The Do-It-Yourself Geiger-Mueller (DIYgm): Circuit Optimization and Evaluation

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Introduction and Motivation

Began as practical undergraduate research project

Provide radiation survey meter for nuclear outreach

- Increase awareness on nuclear issues
- Educate others in radiation detection and methods
- Provide tool to explore environmental radiation

Lack of experience resulted in unnoticed design flaws

- Sensitivity disagreements
- Abnormal background measurements
- Periodic crashing

Mission Relevance

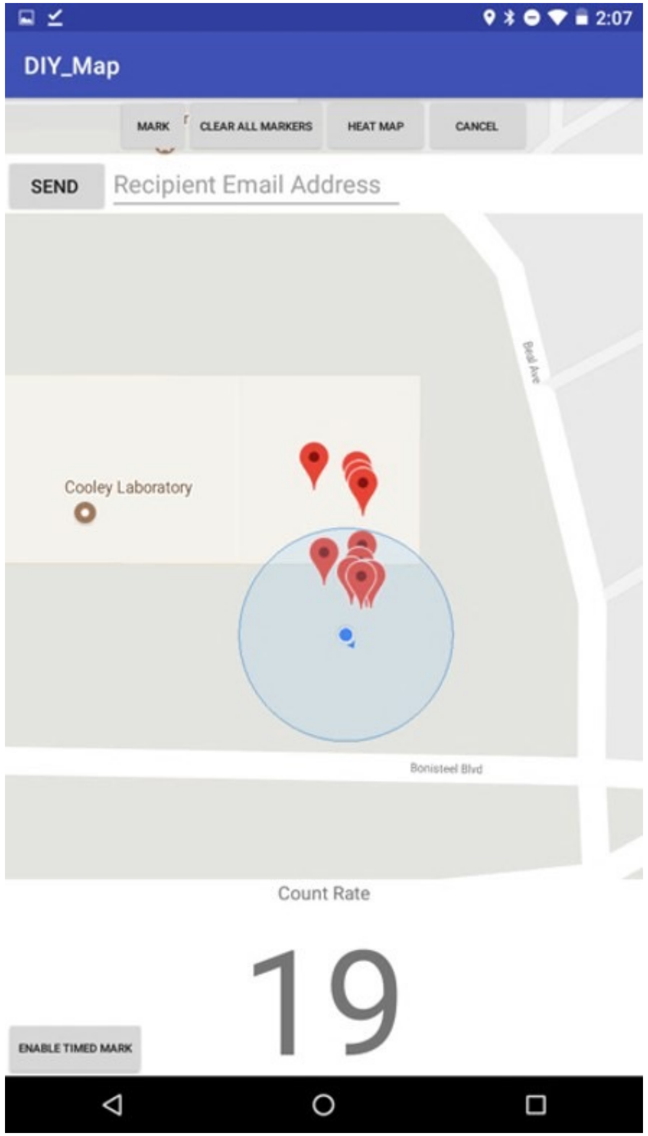
Provide a platform for nuclear awareness

Discuss useful nuclear research tools

- Digital detector emulation
- Quality control methods
- Formal standards as a basis for design framework

Analyze environmental background

- Background composition and variation
- Treaty verification
- Radiological response



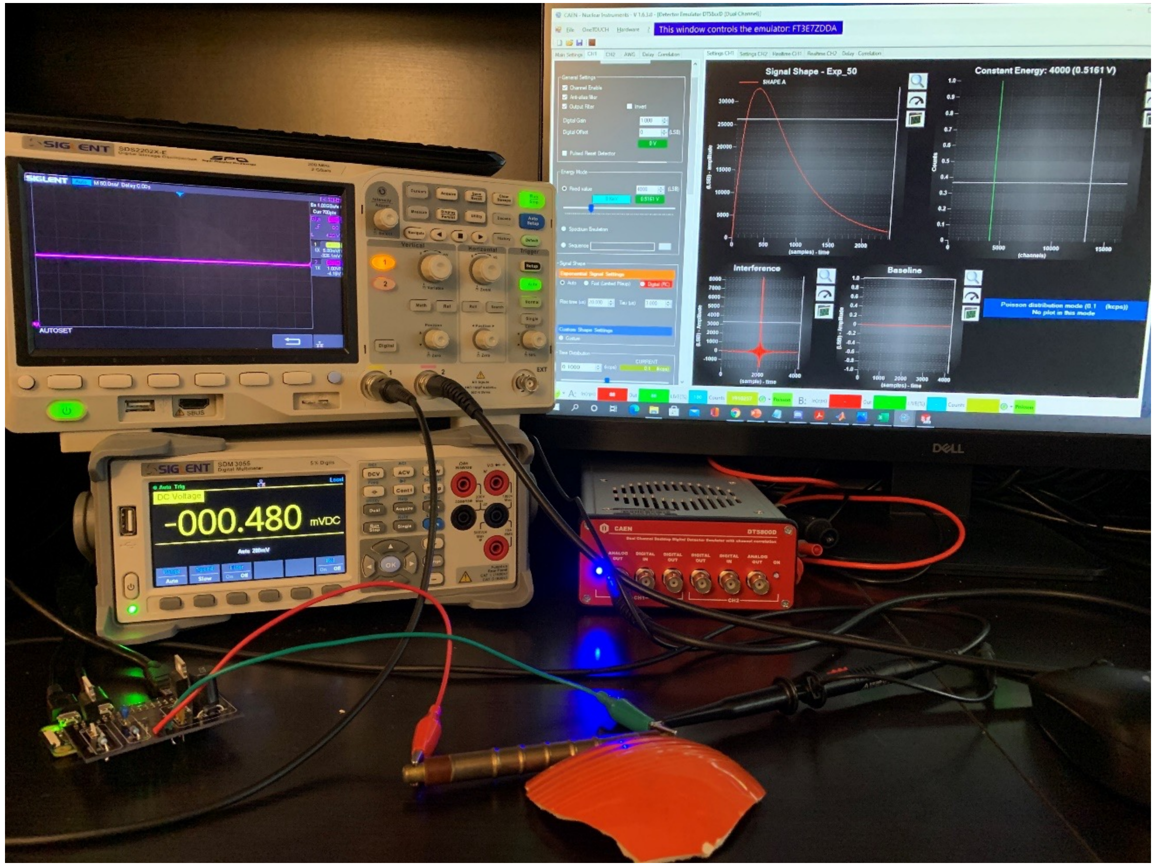
Technical Approach

Emulate pulses using SBM-20 Geiger-Mueller (GM) tube specifications

- Minimum dead time ~ 190 µs
- Sensitivity ~ 22 cps / 37 kBq Cs-137
- Operating voltage ~ 400 V

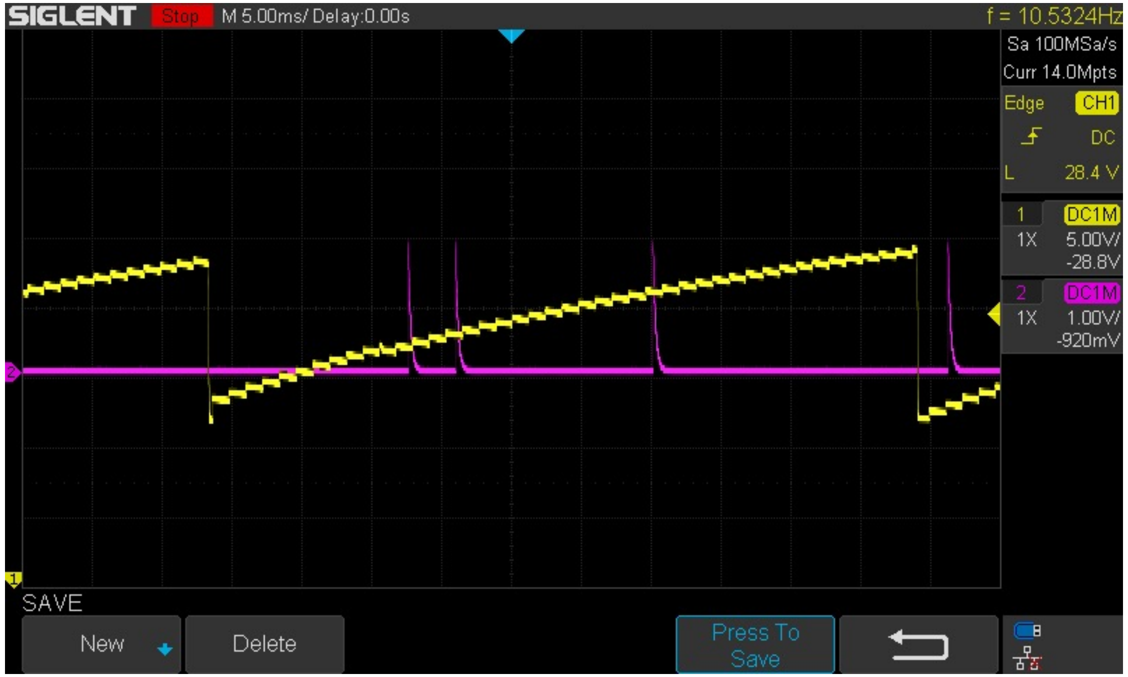
Emulate detector performance to study undesirable signals

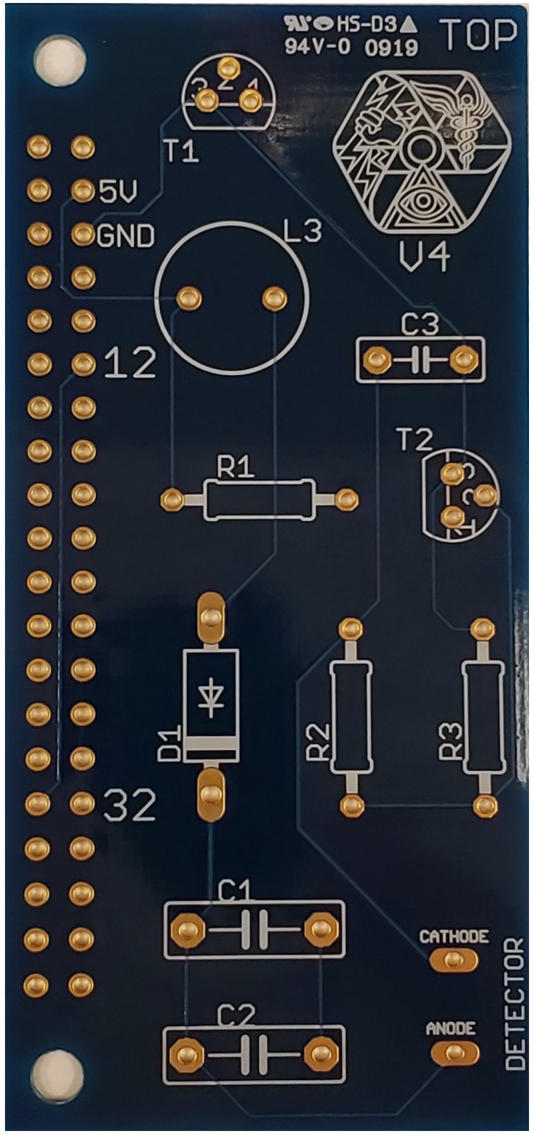
- CAEN Inc. DT5800 Detector Emulator
- Siglent SDS2202X-E Oscilloscope
- Siglent SDM 3055 Multimeter



Technical Approach

- Detector pulses (yellow) vs. emulated pulses (purple)
- GM counts registered
- Pulse shaping is needed





Results

Source: White noise

Cause: Free electron motion with equal intensity vs. frequency

Fix: Reroute GPIO connections, restrict filter bandwidth, and more direct analog traces

Results

Source: Baseline drift

Cause: Fluctuations in thermal response of electrical components

Fix: Capacitors and resistors replaced with higher-rated temperature coefficients and voltage ratings

Results

Source: Electromagnetic interference

Cause: Signals that interfere with components through induction, coupling, or conduction

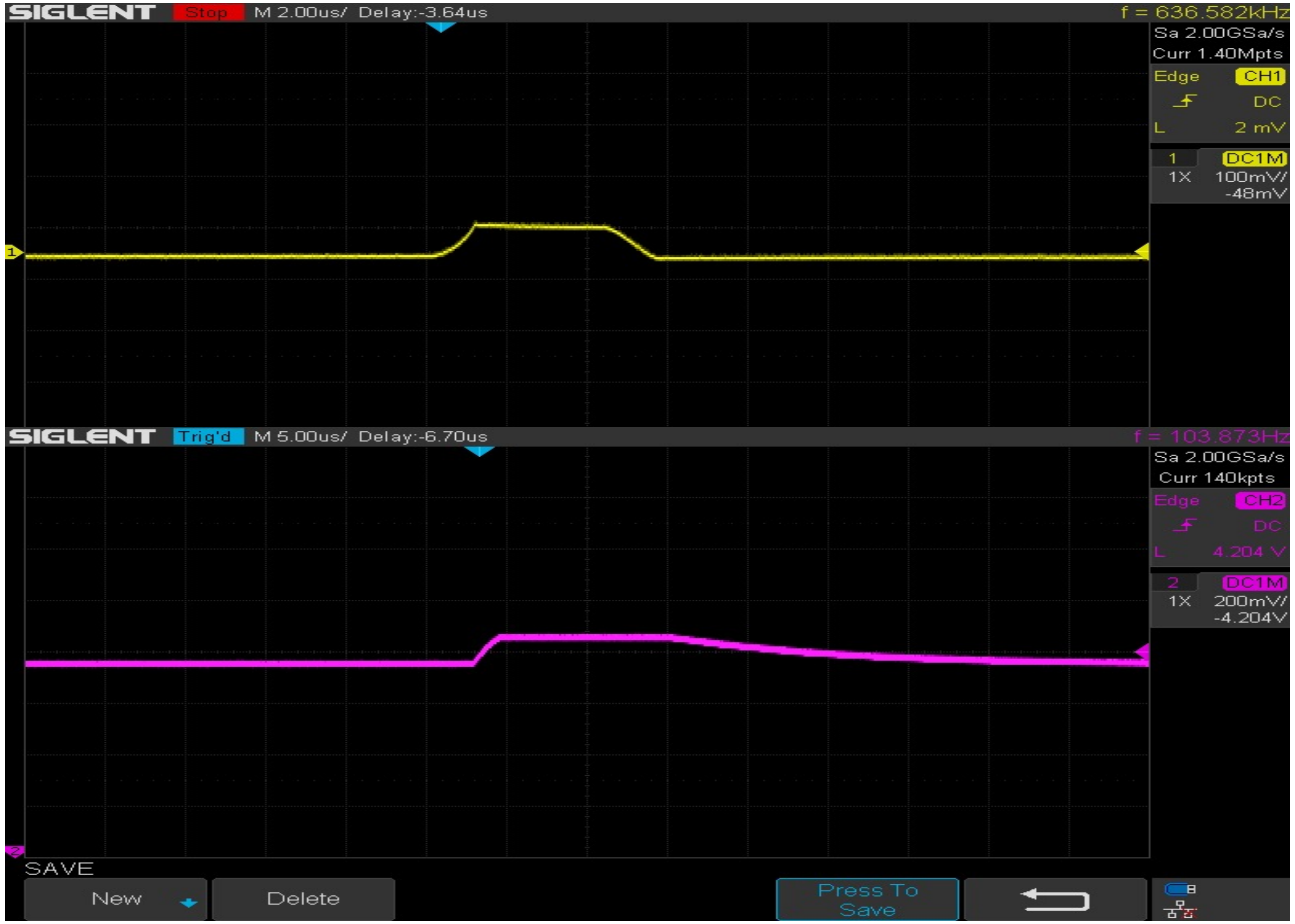
Fix: Inductor replaced with shielded inductor to contain its magnetic field

Results

Source: Shot noise

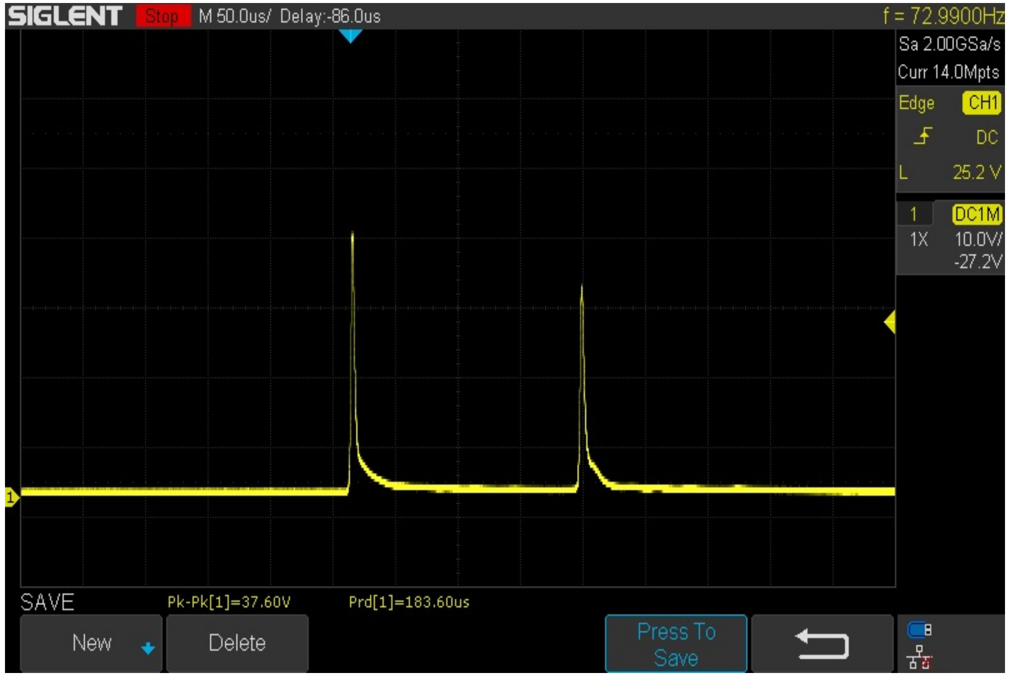
Cause: Consequence of discrete change levels in flow of electrons

Fix: Reorientation and replacement of transistors with different and larger footprint

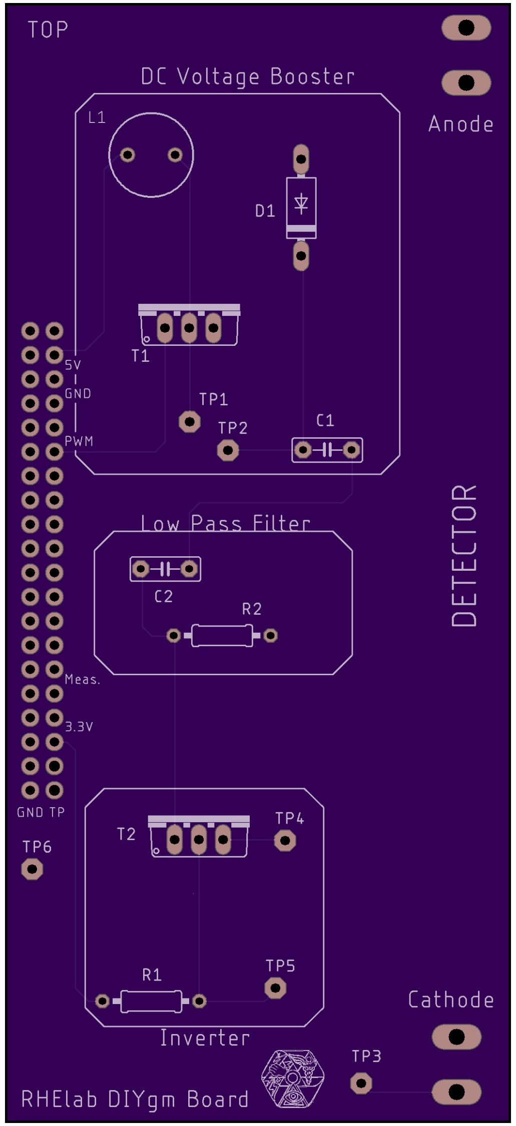


Results

Current circuit board design with measured signal



- White noise reduced
- Baseline drift removed
- Interference minimized
- Shot noise reduced
- Improved detector performance
- Sensitivity agrees with technical specifications



Expected Impact

Enriched experience of using detection emulation

- Detector emulation still relatively new
- Experience may further similar research projects
- Visually explore features of signal analysis

Improved radiation detection device for environmental monitoring

Advanced method to teach applied radiological measurements

- Energy/time spectrum
- Noise and interference
- Predictable sequence generation

MTV Impact

- Early introduction to undergraduate research
- Personnel transfer to MTV projects, graduate schools, and research-oriented positions
- National laboratory collaboration for nuclear outreach
- Workshops for emerging STEM students
- Great public interest from educational institutions
- Platform for additional outreach projects

Conclusion

Detector emulator greatly helped to troubleshoot and fix detector

- Steady background
- Sensitivity agreements with SBM-20 specifications
- Clean signal analysis

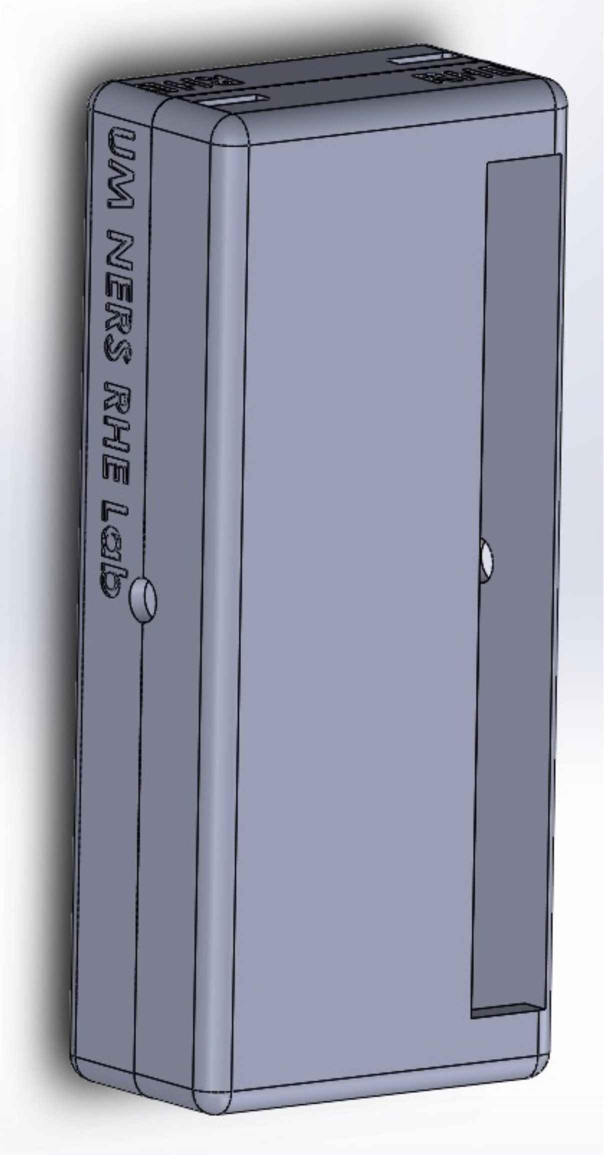
Unique experience of digital detector emulation

- Many signal models analyzed
- Verify detector performance
- Various teaching aspects obtained

Educates students on many aspects of nuclear technology

Next Steps

- Use other commercially-available GM tubes
- Explore different circuit designs
- Implement more user-friendly features
- Establish quality control procedures
- Gather user-feedback
  - Experience with detector build
  - Quality of detection system
  - Amount of material learned

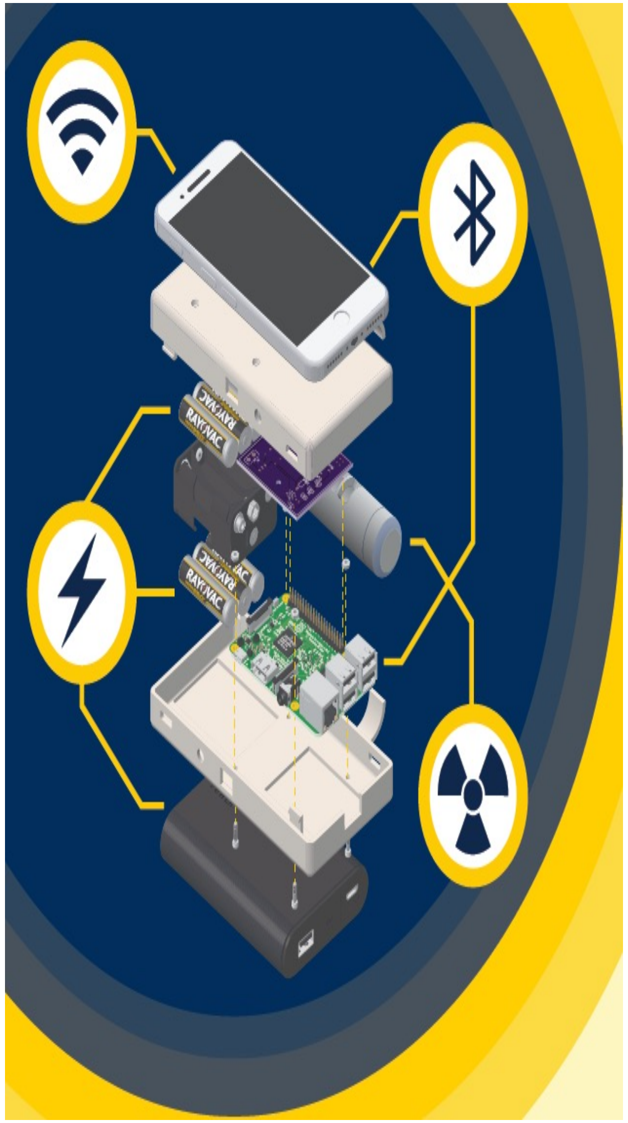


Participants: Design/Build/Test

Undergraduate Designers

LongKiu Chung* Brian Shen*
Mark Dewald ***James Seekamp****
Issa El-Amir ***David Trimas****
Rina McClain ***Regina Tuey****
Jonathan Miller* Foster Wisusik
Weronika Myslak ***Jeffrey Xiao****
Kai C. Schiefer Fangbo Yuan*

Tristan Blackledge ***Andrew Kent***
Margaret Cooney Gillian Mosher
Yifan Gui ***Christopher O'Neil***
Calvin Huang ***Samar Tawfik***
Loris Jautakas ***Marlee Trager***



RHE Lab: Build/Test

RHElab undergraduates (CVT): 57
RHElab undergraduates (MTV): 34

Courses: Build/Test

NERS 586 W19: 18
NERS 484 F19: 5
NERS 582 F19: 7
NERS 586 W20: 15
NERS586 W21: 10

CVT (2014-2019)
Journal Paper CoAuthor
Graduate School*
MTV (2019-present)
Current Team

Acknowledgements

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