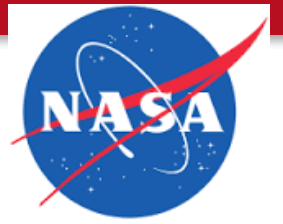
THE OHIO STATE UNIVERSITY

Status of GENETIS

Prof. Amy Connolly, The Ohio State University

Sept. 23, 2024



GENETIS (Genetically Evolving NEuTrIno teleScopes) … and Nebulous

Vision

- To ignite science and engineering breakthroughs through AI advancements

GENETIS (Genetically Evolving NEuTrIno teleScopes) … and Nebulous

Mission

- Accelerate the technology development life cycle of astronomical observatories and radio instrumentation through advancement of AI and computation
- Identify novel designs through AI
  - Accelerate the capabilities of astronomical observatories and radio instrumentation through advancement of AI and computation.

Interdisciplinary, Student-Driven

- AI
- Computer Science
- Engineering
- Astrophysics
- Industry

THE UNIVERSITY OF ARIZONA

REMCOM

MANCHESTER 1824
The University of Manchester

OHIO STATE

JPL
Jet Propulsion Laboratory
California Institute of Technology

UNIVERSITY OF HAWAI'I
MĀLAMALAMA
UA MAU KE EA O KA ʻĀINA I KA PONO
1907

Georgia State University

Beginning tasks (since 2017)

- Begin with
  - Genetic algorithms (GA) to evolve
  - Antenna designs for
  - Ultra-high energy (UHE) neutrino experiments

} GENETIS not limited to these things

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- Branched into two subprojects
  - GENETIS: Standard antenna types - evolve parameters
  - Nebulous: New antenna designs - from scratch

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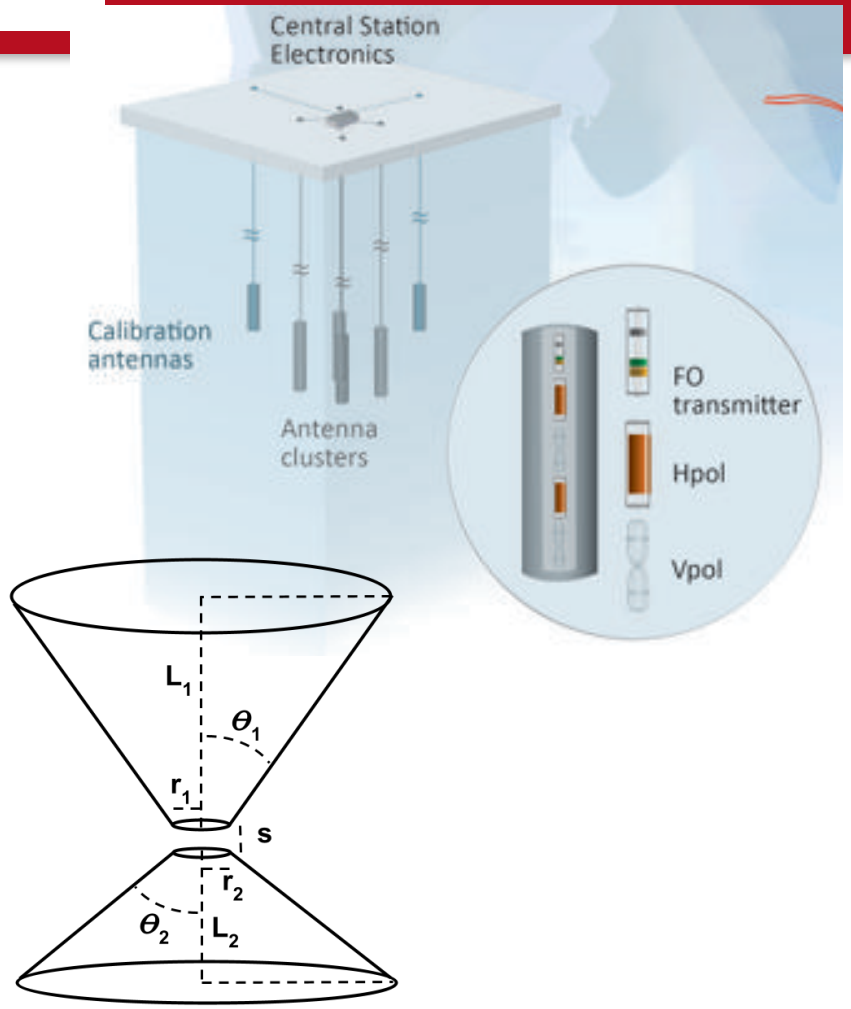
  - GENETIS: Standard antenna types - evolve parameters
  - Nebulous: New antenna designs - from scratch
- Grown organizationally, expanded use cases

This talk

- Results
  - GENETIS
  - Nebulous
- Important developments
- Priorities going forward

GENETIS

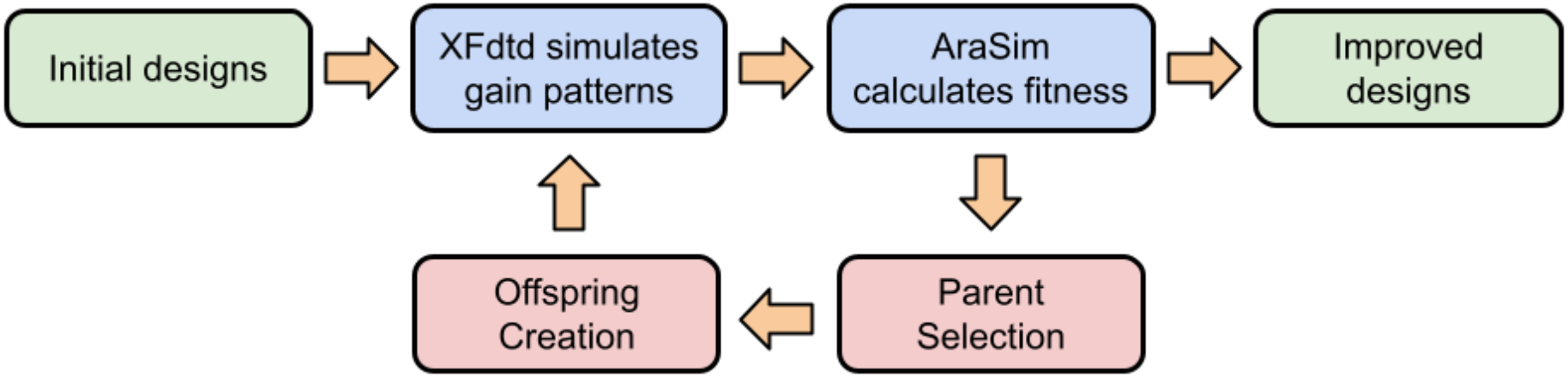
- First major project: design antennas optimized for detection of UHE neutrinos in the ice
- Begin with a bicone-like design
- Fitness score: number of neutrinos detected by ARA when using the evolved "individual"



- Lengths, inner radii, opening angles are "genes"

GENETIS

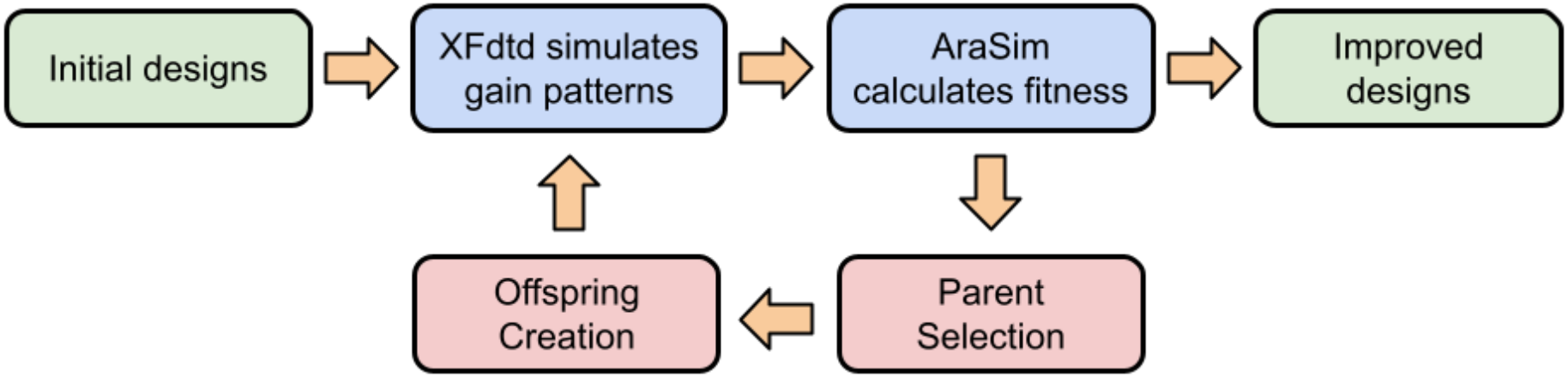
The Loop:



- 50 individuals/generation
- Computing time: 14 hours / generation
- ~35 generations to plateau

GENETIS ARA loop

The Loop:



- Automated - no human intervention
- Interfaces between many types of code (including GUIs)

Parameters of the GA itself

- Parent selection
  - Roulette
  - Tournament
- Genetic operators
  - Mutation
  - Crossover
  - Reproduction
  - Injection

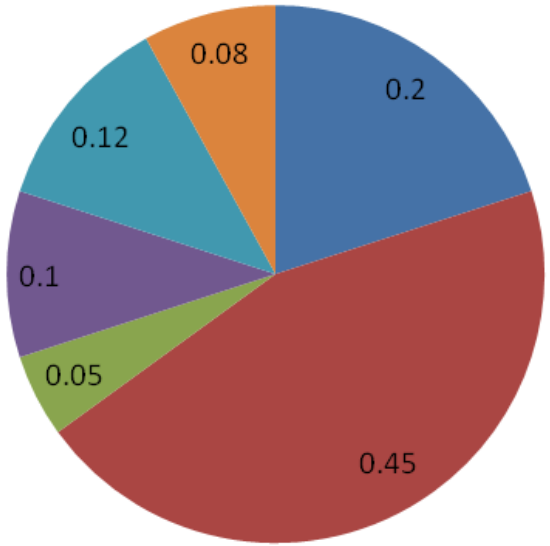
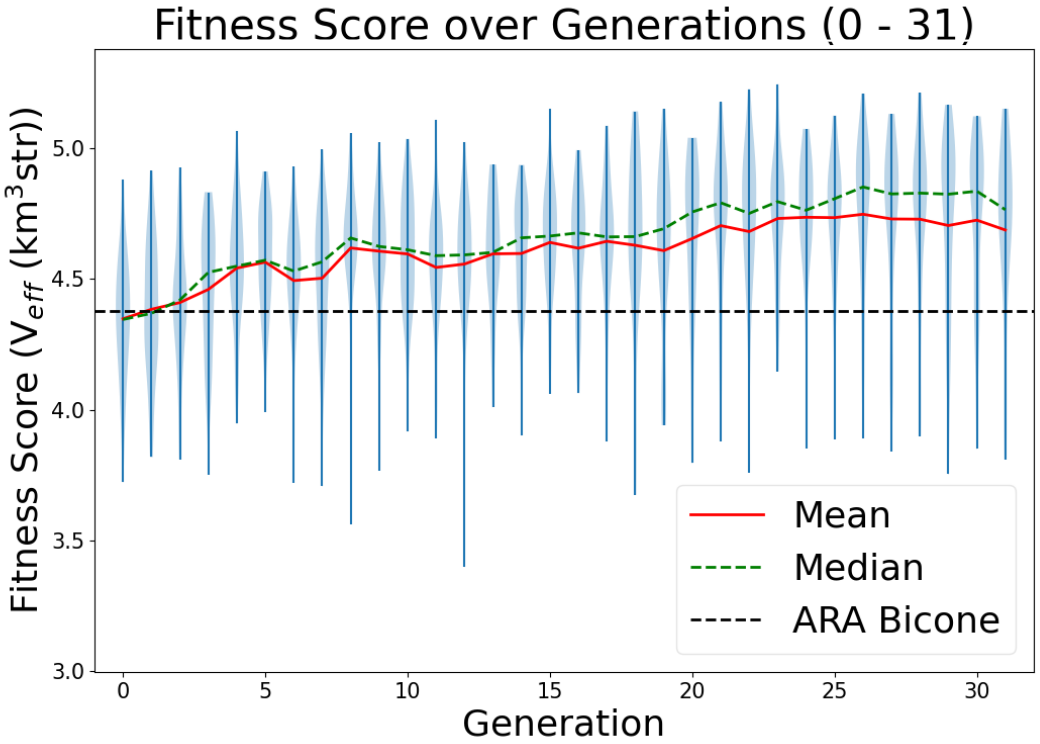
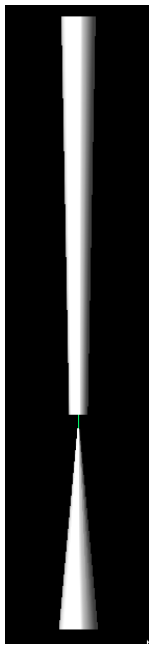


Illustration of roulette selection
towardsdatascience.com

GENETIS antenna optimization

- First results



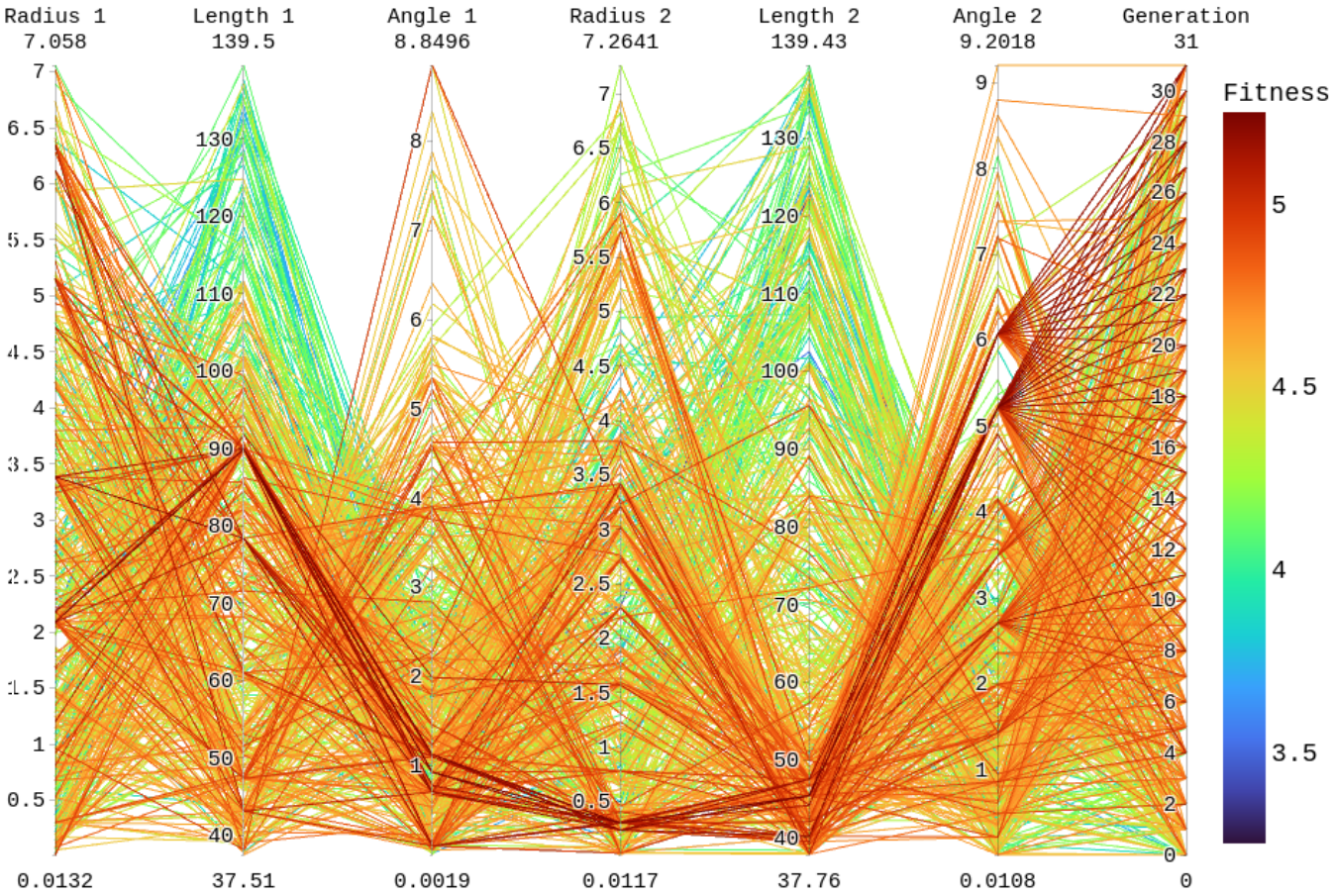


Most fit antenna, first run

J. Rolla et al. [GENETIS Collaboration], Using evolutionary algorithms to design antennas with greater sensitivity to ultrahigh energy neutrinos,Phys.Rev.D 108 (2023) 10, 102002

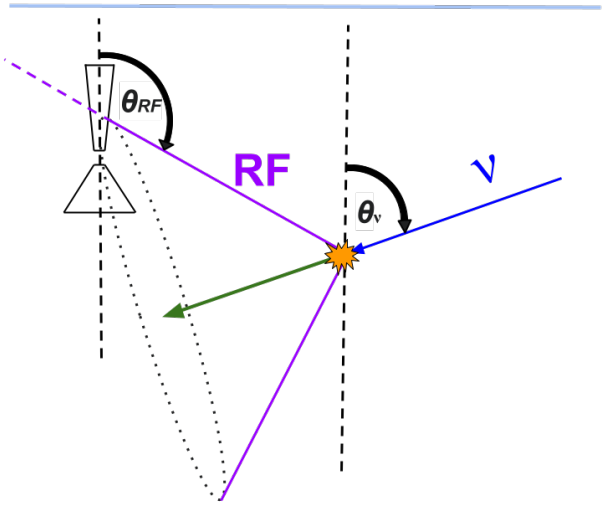
GENETIS Rainbow plot

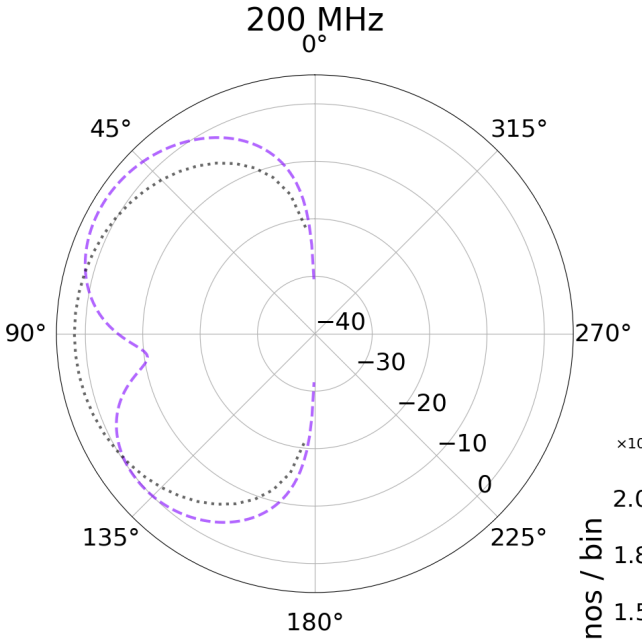
- Most fit antennas have common design parameters

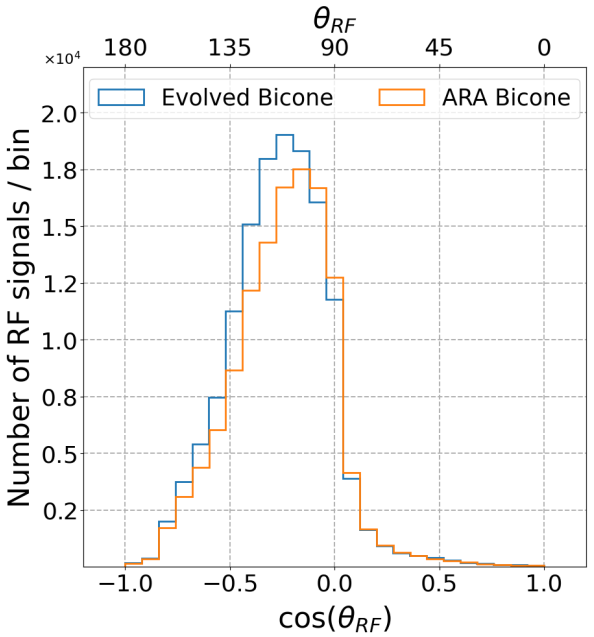


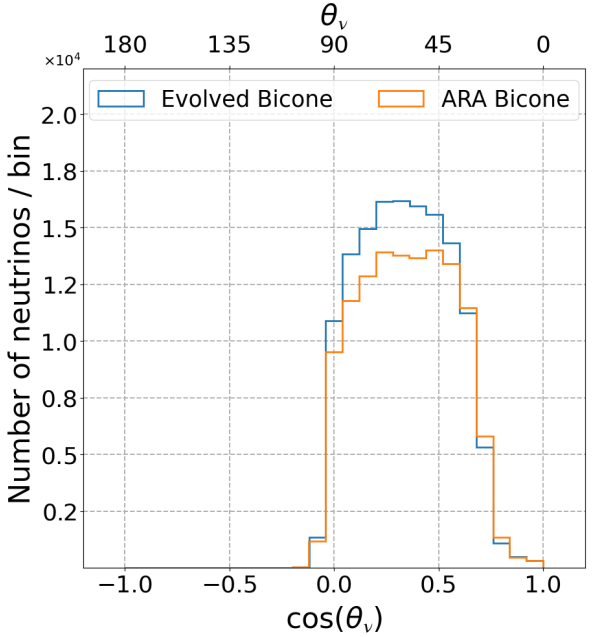
OSU student Ben Sipe

GENETIS: How they can better detect neutrinos



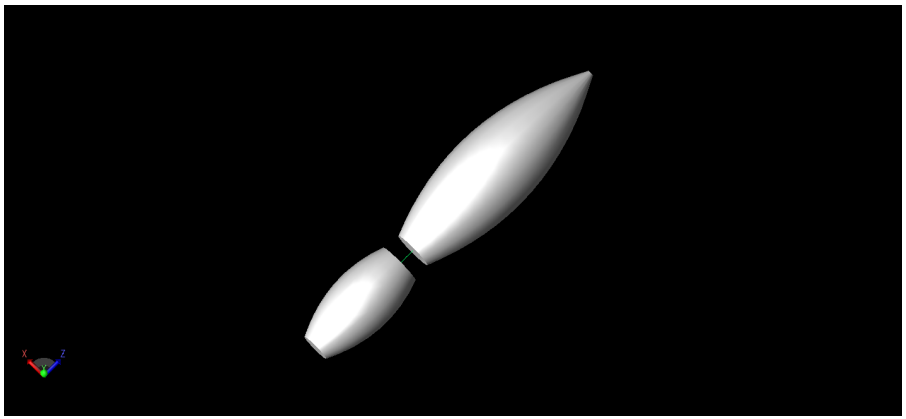


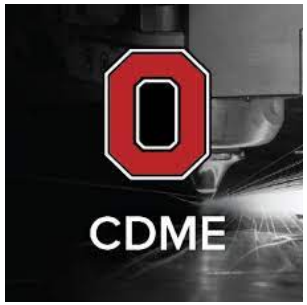




GENETIS Bicone evolution - "Crazy sides"

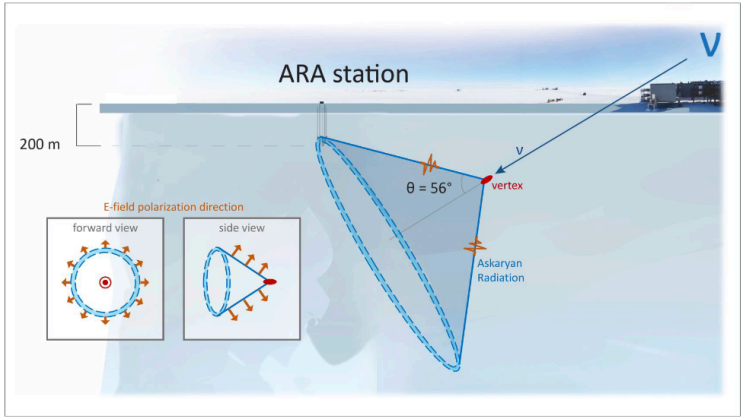
- Curved sides - linear and quadratic terms
- Matching in antenna design
- Prototyping at OSU's Center for Design and Manufacturing Excellence

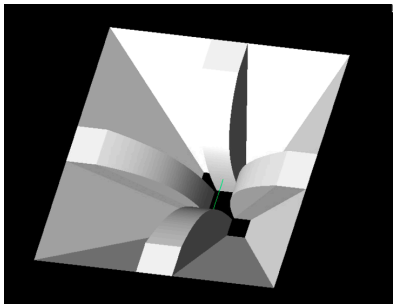




GENETIS: Next steps

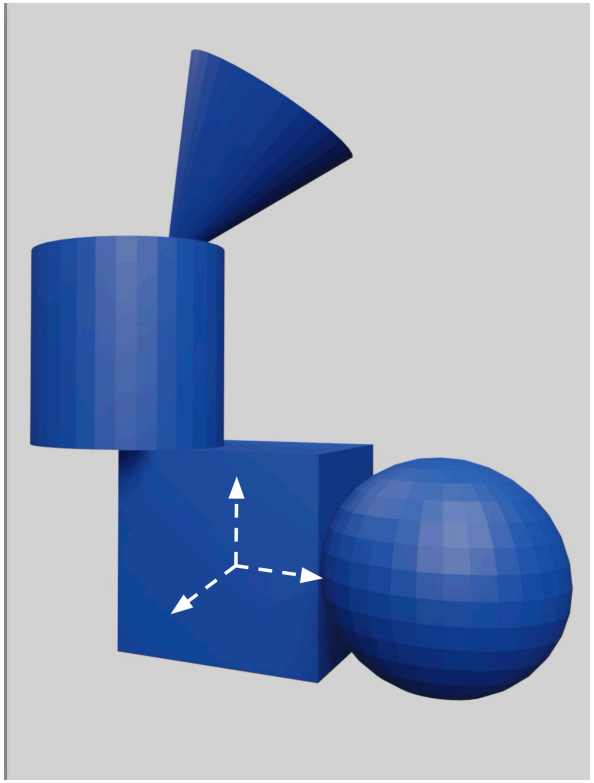
- ARA: more genes and ice birefringence
  - HPol, VPol antennas
  - Antenna placement
- Expanding use cases
  - PUEO antennas
  - RHINO antennas (21cm)
  - Antenna placement other arrays





Nebulous “LEGO” project

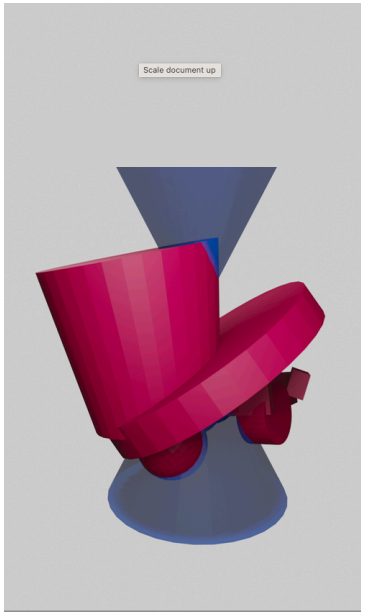
- Instead of starting from preconceived type (bicone, horn), build from shapes LEGO-style



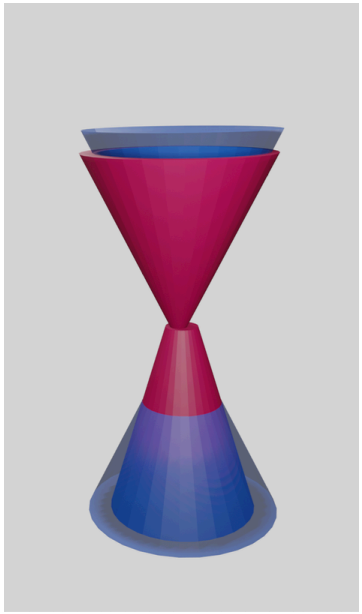
Led by Julie Rolla
JPL Scientist

Nebulous: First evolve shape to a shape Bicone

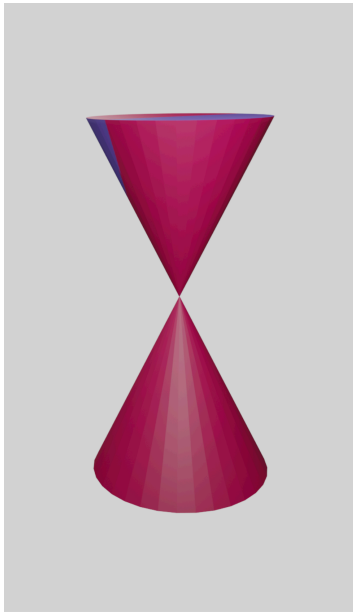
Gen 0

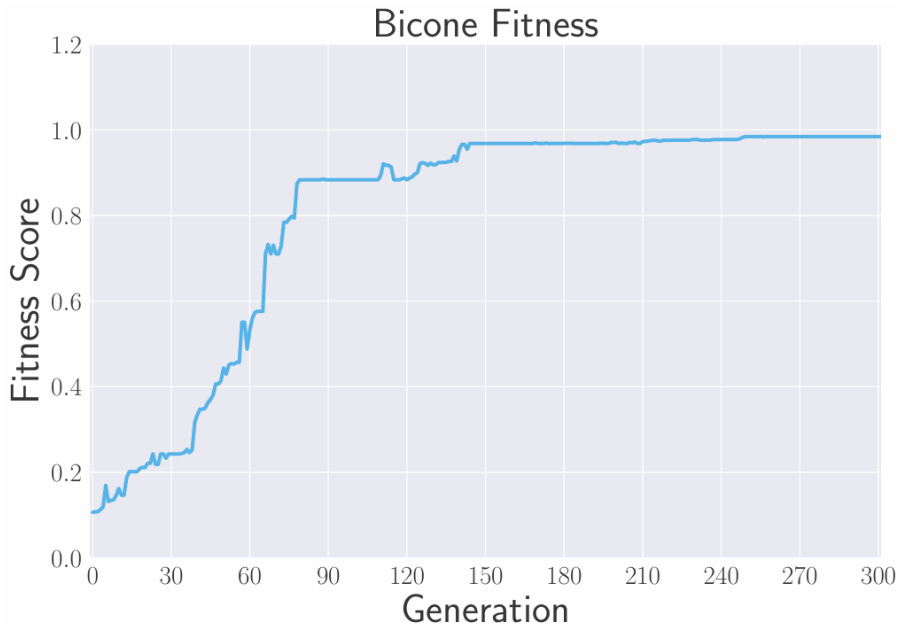


Gen 50



Gen 100

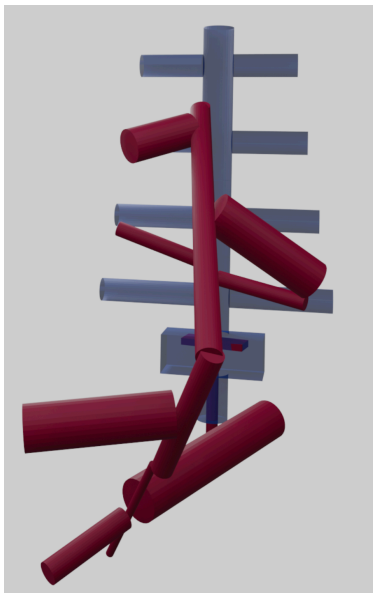


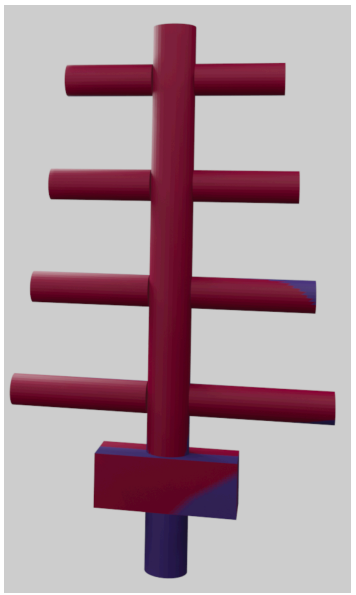


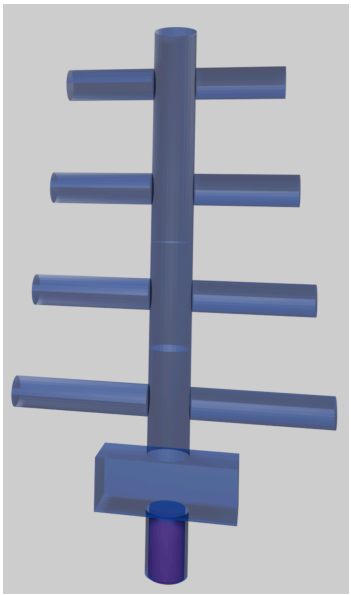
J. Rolla, B. Reynolds, D. Wells, J.Weiler, A. Connolly, and R. Debolt. Design of Antennas from Primitive Shapes Using Genetic Algorithms. The Interplanetary Network Progress Report, Volume 42-237, pp. 1-47, May 15, 2024.

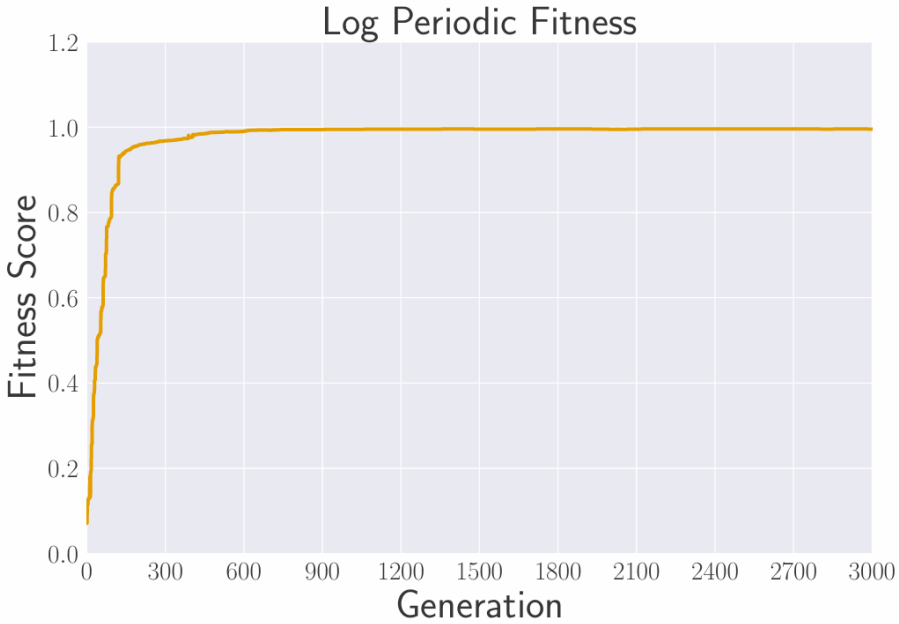
Nebulous: First evolve shape to a shape Log periodic

Gen 0 Gen 50 Gen 100









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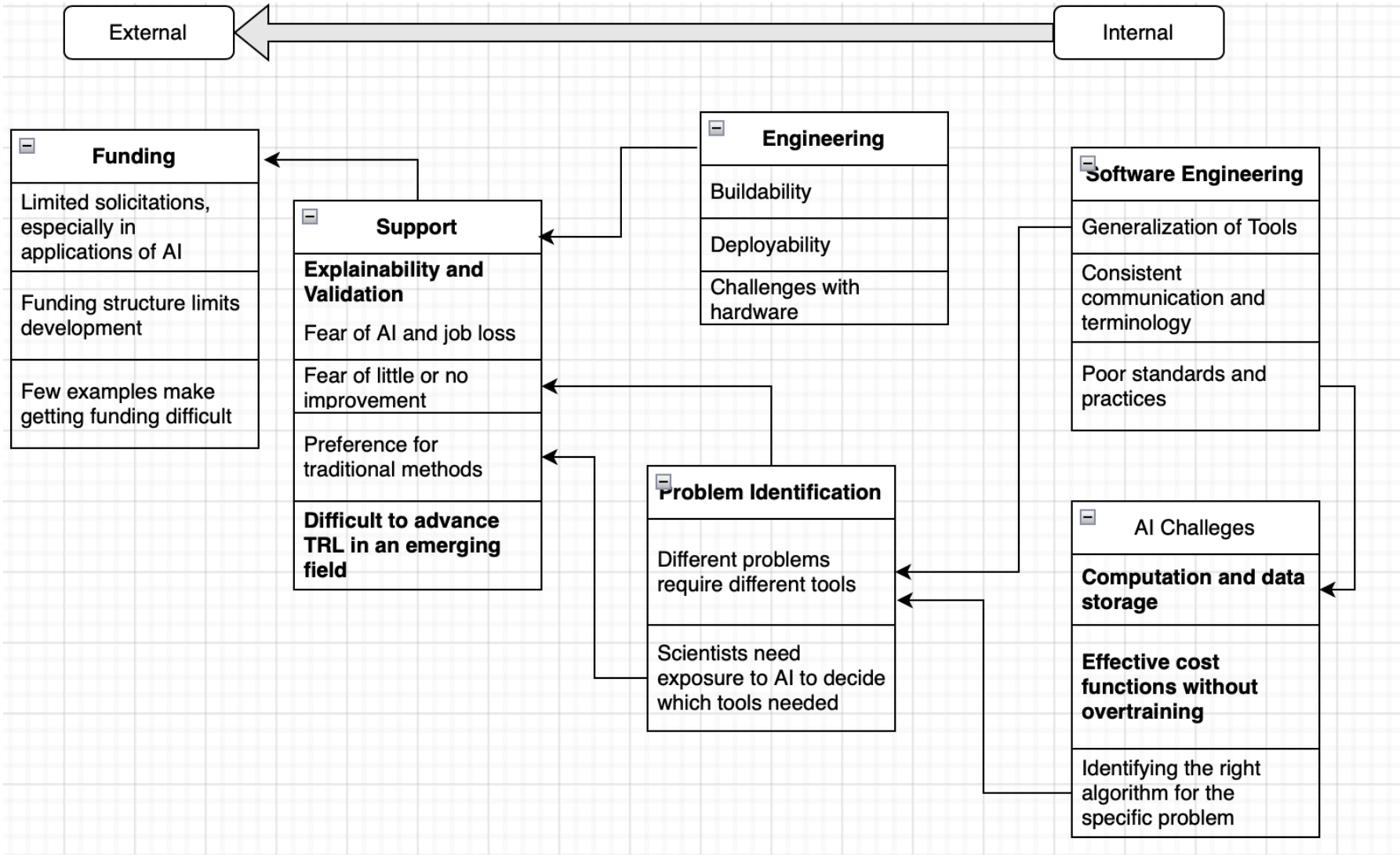
Nebulous: Next steps

- In progress:
  - Beam pattern as fitness score
  - Physics outcome as fitness score

AI for Instrument Design Workshop

- Recently attended a workshop at the Keck Center on Caltech's campus from August 12-13 funded by JPL Blue Sky Studies
- Experts in science, engineering, and AI came together from six academic institutions and industry partners
- Reviewed the state-of-the-art and built a roadmap of necessary developments needed to capitalize on AI for future instruments.
- A white paper is in development and will be published in the coming weeks.

Challenges to Integrating AI with Instrument Design



jpl.nasa.gov

Other important developments

- Selected by OSU to apply for NSF AI Institute
  - Feedback constructive, discouraged this time
- Strategic Planning Exercise
- Blue Sky workshop at JPL
  - White paper on AI for design coming soon
- Interdisciplinary connections strengthened by weekly “experts” calls
- Developments in GAs
- Computation speedups
- Use cases expanded beyond UHE astrophysics

GENETIS / Nebulous future

- Completing initial test projects, publishing
- Expanding test cases
- Funding
- Finding long term, sustainable model - Institute?
- Would love to work synergistically with MODE
  - Use cases
  - Use of GAs