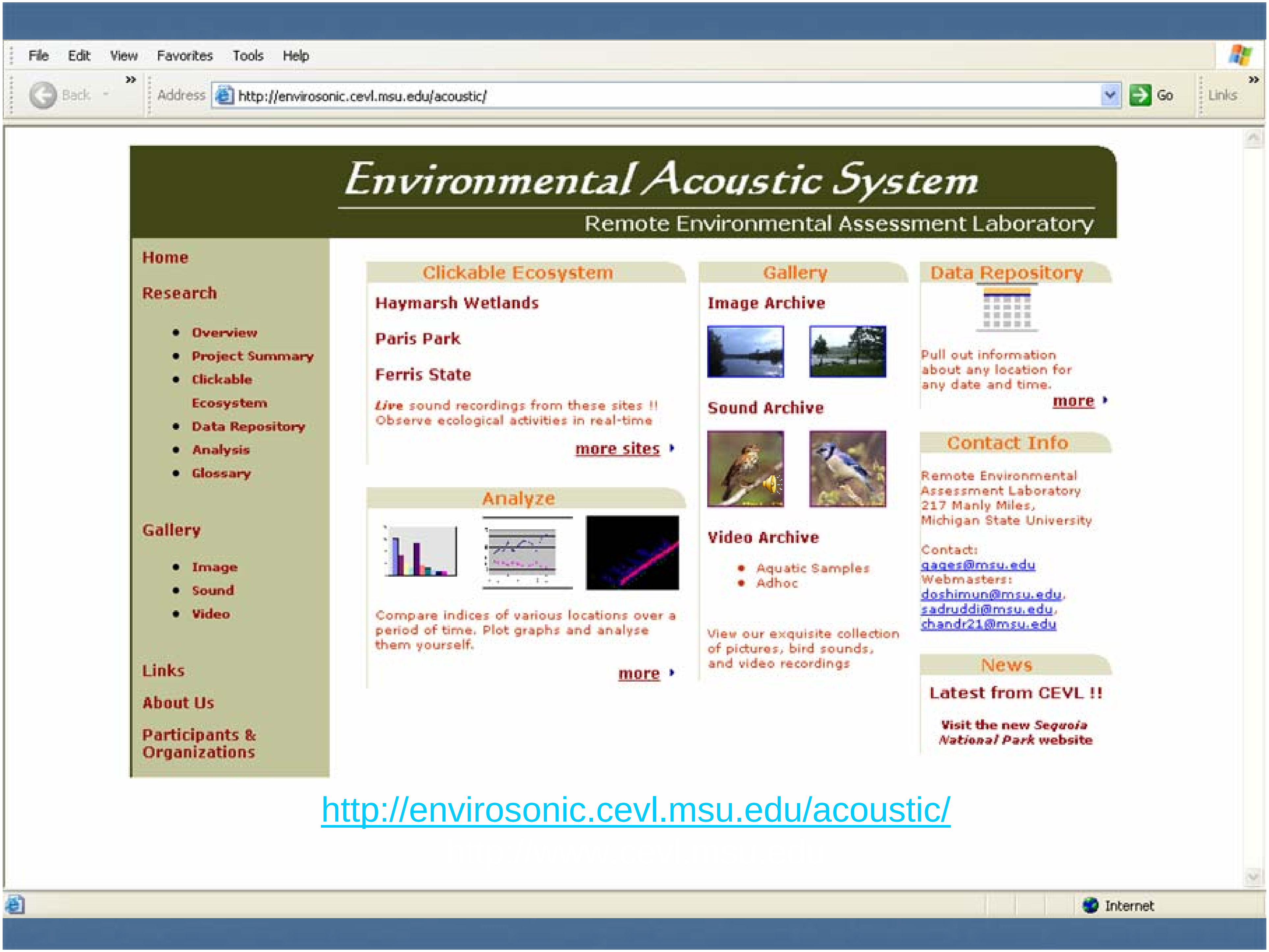


# Automated Acoustic Monitoring Locations

(Sample rate: 30 seconds every ½ hour and transmitted to MSU server)






http://envirosonic.cevl.msu.edu/acoustic/

# Gordon Trutes Residence Site Characteristics

## Audio File Characteristics

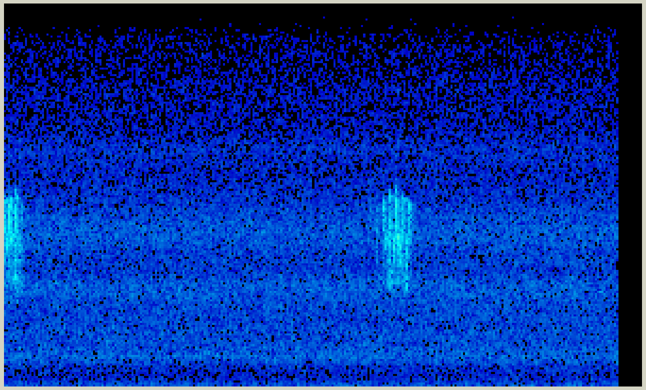
| | |
|---|---|
| **Recording Time** | *6/3/2004 7:30:30 AM* |
| **Recording Location** | *Gordon Trutes Residence* |
| **Coordinates (Lat, Lon)** | *( 43.74876 , -85.39826 )* |
| **Land Use Class** | *Forest Wetlands* |
| **County, Twp, State** | *Big Rapids, Mecosta , MI* |
| **System Date/Time** | *6/11/2004 9:26:24 AM* |

*Clickable Ecosystem Concept* ***Glossary of Terms***

**Site Location**

## Audio File Analysis

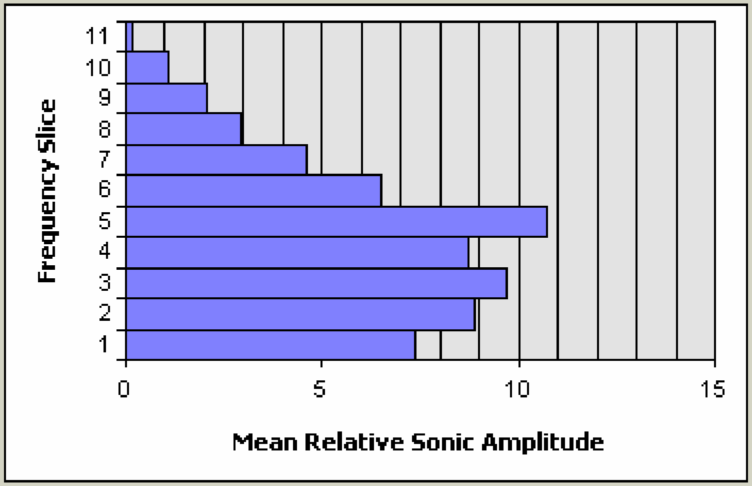
**Sonogram**



**Click on image (sonogram) to hear sound**

Click here to view the data

**Sonic Amplitude in each Frequency Slice**



# Summary

- Standardized measurements and methods permits comparison within and between soundscapes.
- Dividing a spectrogram into frequency domains provides ability to develop ecosystem stressor and indicator indices.
- Quantify environmental acoustics for interpretation of soundscape meaning

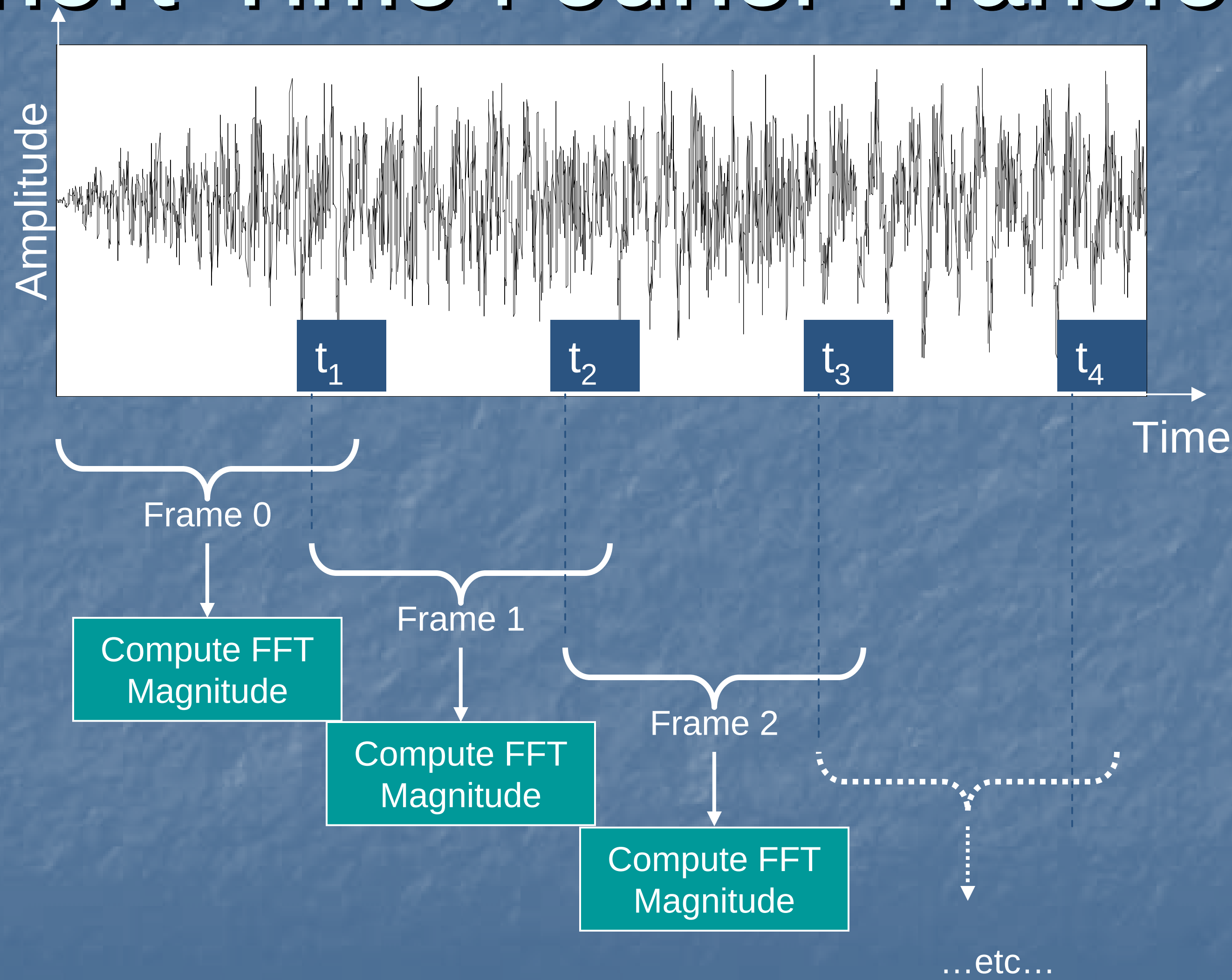
# Summary (cont.)

- Automation provides an ability to analyze and interpret soundscapes at times not usually monitored.
- Linking soundscapes and landscapes via remote sensing provides mechanism to scale to region
- Developing soundscape system demonstrates potential for other sensors

# Acoustical Detection

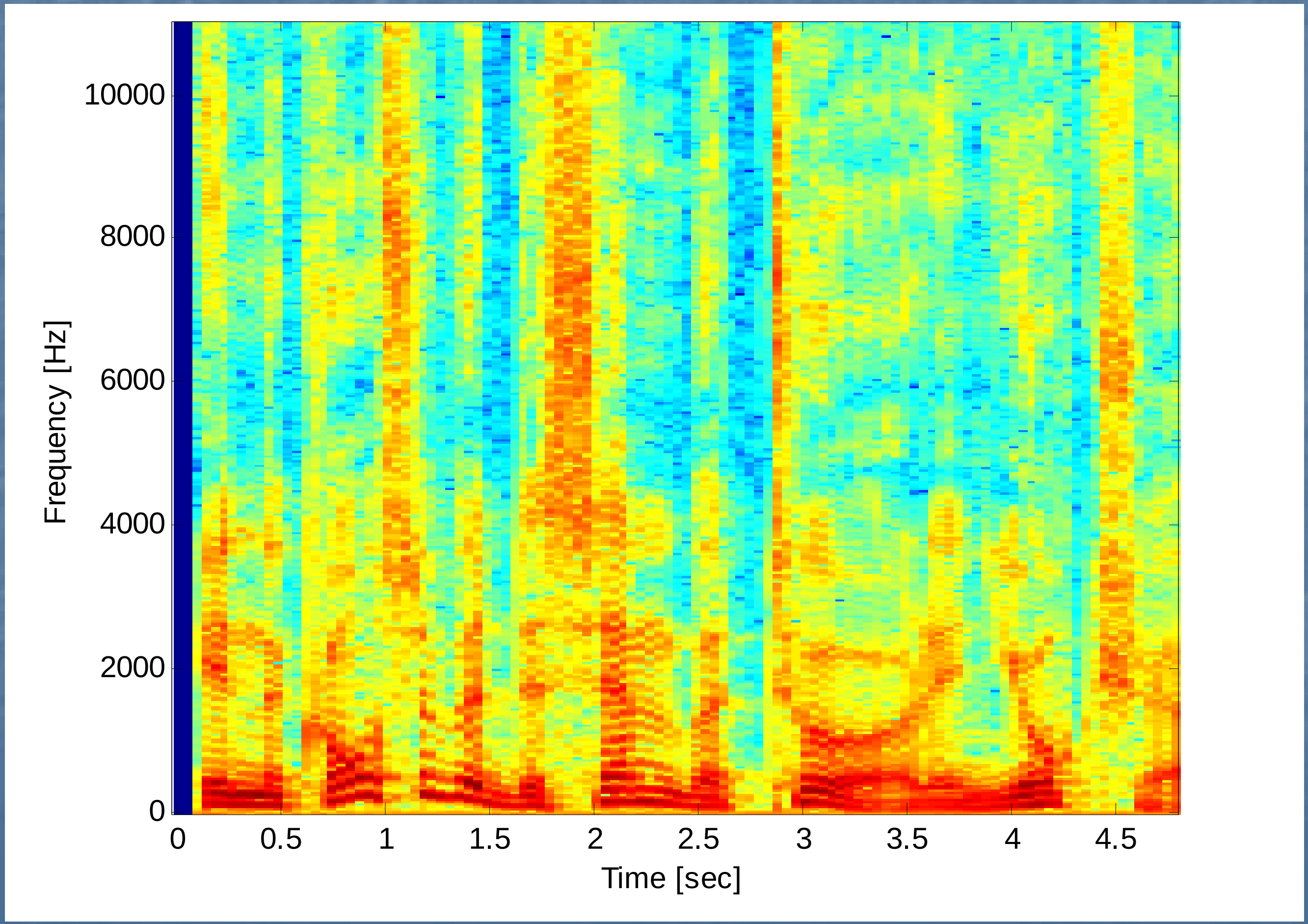
- Time-Variant Spectral Analysis
  - Short-time Fourier transform (STFT)
  - Separate acoustic signal into a sequence of overlapping sections, or *frames*
  - Typical frame length: 20-40 ms
  - View result as amplitude & frequency vs. time (spectrogram), or find *spectral peak tracks*
- After *detection*, need to *classify*

# Short-Time Fourier Transform



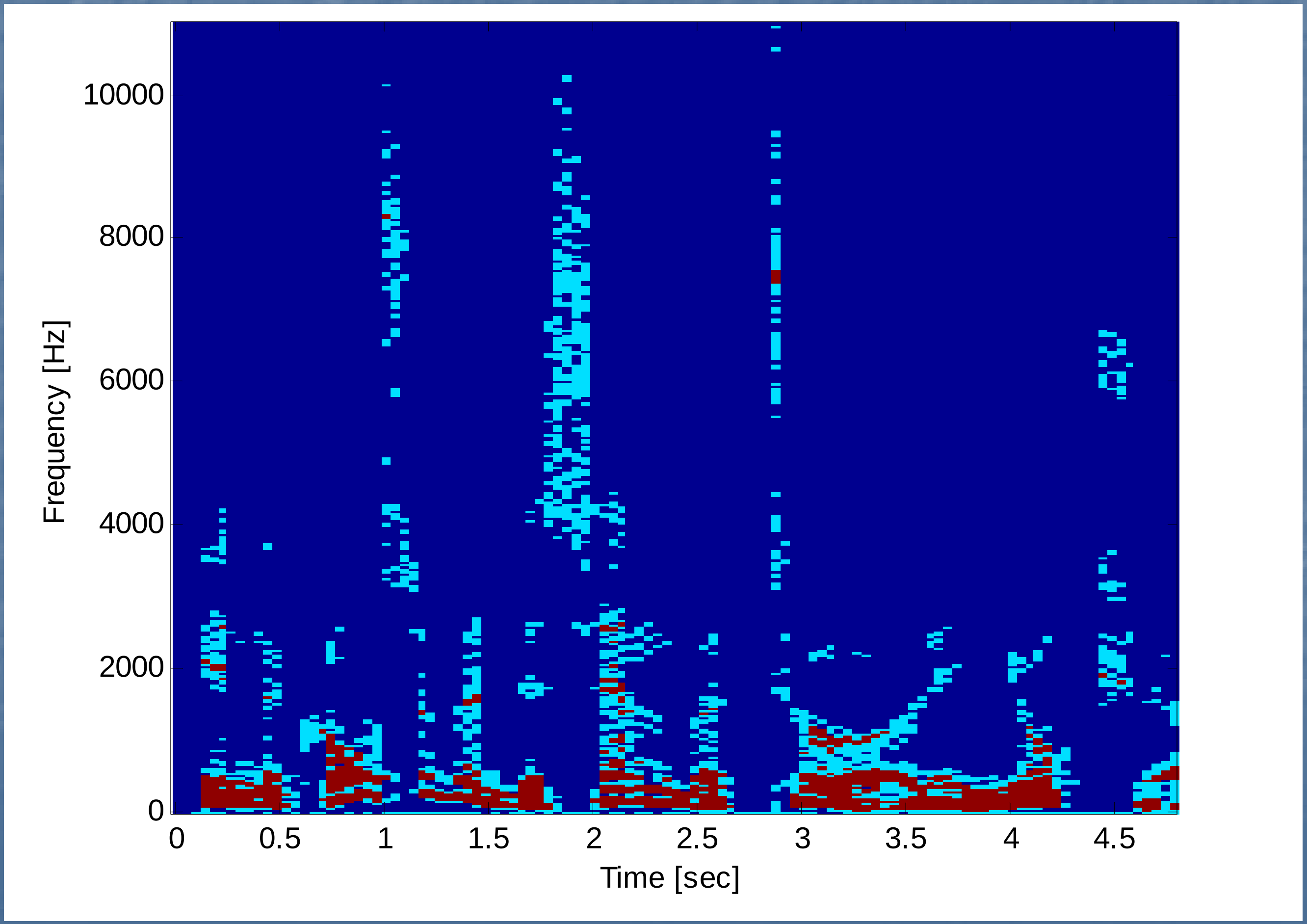
# STFT Spectrogram

- Spectral energy as a function of time



# Peak Track Analysis

- Follow only spectral peaks frame to frame



# Acoustical Classification

- Pattern matching between measured time-variant spectrum and reference templates
- Easy for human brain, hard for computers
- Approaches:
  - Segmentation and warping
  - Model-based analysis
  - Peak track similarity measures
  - Map-seeking circuits
  - etc.

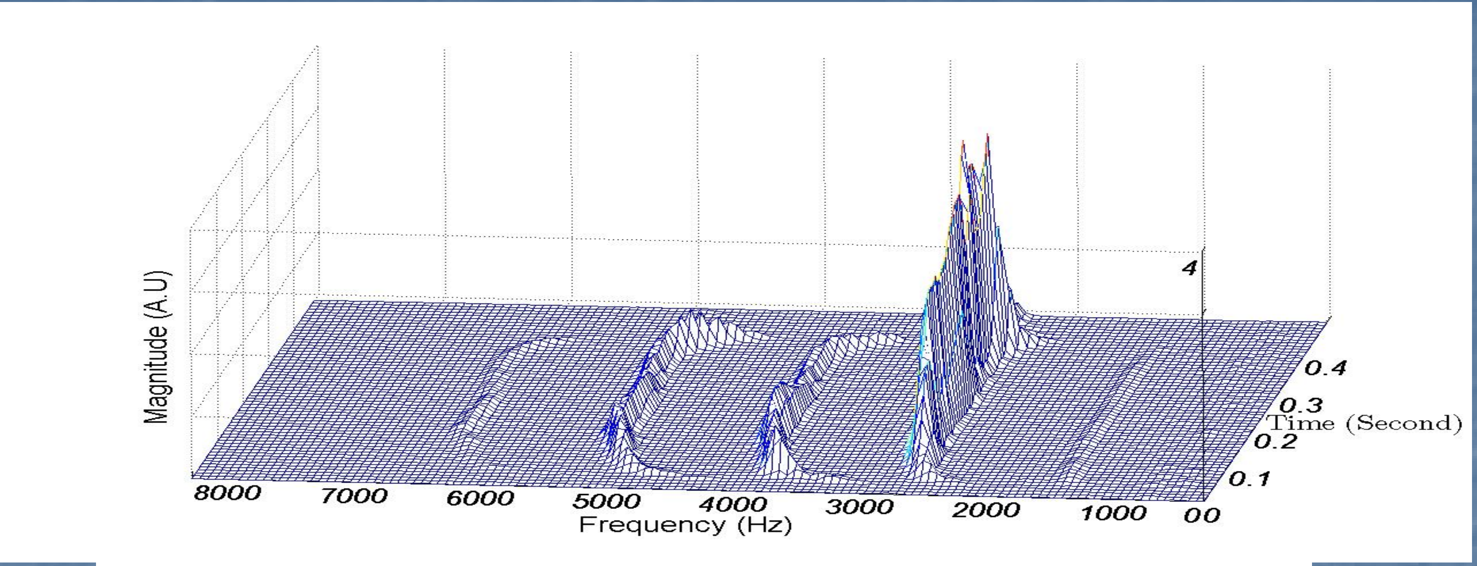
# Example Application: Bird Strikes

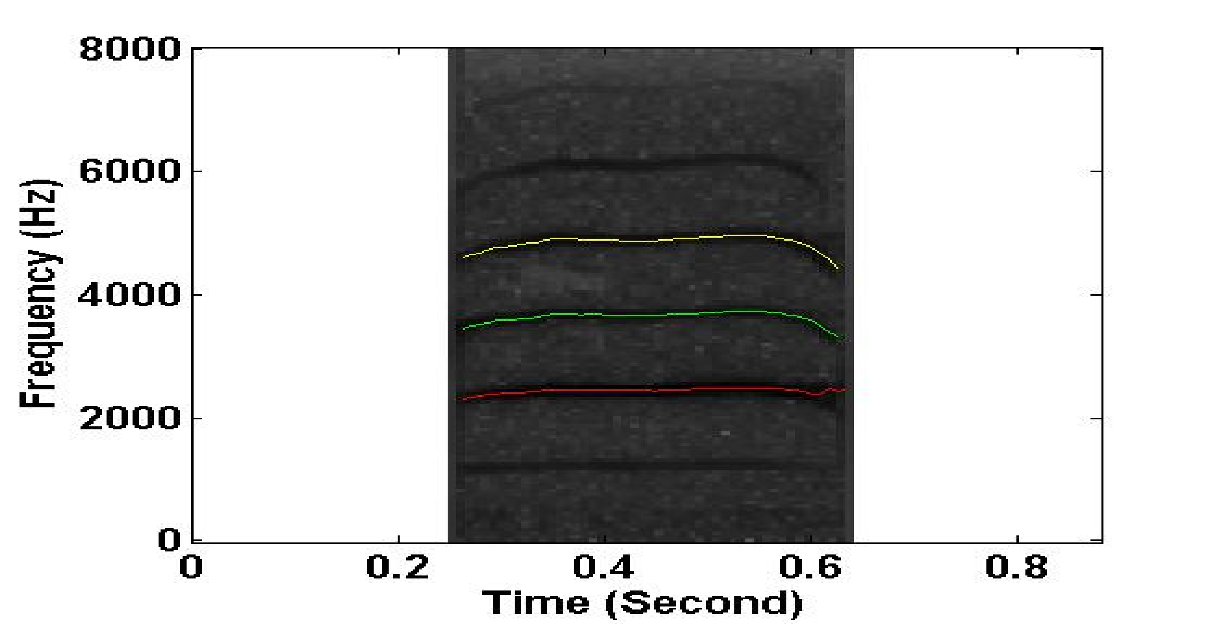
- Bird strikes are estimated to cost US $300 million in damage and downtime
- Various means are available to *detect* the presence of birds, but *classifying* the threat requires identifying the species
- One approach: classification of bird vocalizations

# Bird Vocalization Identification

- Requirements:
  - Achieve high accuracy with small database
  - Reasonable computational complexity
  - Capable of near real-time classification
  - Reliable even in noisy airport environment

# Peak Track Matching Strategy



# Spectral Peak Track Method

- Spectral peak track search:
  - Coarse search (McAulay and Quatieri procedure )
  - 1st fine search (Discontinuous, short or inconsistent)
  - 2nd fine search (Peak track number and order)
- Feature extraction: 12 parameters for every track
  - Frequencies and Frequency differences
  - Shape and Trend
  - Relative intensity
  - Duration
- Target and classification:
  - Represents the desired syllable in the best possible manner
  - Compares an unknown bird sound with targets of bird species

# Syllable Identification Experiment

- Bird Species
  - 12 natural bird species (crow, goose, swan, gull, bluejay, etc.)
  - 16 synthesized bird species (tonal, harmonic, inharmonic)
- Bird Sound Format
  - Single channel
  - Sampling frequency: 16 KHz
  - Quantization: 16 bits
- Syllable Format
  - *Manual* syllable extraction from the bird sound
  - Silent onset and release at syllable boundaries

# Classification Results

| S/N (dB) | Natural Sounds (10 instances of 12 species) Error Tally: | Natural + Synthetic Sounds (10 instances of 28 sound classes) Error Tally: |
|---|---|---|
| Clean | 1 / 120 | 2 / 280 |
| 30 | 1 / 120 | 2 / 280 |
| 24 | 1 / 120 | 2 / 280 |
| 18 | 1 / 120 | 2 / 280 |
| 12 | 0 / 120 | 1 / 280 |
| 9 | 2 / 120 | 3 / 280 |
| 6 | 3 / 120 | 4 / 280 |
| 3 | 5 / 120 | 5 / 280 |

# EcoEars

## Ecological & Environmental Acoustic Remote Sensor

Portable Monitor

Permanent Monitor

# Grand Teton National Park – Permanent Monitors

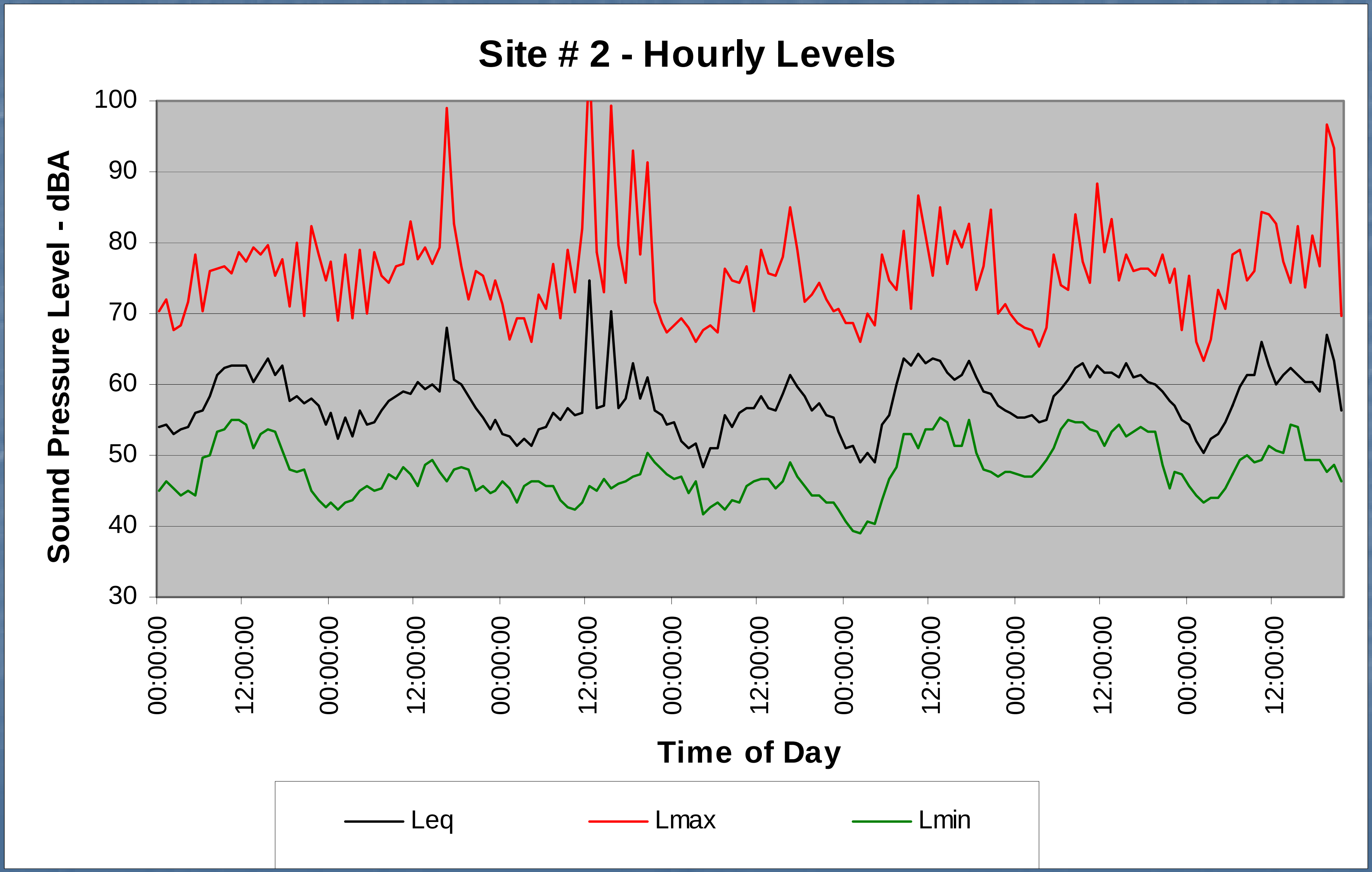
# Semi-Permanent Monitor

# Permanent & Portable Equipment Types

DataLogger and RF modem

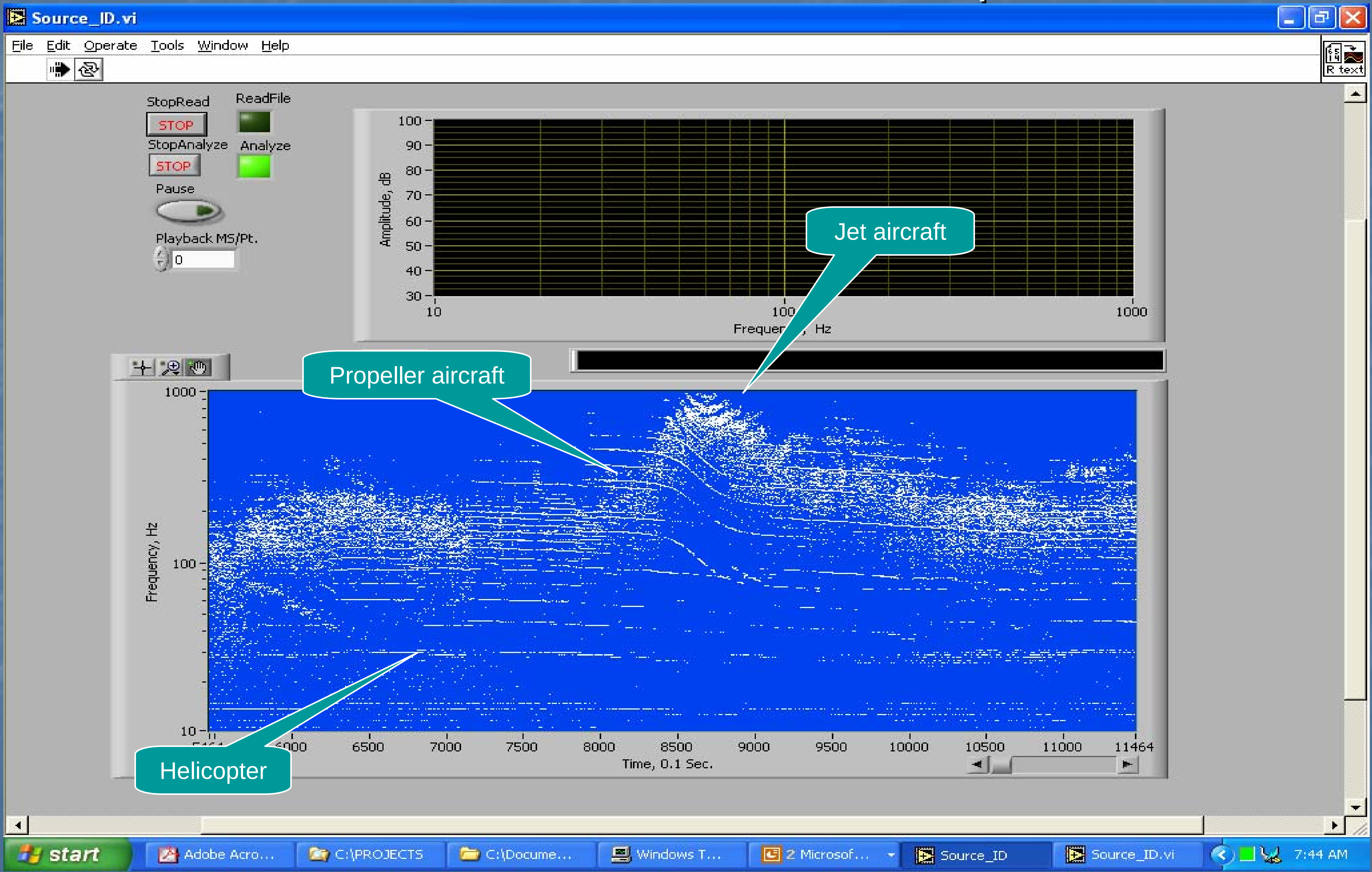

MP3 Recorder

# Typical Sound Level Report (use to monitor trends)



# Grand Canyon National Park

## Automated Identification of Mechanical/Repetitive Sounds



# EcoEars System Specifications

- Low power data acquisition device capable of collecting and transmitting the following information:
  - Audio data (WAV or MP3 file format)
  - Environmental data (wind speed & direction, air & soil temperature, solar radiation and rain)
  - On-board GPS for precise timing of data and location of sensor
  - Data storage to hard drive and/or compact flash

# EcoEars System Specifications (cont.)

- Wireless communication
- Real-time tracking/identification of mechanical sounds
- Low cost - about $1000 per unit without the sensors
- Real-time identification of animal sounds (some is done currently and more in the FUTURE)

## Benefits of the EcoEars System

- Acoustic signals provide information on wildlife and habitat trends/changes
- Allows the users to document current conditions
- Weather information provides additional insight
- Monitors noise levels in real-time
- Tool to remotely detect and monitor the presence/absence of animal species
- Ability to monitor noise impact from sources like military equipment/aircraft/vehicles/etc
- Non-invasive type of monitoring (minimizes biased measurements and reduces labor)
- Long term acoustic recordings can be used for post-processing by other scientists (if properly documented and calibrated)

# Thank You