Passive Audio Amplification for Wildlife Recording System

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Project Background

Problem Description

- More than half of U.S. bird species are threatened by climate change
- To track migrations and population numbers, need large scale data collection on songbirds in U.S. and remote regions of the world
- Documenting the activity of songbirds is a challenge with high costs for data collection and storage
- Backyard Brains, in conjunction with MDP, developed a device to collect and store audio data to identify bird songs, insects, and rainfall

[1]

[2]

[1] Image by Benjamint444 - Own work, GFDL 1.2
theamazonrainforestanimals.blogspot.com/2018/04/amazon-rainforest-animals-scarlet-macaw.html
[2] Image, Andean Cock-of-the-Rock
www.galapagosunbound.com/birds-ecuador

MDP Project: Sponsor and Goals

Backyard Brains

- Based in Ann Arbor
- Citizen science company

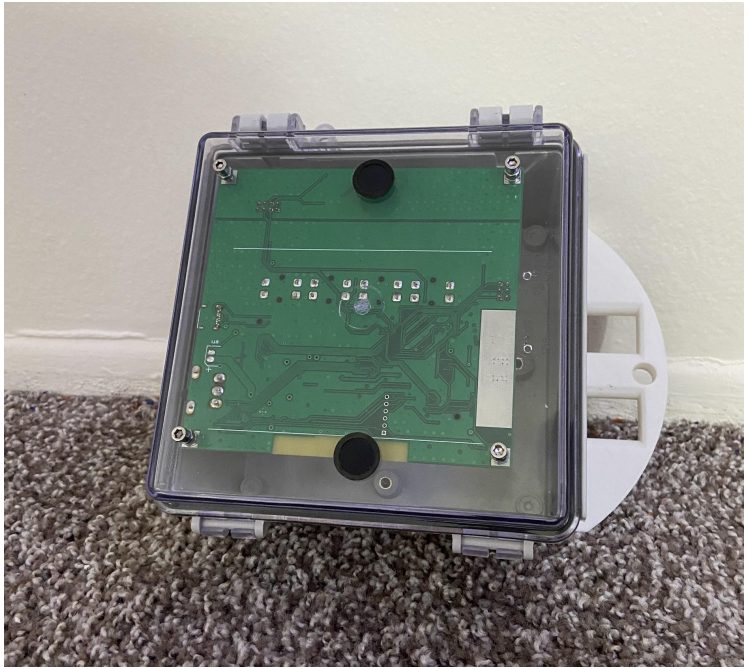
Project Goals

- Study bird species affected by climate change
- Develop device to record data about bird songs
- Inexpensive product for consumers with device performance for researchers

RISE Project Origin

Audio Recording Issues

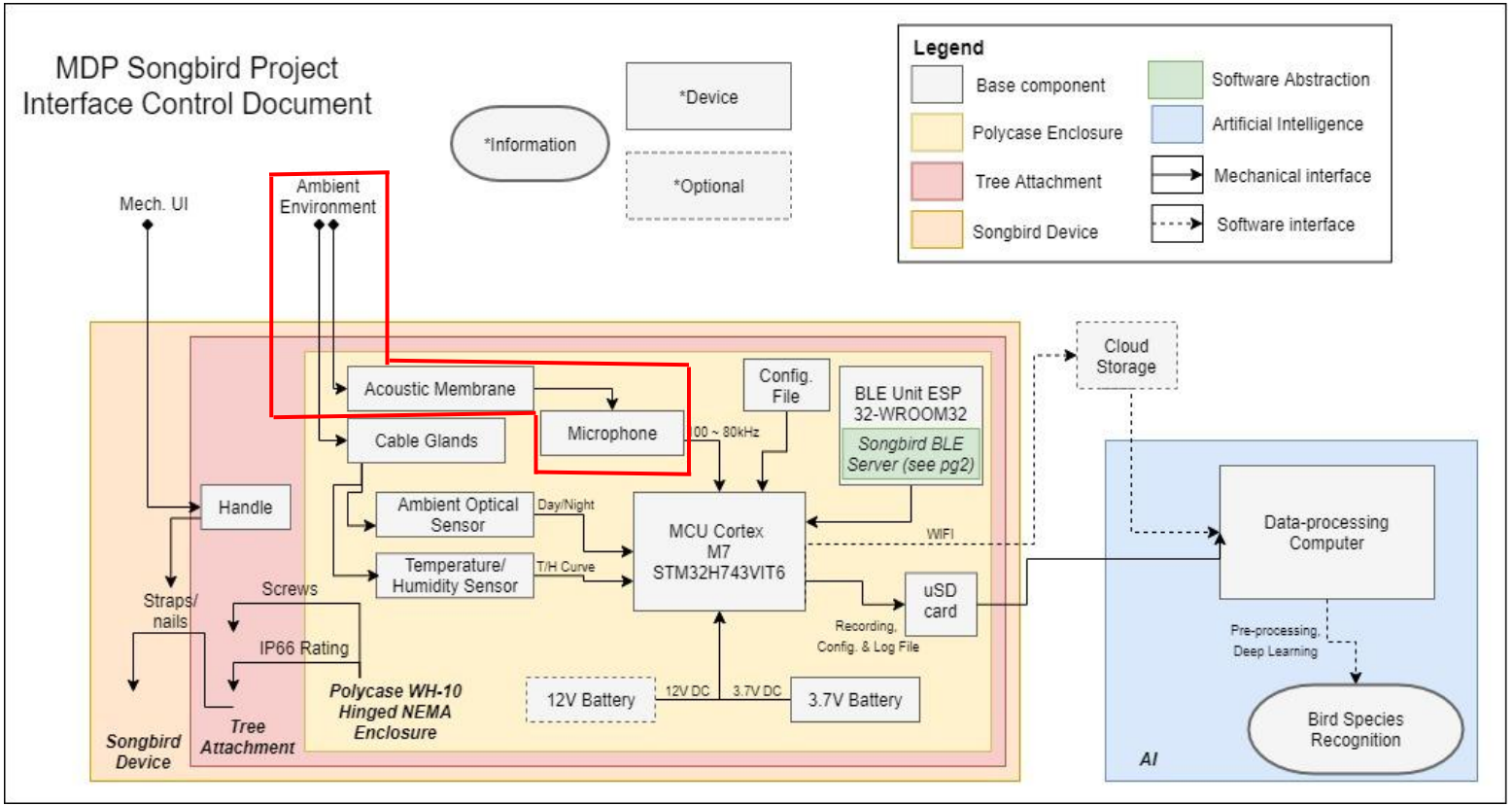
- During device development of WN21 team found:
  - Enclosure significantly damped recordings
  - Benefits of the enclosure outweighed this issue
- Generated need for inexpensive audio amplification
  - New microphone too expensive
  - Agreed upon that passive audio amplification plausible alternative



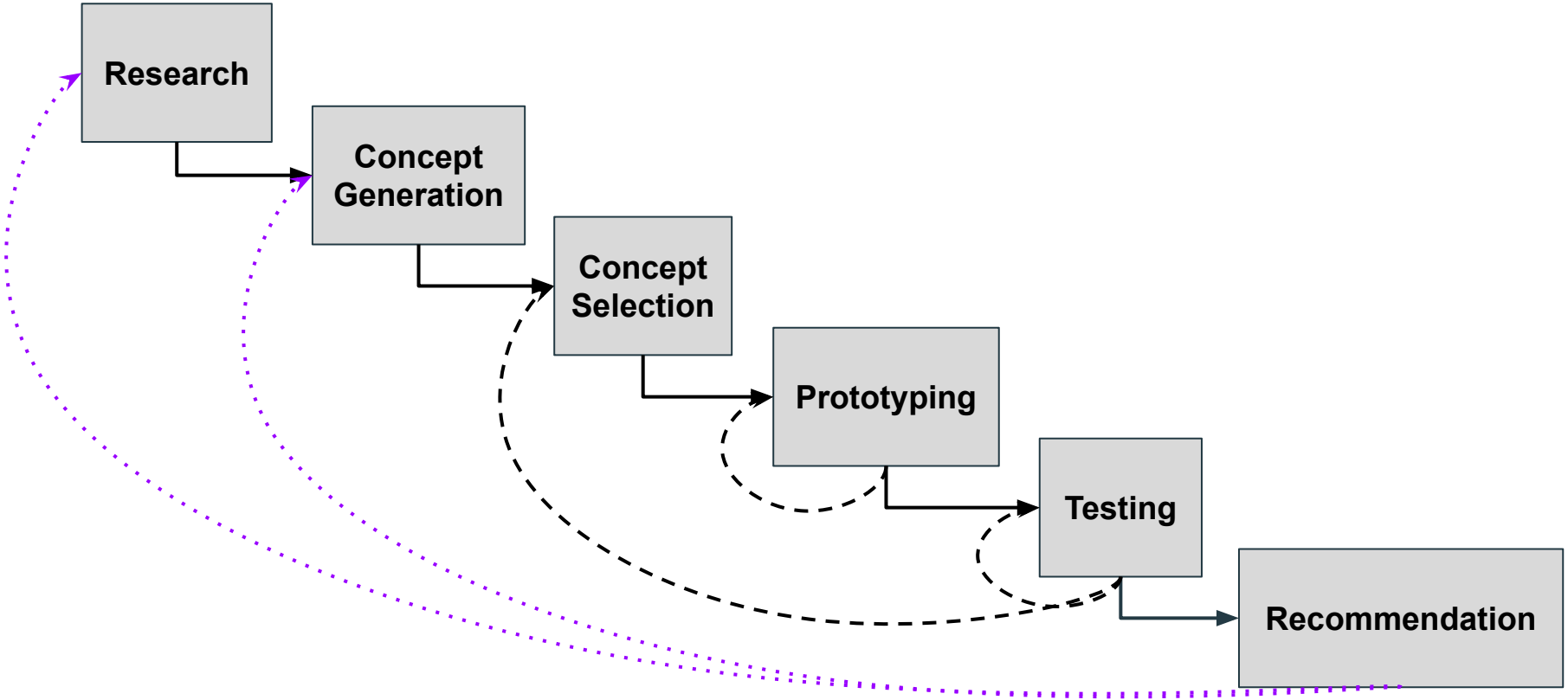
RISE Project Goals

1. Passive audio amplification research
2. Concept generation of numerous potential solutions
3. Rapid prototyping of multiple concepts for evaluation and data collection
4. Develop a testing plan for the passive sound amplifier prototypes
5. Concept evaluation using collected testing results
6. Finalize amplifier design and recommendation

Device Schematic and RISE Scope



Project Design Process

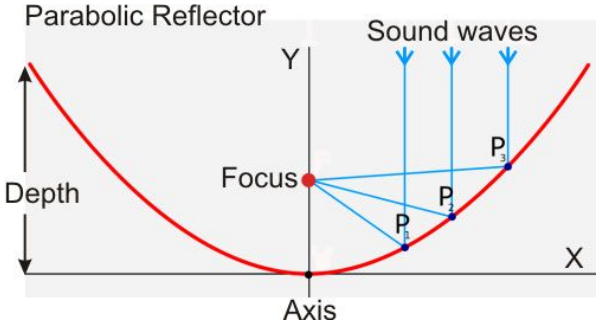


Stage 1: Research

Passive Amplification Research

Parabolic mic ⟶ sounds are too weak for normal microphones, highly directional microphone is needed, boosting sounds for human ear [1]

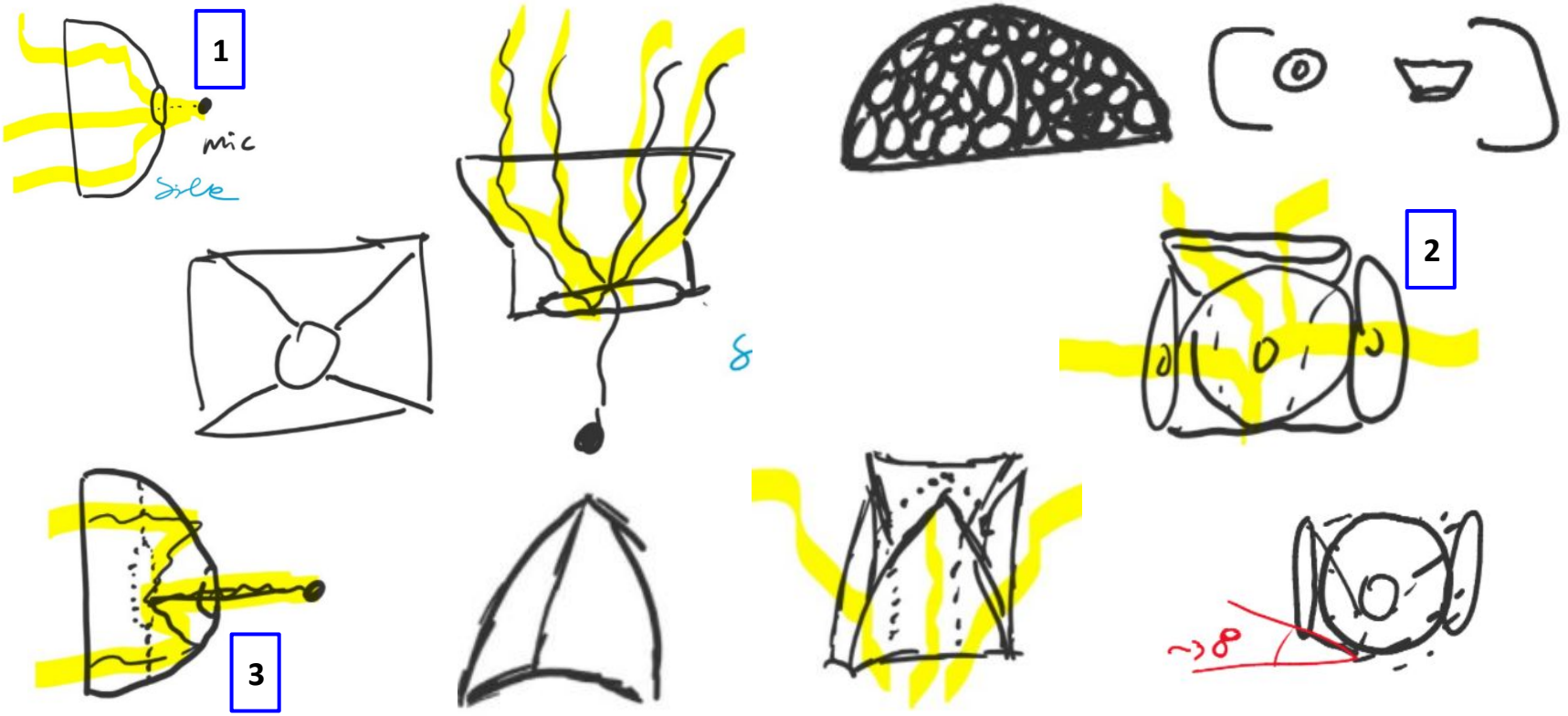
- Benefits:
  - Bird w 2kHz call will appear 20x closer and bird with 5kHz voice will appear 40x closer [2]
- Drawbacks:
  - Parabolic mics sensitive to sounds in one direction [2]
  - Not capable of full fidelity recordings ⟶ at 20Hz parabolic mic needs to be 17m across [2]



[1] Wildtronics, LLC, "Parabolic Microphone: Theory, Use, Performance," 2021 www.wildtronics.com/parabolicarticle.html
[2] Creative Field Recording, "Review: Wildtronics Parabolic Microphone Dish", July 2019 www.creativefieldrecording.com/2019/07/24/review-wildtronics-parabolic-microphone-dish/
[3] Photo by Leah Monson, USGS, UMESC, 2004 Accessible: www.umesc.usgs.gov/images/photos/scientists/parabolic_microphone_lm04.jpg

Stage 2: Concept Generation

Amplifier Concept Generation



Stage 3: Concept Selection I

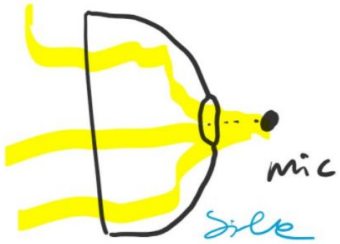
Concept Selection Criteria

Criteria:

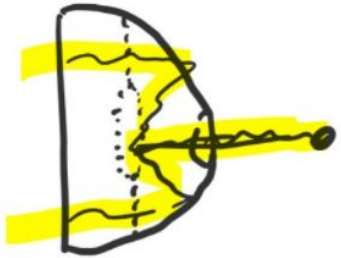
- Researched Functionality (3)
- Complexity (2)
- Creativity (1)
- Design Preferences (1)

Weight	3 - Critical for success
	2 - Contributor to success
	1 - Not likely important to success
Score	3 - Large potential
	2 - Mid-potential
	1 - Low potential
	0 - No potential

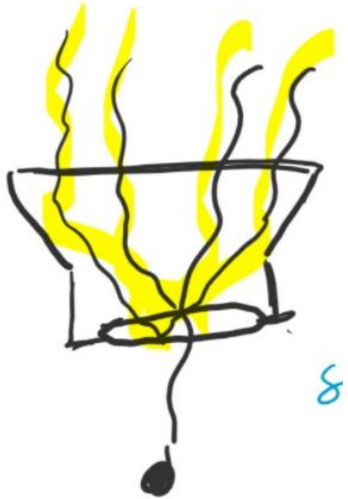
Selected Amplifier Concepts



Parabolic Mic



Parabolic Mic w Reflector

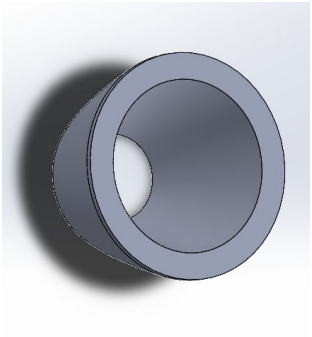


Round Funnel

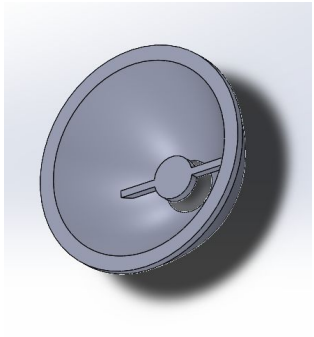
Dog's ears

Stage 4: Prototyping

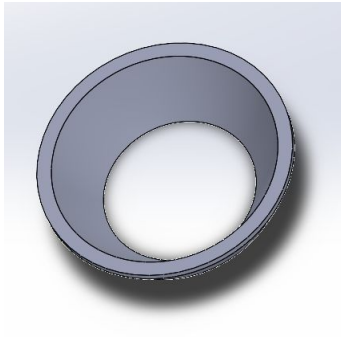
Amplifier Prototype CAD



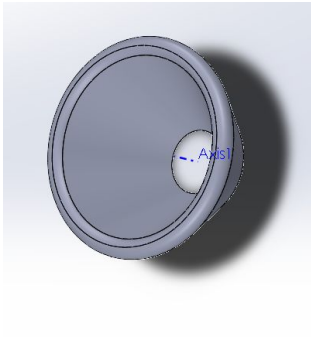
Parabolic



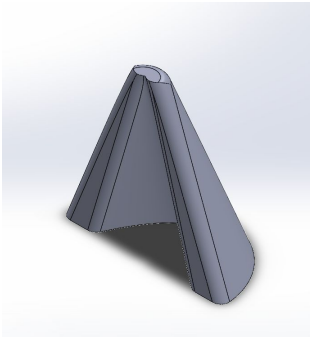
Parabolic Reflector



Parabolic Audio Moth (AM)



Funnel



Dog Ear

Notes:

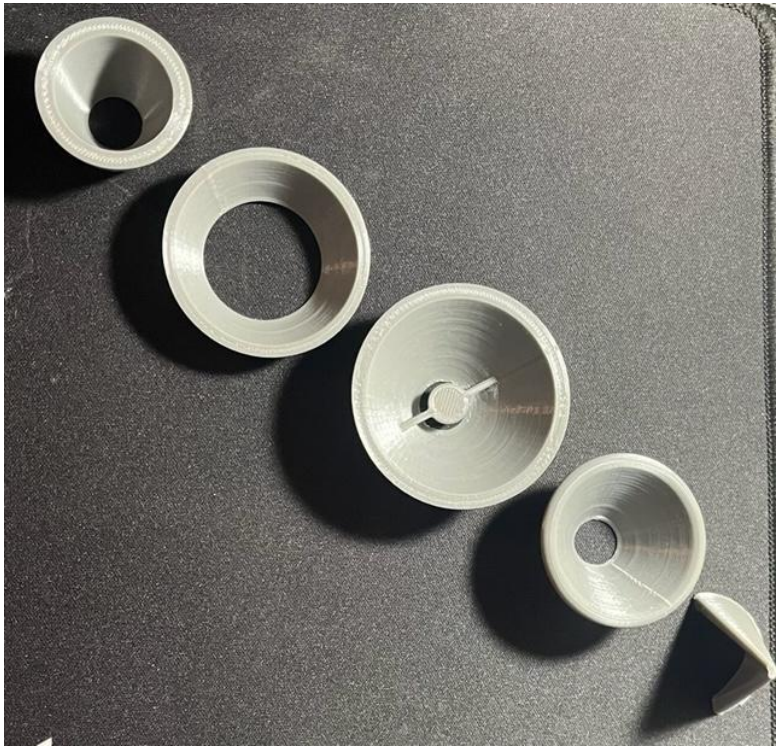
- Parabolic Audio Moth (AM) design was added since selection from competitor's device (seen at right)
- Each CAD model is ~20mm in height

Amplifier Prototype Manufacturing

Preliminary prototypes printed with PLA (shown at right)

Worked with Kaylla Cantilina at C-SED to determine improved prototyping materials:

- Harder materials better
- SLA (Resin) printing
  - No printing layers
  - Cost-effective
  - Ease of manufacturing



Stage 5: Testing

Amplifier Performance Testing

Testing Scenarios:

1. No Case
2. Case (No Amp)
3. Parabolic Amp
4. Parabolic Audio Moth Amp
5. Parabolic Reflector Amp
6. Funnel Amp
7. Dog Ear Amp (Vertical Orientation)
8. Dog Ear Amp (Horizontal Orientation)

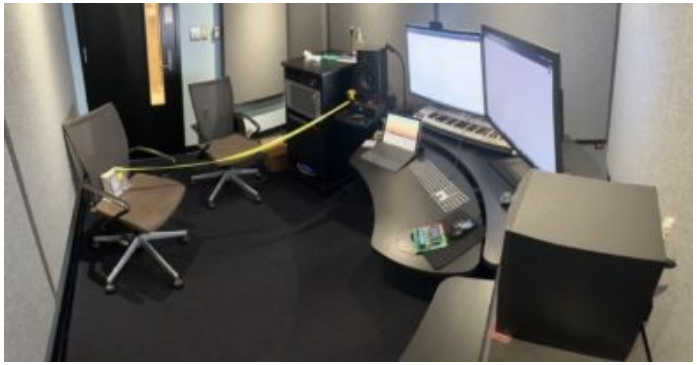
Testing 1 - Bird Call Testing

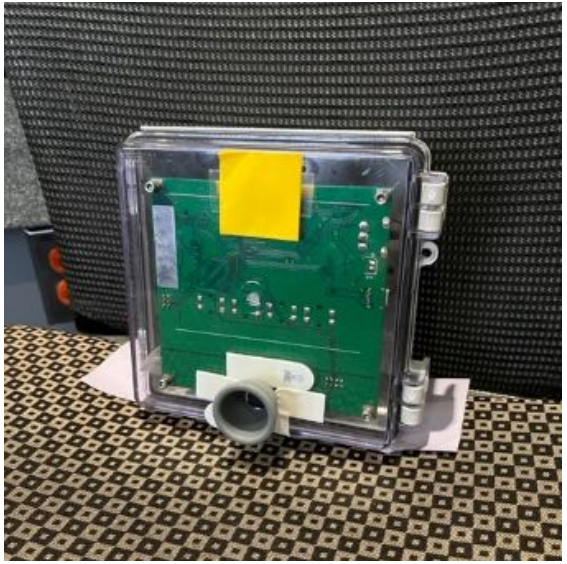
- Played four (4) different bird call audio files
- Measured peak amplitude (dB) of each testing scenario

Testing 2 - Speaker Sweep Testing

- Played 20Hz - 20kHz audio sweep from computer
- Plotted frequency response of each testing scenario

Amplifier Performance Testing Setup





Bird Call Testing

	No Case	Case (No Amp)
Bird Call	Peak Amplitude (dB)	Peak Amplitude (dB)
Olive Warbler	-17.32	-27.01
Robin	-11.73	-22.68
Blue Jay	-20.95	-25.69
Parrot	-15.27	-24.21

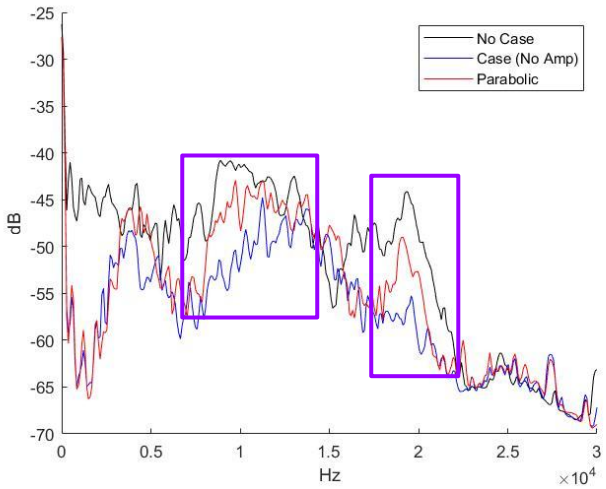
Bird Call	Max Positive %Change	Amplifier Used for Max
Olive Warbler	31.14%	Funnel
Robin	42.77%	Dog Ear (Vert)
Blue Jay	14.25%	Parabolic
Parrot	17.72%	Parabolic Reflector

Findings:

1. Significant damping effect of the enclosure with bird calls
2. Amplifiers are performing as intended
3. Bird call testing inconclusive for amplifier selection

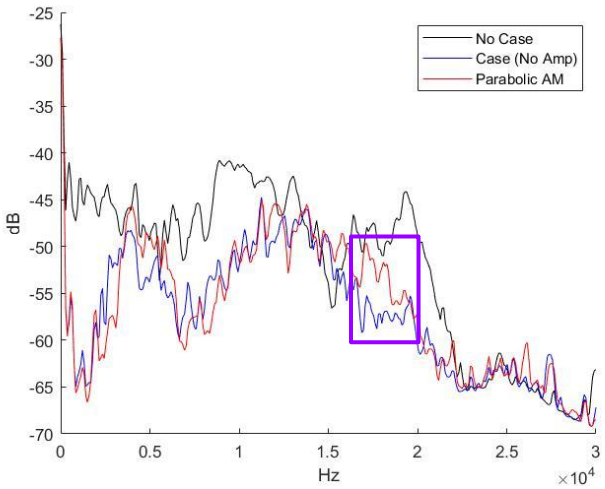
Computer Speaker Frequency Sweep Testing

Parabolic Amp Freq. Response



PASS

Parabolic AM Amp Freq. Response

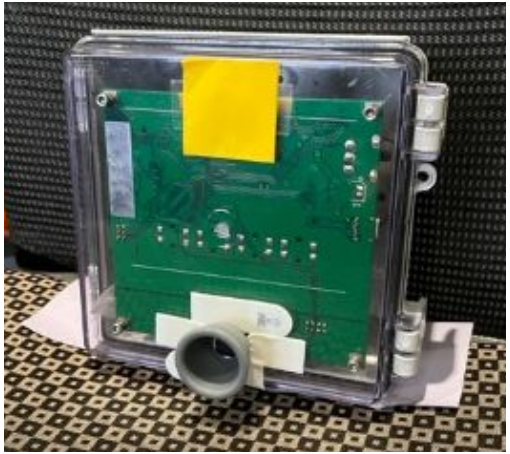


FAIL

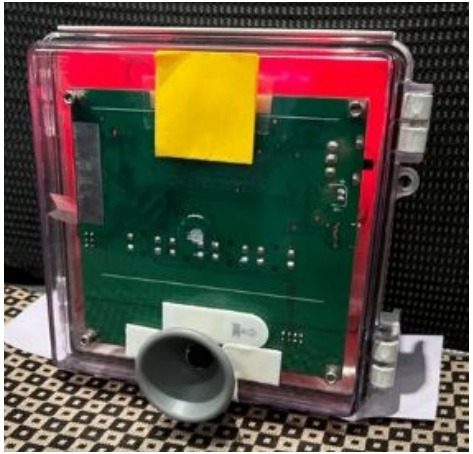
Findings:

1. Most amplifiers performing as intended
2. Results can be used for concept filtering
3. Further ultrasonic (>20kHz) testing required with different method

Amplifier Filtering Results



Parabolic Amp



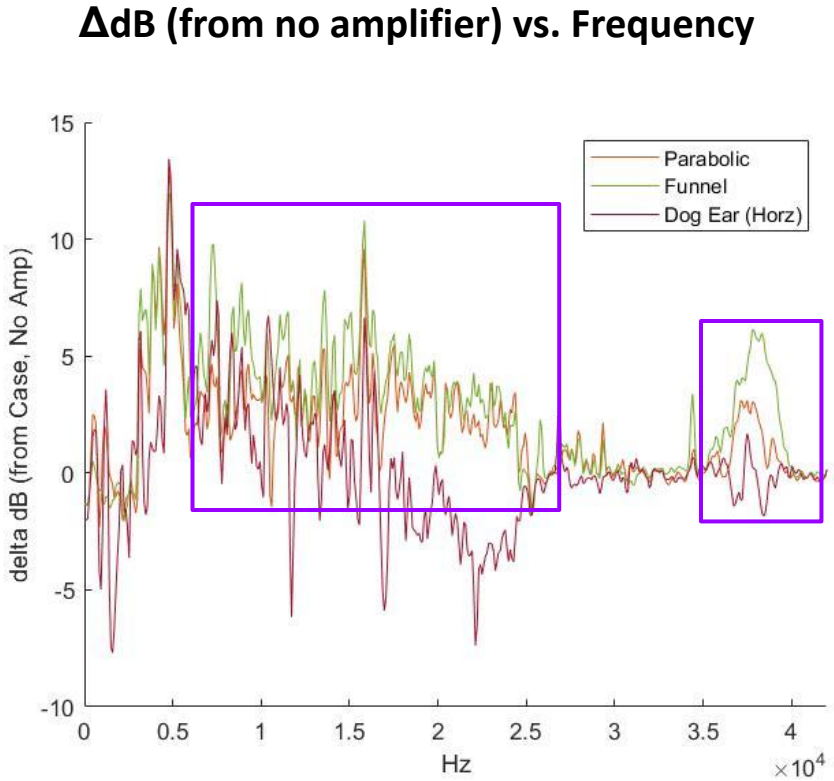
Funnel Amp

Dog Ear (Horizontal)

Function Generator Frequency Sweep Testing

Testing 3 - Function Generator Testing

- Played 10Hz - 40kHz audio sweep from function generator
- Plotted ΔdB vs. frequency for each amplifier compared to case with no amplifier



Stage 6: Recommendation

Recommendations and Final Device Prototype

Final Recommendation

- Use of **Funnel Amplifier** in the field for passive audio amplification

Recommended Next Steps

- Iteration of concept generation phase (additional parabolic shapes)
- Controlled testing iteration with new concepts
- Field testing with different amplifiers

Acknowledgments

RISE:

- Professor Shanna Daly and Robert Loweth

MDP:

- Lin Van Nieuwstadt
- Andrew Cao, Noah Lichtenberg, Kane Sweet, Igor Veklenko, Kefan Zhou

Backyard Brains:

- Greg Gage, Wenbo Gong, and Miroslav Nestorovic

Contact Information

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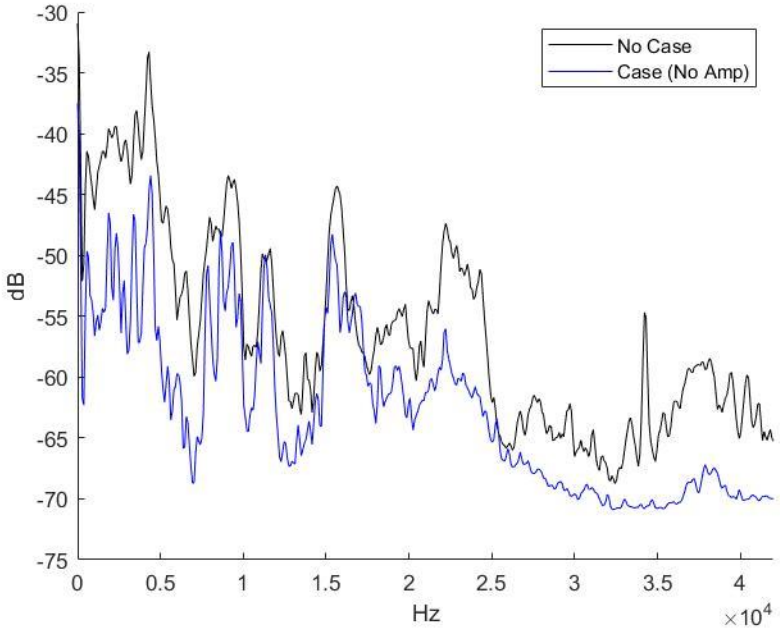
Recording Damping Quantified

Utilized a function generator to produce a 10Hz - 40kHz audio sweep

Plotted frequency response data to visualize and quantify the effect of the enclosure on recording amplitude

No Case & Case (No Amp) Frequency Response



Amplifier Concept Selection

Name		Researched Functionality	Complexity	Creativity	Design Preference
	Weight →	3	2	1	1
Parabolic Mic		3	3	1	1
Parabolic Mic w Reflector		2	2	3	1
Funnel		2	3	1	0
Square Funnel		1	3	2	0
Dog's Ears		2	2	3	1
Quad Funnels		1	1	2	0
Cube Funnel		2	1	2	1
Funnel + Dog's Ears		1	0	2	0
Pockmarked Mini-Funnel		0	0	3	0
		High score = high functionality potential	Low complexity = high potential = high score	Highly creative = High Score	

Bird Call Testing

	No Case	Case (No Amp)
Bird Call	Peak Amplitude (dB)	Peak Amplitude (dB)
Olive Warbler	-17.32	-27.01
Robin	-11.73	-22.68
Blue Jay	-20.95	-25.69
Parrot	-15.27	-24.21

Parabolic	Parabolic AM	Parabolic Reflector	Funnel	Dog Ear (Vert)	Dog Ear (Horz)
Peak Amplitude (dB)	Peak Amplitude (dB)	Peak Amplitude (dB)	Peak Amplitude (dB)	Peak Amplitude (dB)	Peak Amplitude (dB)
-19.56	-21.01	-22.9	-18.6	-18.97	-20.43
-15.54	-18.03	-18.14	-16.2	-12.98	-15.83
-22.03	-23.78	-23.57	-23.39	-23.81	-25.3
-21.73	-24.45	-19.92	-21.96	-23.03	-21.4

Appendix Documents

Bird Call Testing Plan:
https://docs.google.com/document/d/1M9KLAnDRkhVpH_hONTqH3vPULE-y-npLp9ZaE4V4eg8/edit?usp=sharing

Bird Call + Computer Speaker Sweep Setup:
https://docs.google.com/spreadsheets/d/1XfepHQq48t7t2OAuNSgvy4H7ibN1lH8ilNUKYRUoqQ4/edit?usp=sharing

Computer Speaker Sweep Results:
https://docs.google.com/document/d/1aeWaNYwXhXFakbMT9x5uBl2cSSWcEM3wxKdn03z6u7A/edit?usp=sharing

Function Generator Sweep Setup:
https://docs.google.com/document/d/1jQiRbVijyyDziMfjhSZFGlGVR9LpIXE9fOGUOEGOGO0/edit?usp=sharing

Function Generator Sweep Results:
https://docs.google.com/document/d/1cqp6A32-jsnfpslTOIiAwxYJPVq-f0tLTCVgWlDK-Ms/edit?usp=sharing