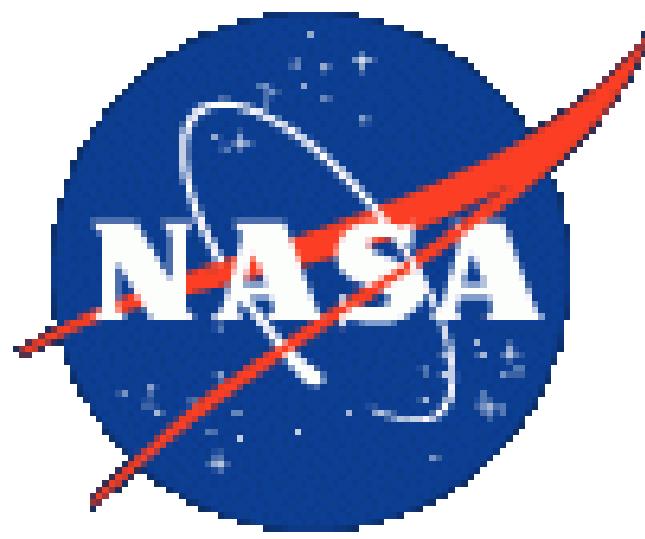




# Doing Research with Undergraduates in a Bachelor's-only Physics and Astronomy Department

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## Introduction

For many disciplines, it appears that the number of undergraduates involved in research is increasing. One can certainly argue that this is true for physics and astronomy. This is encouraging given the range of benefits students gain from such an experience. At the University of Northern Colorado (UNC), we have been fortunate to have undergraduate research as a component of the program for over 30 years. However, many students are overcome by classwork and do not see research as a viable option during their undergraduate career. Indeed, some are wary of approaching such a challenge given their limited experience. Moreover, without the extensive research efforts, facilities, graduate student mentors, and other important resources associated with graduate institutions, can an undergraduate program provide a meaningful research experience for its students? The lack of funding for student projects and the limited external collaborations can have students wondering about opportunities which they could be missing. They also ask if they have been given the full range of tools for current and future success. These are frequent questions.

Here, we would like you to ponder the above as we present a survey of some of the journeys in research we have taken with our undergraduates. Given our persistent attention to the evolving needs of our students along with an understanding of our advantages and limitations, we believe our program has substantial positive outcomes to report.

## The Program at UNC

- Eight full-time faculty members
- Graduate approximately 10 - 15 majors each year
- Offer a B.S. in Physics with a choice of four emphasis areas
  1. Mathematical Physics
  2. Engineering Physics – most popular
  3. Astronomy – being expanded
  4. Secondary Education – 2 to 3 graduates a year
- Senior research required (credit granted)
- Have limited resources in materials and space

## How We Do It

- Students work on faculty research projects or develop their own projects
  - Develop projects that match student interests and goals
- Collaborations
  - Colorado Space Grant Consortium (COSGC)
  - Other institutions (AIMS, CSU, CU Boulder, NREL)
  - Multidisciplined efforts with other departments
- Internships
- Funding
  - COSGC
  - Physics Foundation Accounts (specifically for student research)
  - Grants from the OUR and College Student Research Fund
- As always, the student must be able to take ownership.

## Assessment

Assessing a student's progress is left to their advisor(s). However, the faculty agrees that the student should produce output in the form of a written report or oral/poster presentation (or some combination of these). Such dissemination may be internal or external to UNC (or both).

Yet, one might ask, how do you know if a student is developing as a physicist or astronomer. As said above, it is left to the advisor to choose or devise a metric. For example, one of the authors would try to gauge analytic maturity by, among other things, tracking a student's development in discussing the physics behind a phenomenon. As the depth and precision of description increases, a vision for and ownership of the work seems to follow. This can be the mark of a successful undergraduate research experience.

## Example: Biomimicry - Design and Construction of a Multilegged Robot

Student : A. Sweitzer

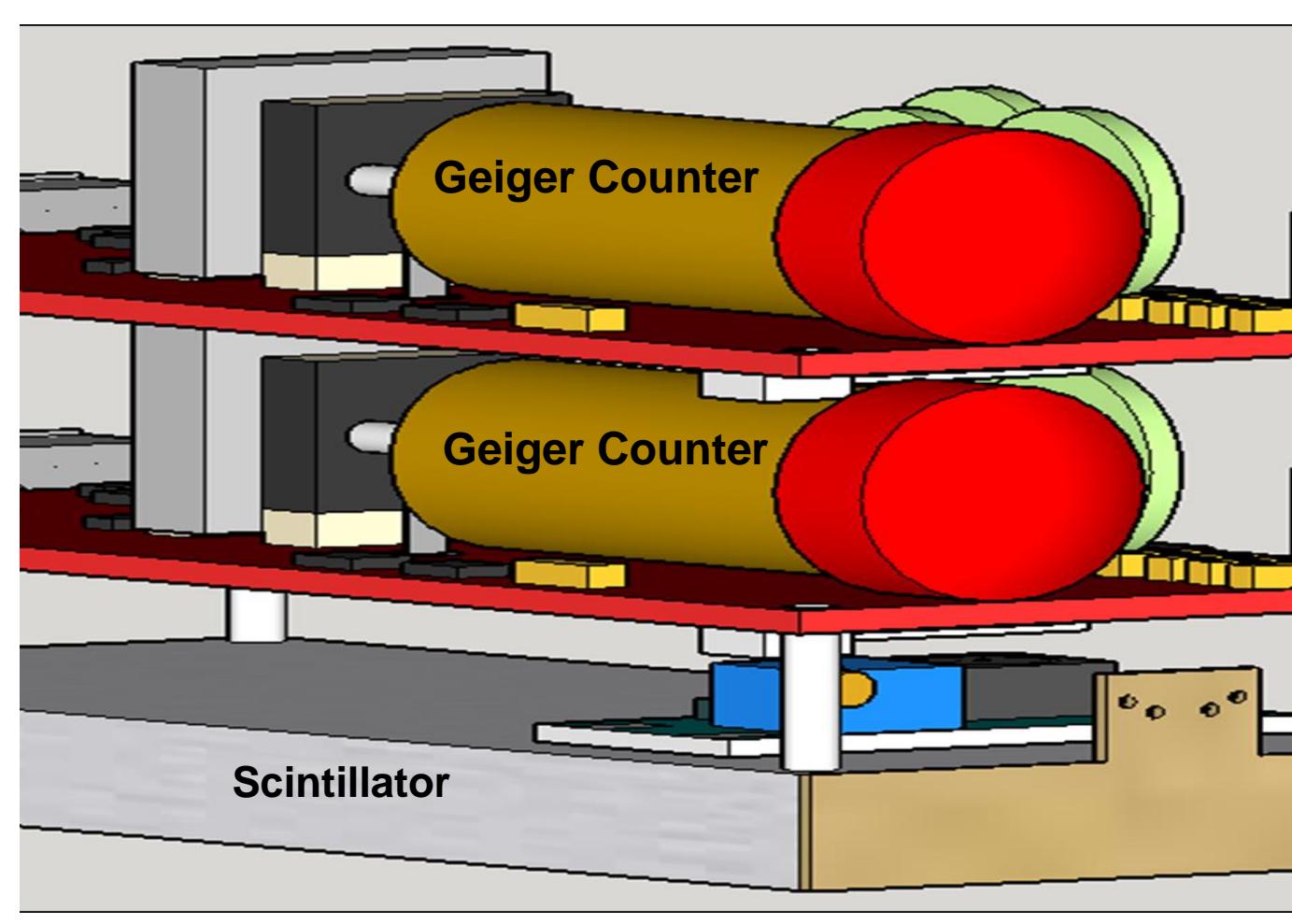
- Student wanted to pursue studies concerning locomotion
- Project allowed for a development of skills and a working knowledge of biomimetics
  - Made mathematical models of the leg dynamics
  - Simple programming and integration of microprocessors and motor controllers
  - Extensive use of 3-D printing and other building tools
- Work funded by COSGC
  - Earned award at COSGC Robotics Competition



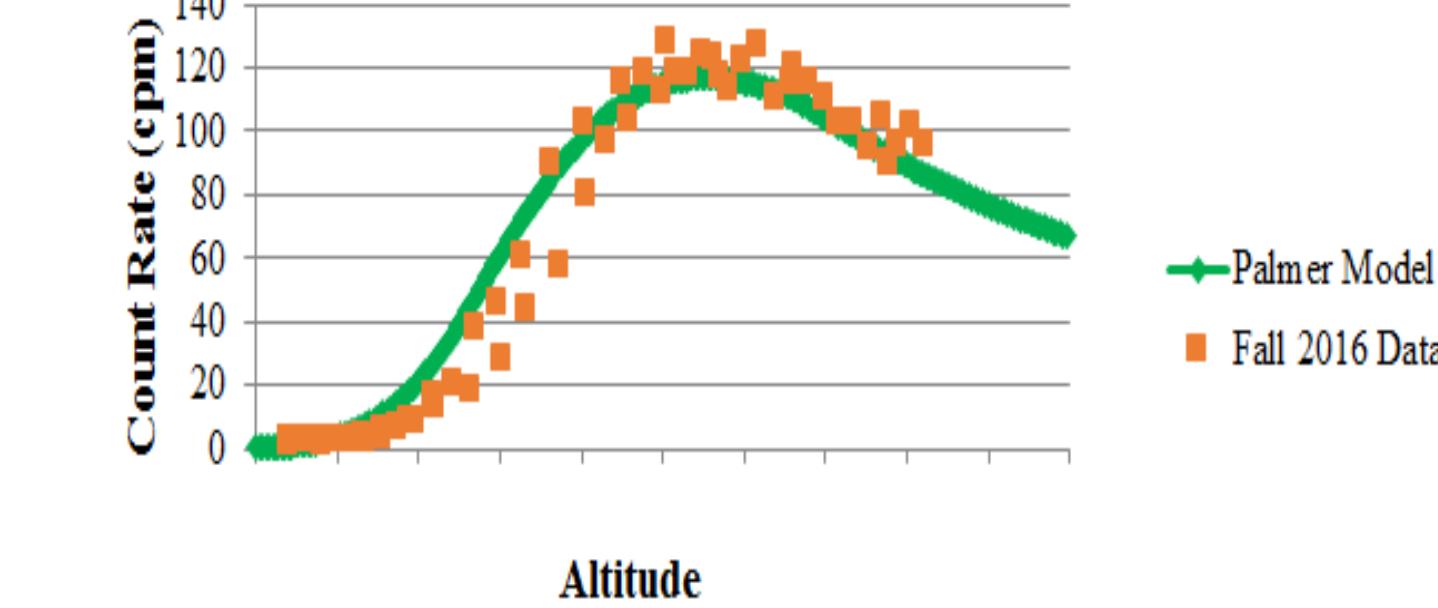
## Example: Investigating Atmospheric Radiation Using a Multiple Detector Apparatus

Students: J. Fender, J. Ringler, J. Morse

- Students had an interest in building devices and data analysis
- Constructed an autonomous balloon payload containing a scintillator coupled with a silicon photomultiplier and two Geiger counters all connected to a coincidence circuit
- Challenging programming, device interfacing, circuit building, and general fabrication
- Fitting a model to the data
- Work Funded by COSGC
  - Group work
  - Design reviews
  - Oral, written, and poster reporting
  - Launched during last solar eclipse



Palmer Model: Count Rate vs Altitude



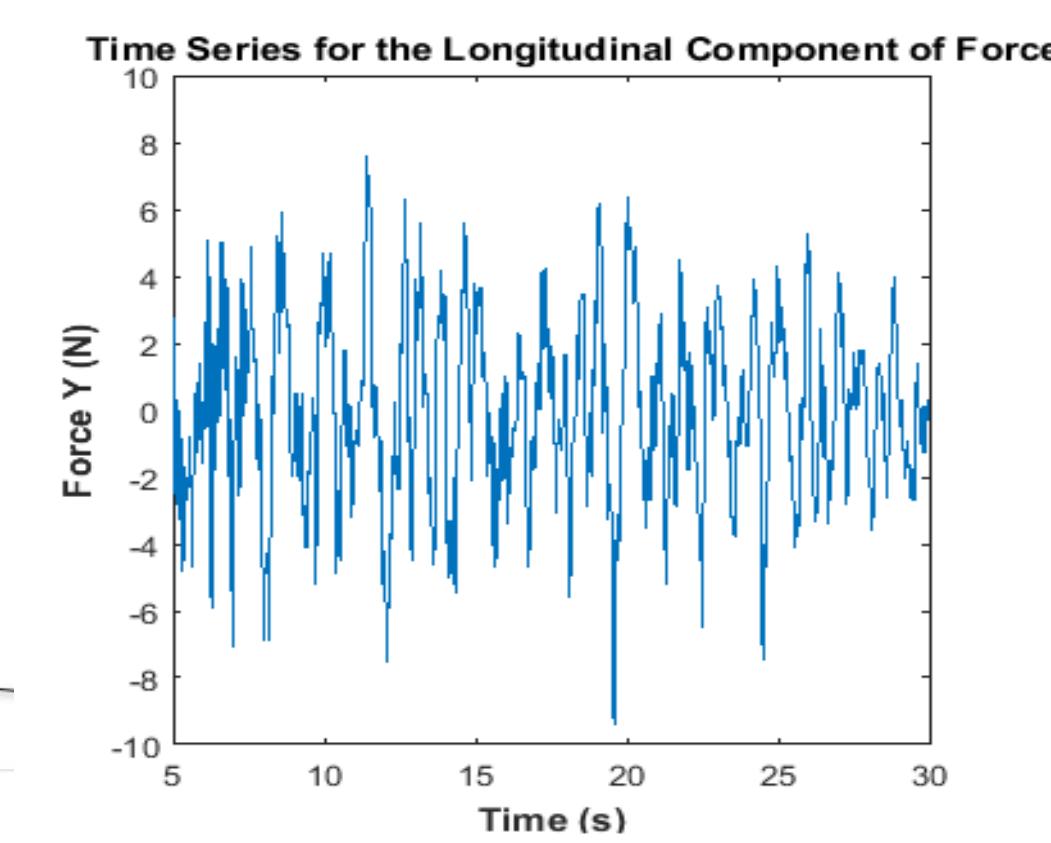
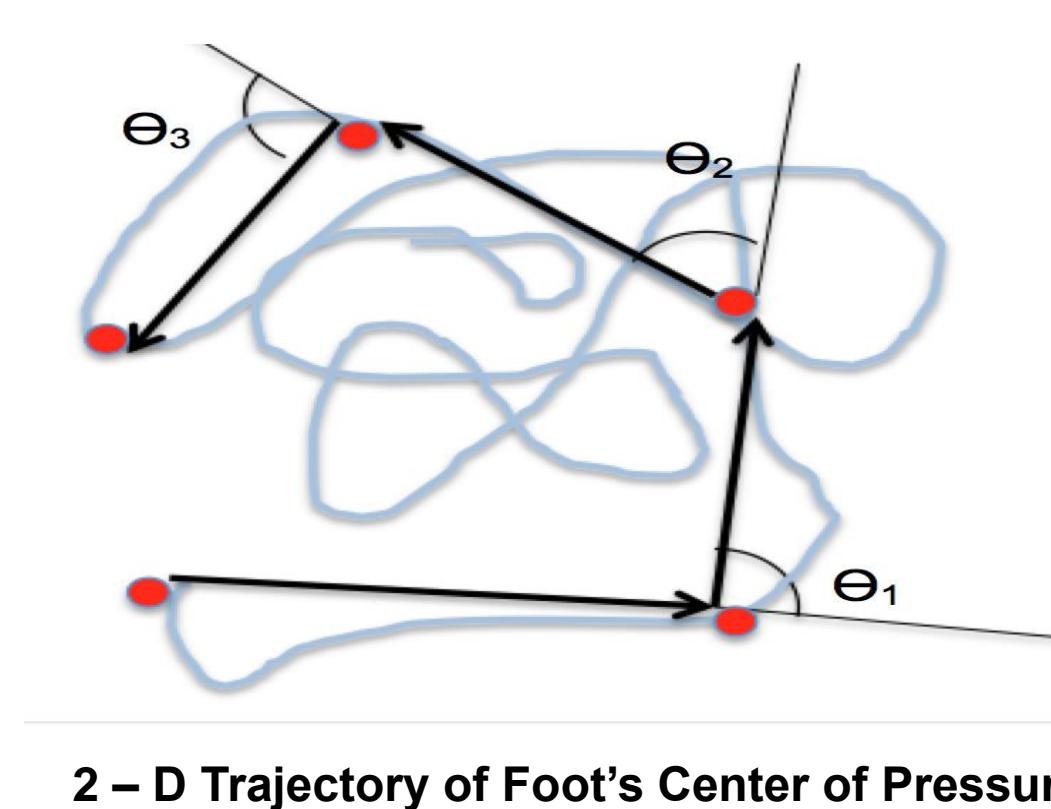
## Acknowledgments

Kendall Mallory, Robert Walch, Charles Kuehn, Chris Koehler, Bernadette Garcia, Brian Sanders, COSGC, NASA

## Example: Examining the Process of Human Unipedal Balance

Student: Z. Hafen

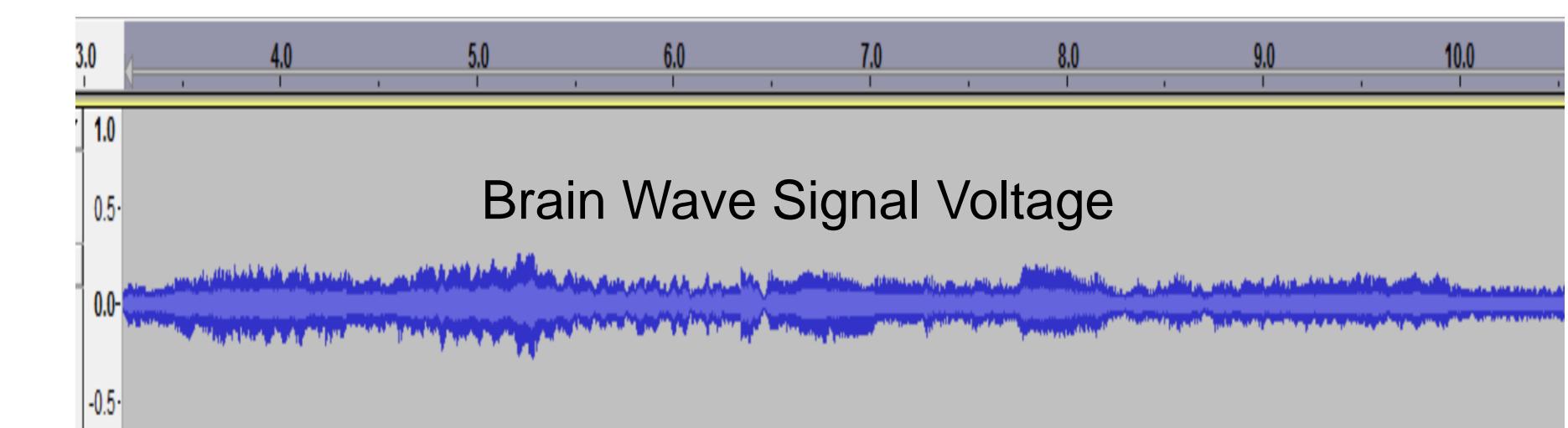
- Student had strong interest in theoretical physics
- Needed to analyze data concerning human unipedal stance
  - Characterizing data on which to base a model - attempted to understand temporal correlations and stochastic quality
  - Surveyed stochastic dynamics
  - Work on simulations
- Work under COSGC and collaborated with UNC's School of Sport and Exercise Science
  - Oral, written, and poster presentations
- Pursued internship in gravitational wave simulation and continues this work as a graduate student in Physics at Northwestern University



## Example: Psychoacoustics - Understanding Sonic Intelligibility

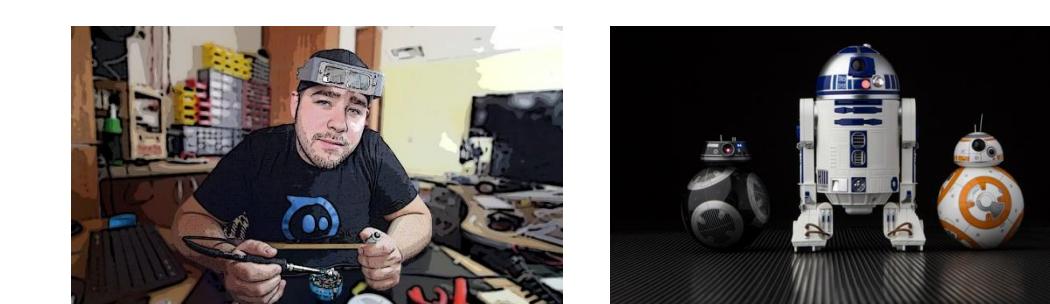
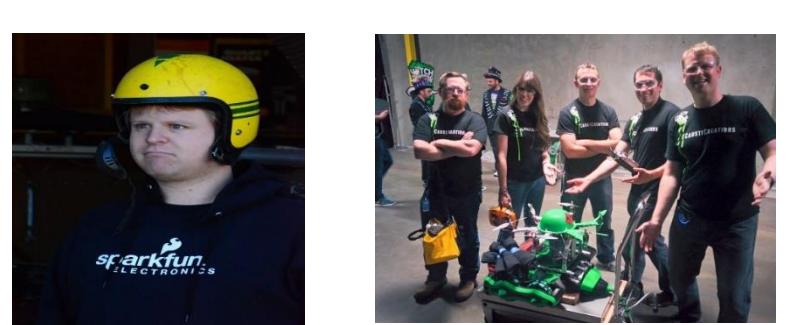
Student: A. Briggs

- Classically trained violinist interested in psychoacoustics
- Wanted to understand what characteristics of an audio signal are essential for that perception to reflect the actual sonic content of the signal
- In this project, the effects of sound on the human brain's electrical activity are analyzed using electroencephalography (EEG) to measure the intensity of alpha and beta brain waves
- Written reports and poster presentation
- Now a graduate student in Acoustics and Music Technology at the University of Edinburgh



## Long Term Student Achievement

- Casey Kuhns – Honeybee Robotics Spacecraft Mechanisms Corp., System Engineer
- Also on ABC's Battlebots



- Adam Wilson – Sphero, Chief Scientist/Co-founder