ANNUAL REPORT

BENTLY CENTER FOR ENGINEERING INNOVATION
AWARDS AND WORK COMPLETED

2019-2020

Compiled by Charles Birdsong, Bently Center Director 2018-2021
February 2021

CAL POLY

Introduction

The Donald E. Bently Center for Engineering Innovation was established in spring 2003 through a substantial donation by Donald E. Bently. The Center is contained within the Mechanical Engineering Department. The purpose of the endowment is to promote innovation within the discipline, support applied research, expand the curriculum and bring vision and breadth to engineering instruction. The mission of the Center is advancement of research, education, and the practice of mechanical engineering with innovation as a guiding principle. Rotor dynamics is the primary focus of the center; however, the center supports a broad range of secondary focus areas.

Every year the Center issues a request for proposals to the Cal Poly M.E. faculty to sponsor faculty release time. The proposals are reviewed by a committee consisting of the Bently Center Director, ME Department Chair, and a third reviewer, typically the CENG Associate/Assistant Dean of Research. Awards are made based on criteria that includes meeting the mission of the Center, leveraging the award, deliverables, past performance, need and the proposal quality. The Bently Director is awarded 24 WTUs per year and expected to further the mission of the Center and administer the endowment, RFP process and documentation.

Awardees that are granted 12 – 18 WTUs are given the title of "*Bently Professors.*" In addition to the *Bently Professor* awards, smaller awards are granted as well. A short bio of the 2019 *Bently Professors* is given below.

John Chen, Professor of Mechanical Engineering

Dr. Chen's research focused on (i) grit and how it is affected through students' learning experiences, (ii) the collection of non-cognitive (NCA) factors related to student success, and (iii) metacognition, or awareness and control of one's learning. Professor Chen regularly teaches statics, introductory and advanced thermodynamics, and heat transfer. He enjoys the varied mix of students from different majors across the College of Engineering in the introductory courses, as well as working with students that are learning deeper disciplinary content within Mechanical Engineering.

Steve Klisch, Professor of Mechanical Engineering

Dr. Klisch served as the Bently Center Director from 2014-2017. His research is focused on developing experimental and analysis protocols and conducting motion analysis studies of gait, cycling, elliptical training, and baseball pitching for our funded research projects. Dr. Klisch teaches courses in solid mechanics and biomechanics.

Final project reports are due a month after the end of the Bently support period. The reports include a the awardee's name, the number of weighted teaching units (WTUs) granted in the award, a summary of accomplishments, publications and other deliverables, student impacts, proposals and other leverage.

Below is a list of all the 2019-2020 awardee names, proposal titles, and the number of WTUs awarded. A report from each awardee is included in the following pages. Assigned time (6 WTUs for summer 2019) was awarded as part of a start-up package to two new tenure track hires: Ben Lutz and Lauren Cooper. These awards were requested by the ME Department chair at the time of their hire; they did not submit proposals. These awardees submitted a short report included below.

List of Awardees

Awardee, Proposal Title, Number of WTWs awarded — Page

Charles Birdsong, Professor and Director of the Bently Center for Innovation, "Bently Center Administration and Automotive Safety and Automation", 25.5 WTUs Awarded

Awardee

Charles Birdsong, Professor and Director of the Bently Center for Innovation, Mechanical Engineering, cbirdson@calpoly.edu

Award

Total units 25.5 (7.5 units summer 2018, 6 units fall 2018, 6 units winter 2019 and 6 units spring 2019)

Summary of Accomplishments

The assigned time was used in two main areas: first in the administration of the Bently Center for Innovation and second, in the professional development in the area of automotive safety and automation.

Bently Center Administration

The administrative activities for the 2019-2020 year included distributing the annual request for proposals, organizing the proposal review committee, meeting with the committee to review all proposals and collecting input for recommendations to fund specific proposals, announcing the awards, soliciting reports from each awardee and documenting the awards in this report.

In addition, to these regular annual activities other administrative activities were conducted. A taskforce was created in the Mechanical Engineering Department to review the charter and procedures for the Bentley awards. The Bently Center Taskforce included 5 ME faculty members including the Bentley Center Director and met periodically during the fall 2019 term. The committee was asked to review the charter and RFP procedures and make recommendations for changes and improvements. The conclusions of the taskforce included two main results: 1) student impact should be more explicit in the RFP rubric, and 2) a short definition of each RFP rubric category should be provided by the director and included in the RFP. The director received the taskforce input and made changes to the 2020 RFP that addressed the conclusions and streamlined the rubric categories. The taskforce report and the new rubric used for the 2020 RFP is attached in the Appendix.

Professional Development

Assigned time was used to pursue professional development in the area of automotive safety and automation. These activities included sponsoring and advising undergraduate students on senior projects, summer research projects and student competitions, developing hardware that will be used in the controls laboratory, advising MS students, collaborating with industrial sponsors and managing externally funded sponsored projects.

Publications and other Deliverables

Poster Sessions

Cal Poly College of Engineering Summer Undergraduate Research Project Symposium, fall 2019, poster, "Scaled Autonomous Vehicle Development and Testing"

Cal Poly College of Engineering Summer Undergraduate Research Project Symposium, fall 2020, poster, "High Speed Autonomous Vehicle Development"

Student Impact

Student Projects

Electronics and software for autonomous truck project, fall 2019-spring 2019 undergraduate ME students: Nate Furbeyre, Fernando Mondragon and Ricky Tan. Project continued through fall 2020 with undergraduate student Ben Robinson manufacturing a second chassis and MS student Robby Ketchum revising the electronics hardware to implement improvements identified in the prototype development.

Tractor Trailer State Estimation Senior Project Sponsor. I sponsored an ME428 team of 3 undergraduate MEs to develop a sensor system that allows a tractor trailer vehicle to estimate the angular position, velocity and size of a trailer based on remote sensing placed only on the tractor. Funded with professional development funds.

Development of DC Servo Lab Trainer system. 2018-2020 I worked with a team inclulding Charlie Refvem and James Gearhart to replace the outdated DC Servo trainer "Motomatic" apparatus in the Parker Controls Lab with a more modern apparatus. Charlie Refvem developed the digital microcontroller board and software. James Gearhart started with the prototype developed by a senior project that I sponsored in 2017 and redesigned the mechanical design to improve the ruggedness and manufacturability. The plan is to produce 10 units for the lab. Expected roll out date is fall 2021.

High Speed Autonomous Vehicle Development and Indy Autonomous Challenge. Summer 2020, I supervised 2 SURP students, Daniel Leavitt, Electrical Engineering and James Roberts, Computer Science to participate in an industry sponsored grand challenge to develop software that will allow an Indy Lights Formula racecar to drive autonomously in a head to head race at the Indianapolis Raceway. The sponsored donated access to ANSYS SCADE and VR Experience software running on Microsoft virtual computers for software development. Students collaborated with autonomous systems industrial partners including GM Cruise and United Technologies. They developed software that allowed a virtual racecar to navigate the race course.

Proposals and other Leverage

Active awards during the period of support

Cal Poly Summer Undergraduate Research Project, "Scaled Autonomous Vehicle Development and Testing" summer 2019, $15k (funded)

Cal Poly Summer Undergraduate Research Project, “High Speed Autonomous Vehicle Development” summer 2020, $10k (funded)

Co-PI with Simon Xing and Joseph Joseph Callenes-Sloan, industry sponsored project to apply laser interferometery to mechanical systems for system identification, real-time feedback control and electronic interface development. spring 2021-spring 2022, Keysight Technologies $335,000 (funded)

Proposals submitted during the period of support

Cal Poly office of University Diversity and Inclusion, Beacon proposal, “Autonomous Vehicle Control Development,“ Fall 2020, $2500 (not funded)

Cal Poly College of Engineering RIDC proposal “Student Support for Developing Cybersecurity in Vehicle Platooning,” Fall 2019, $13, (not funded)

Mid-Size Autonomous Vehicle Platform, $18,000, Cal Poly RSCA 2021 (pending)

John Chen, Professor, "Beyond Talent: Factors that Help Students Succeed", 12 WTUs Awarded

Awardee

John Chen, Professor, Mechanical Engineering, jchen24@calpoly.edu

Award

Total units awarded: 12 WTUs, originally assigned as 6 WTUs in 2020 Winter quarter and 6 WTUs in 2020 Spring quarter. Actual assignment became 3 WTUs in Winter 2020, 6 WTUs in Spring 2020 and 3 WTUs in Summer 2020; the changes were made in response to teaching needs in both quarters.

Summary of Accomplishments

The overarching question motivating my research asks: Why do some students succeed in engineering studies while others, at least equal in talent and academic qualifications, do not? Why are intelligence and academic preparation – which every entrant to Cal Poly's engineering program possesses – not enough to guarantee success? Importantly, there is growing awareness that innate talent – i.e., IQ or intelligence – is neither the only nor the most important trait for predicting future success or a wide range of achievement outcomes in adults or younger populations from adolescents to university students. Many traits not directly related to knowledge acquisition have been shown conclusively to have a significant impact as well, including, for example, optimism, self-control, and self-efficacy. In addition to psychological traits, there are learning-related factors that impact academic success, such as motivation, study strategies and self-regulation of learning.

The Bently-supported projects during the past year can be grouped into two topics. These are (i) grit and how it is affected through students' learning experiences and (ii) the collection of non-cognitive (NCA) factors related to student success. In the following sections, I describe the accomplishments from this past year.

Grit

This project continued to collect data contributed by study participants in two separate studies: Undergraduate ME students taking the mechanics sequence and first-year ME students. The participants track, through a smartphone app, their level of engagement in each course during both in- and out-of-class learning times. In the first study, students are recruited in ME 211 (statics) and are tracked as each undertakes the mechanics sequence of ME 211 – CE 204/ME 212 – CE 207 – ME 326. Two cohorts of participants have been recruited into this study, in Fall 2016 and Fall 2017, for a total of 70 students. The first cohort had mostly graduated in June 2019, so data collection is complete for them. The second cohort ended their participation in the study in June 2020. We are beginning data analyses for this study presently and expect this to continue for at least one year. The second study, consisting of 80 first-year ME students recruited in Winter 2018 and Winter 2019. Participants in this study are similarly contributing data through the smartphone app but all of their major courses are

being tracked. The first cohort of students have ended their participation in this study. The second cohort would have ended their participation in June 2020 but because of the coronavirus pandemic, they are extending their participation in a new phase of the study described below.

As a result of the pandemic, all Cal Poly classes shifted to remote learning for the spring 2020 quarter. This sudden and forced change in the teaching and learning modalities presented a unique opportunity to study how students shifted their patterns of learning. The students still participating in the study continued to contribute data, and they have been asked to extend their participation through all of the 2020-21 academic year. This will provide us with a comprehensive view of the changes in their learning engagement and patterns before, during and after the pandemic. In addition to this cohort, a second group of 60 other ME undergraduates were recruited to contribute data during the spring 2020 quarter and through the next academic year.

NCA factors

This project, which is a collaboration with Purdue University and University of Texas, El Paso, completed a third year of data collection at Cal Poly. During the past year, Cal Poly students contributed over 800 completed surveys to the study. The participants consist of engineering and computer science students in their first year of studies from across CENG, and a more detailed survey of ME students across all years of study. The results from these efforts are documented in the conference publications and journal manuscripts listed below. In the coming academic year, the survey will continue at Cal Poly so that we can track the students longitudinally as they progress through their curriculum.

Publications and other Deliverables (students in bold)

Peer-reviewed journal and conference papers

1. Scheidt, M., Godwin, A., Chen, J., Widmann, J., Self, B., Gates, A., and Berger, E., "Engineering Students' Non-Cognitive and Affective Factos: Group Differences from Clustering Analysis," under second review in *Journal of Engineering Education*, June 2020.
2. Ge, J., Jensen, K., Major, J., Froiland, J., Chen, J., Godwin, A., and Berger, E., "A Conceptual Model of Engineering Thriving: Broadening Understandings of Success for Undergraduate Engineering and Computing Students Based on a Scoping Literature Review," under review in *Engineering Studies*, June 2020.
3. Scheidt, M., Goodwin, A., Major, J.C., Kim, S., Self, B., Chen, J., and Berger, E., "Institutional characteristics' relationship to student non-cognitive and affective (NCA) profiles," manuscript in preparation for submission to *Research in Higher Education*, July 2020.
4. Widmann, J., Self, B., Chen, J., Chambers, C., Kusakabe, L., Landy, J., Berger, E., and Ge, J., "Academic SUCCESS: An analysis of how non-cognitive profiles vary by discipline and year for engineering and computer science students," *Proceedings of the 2019 Research in Engineering Education Symposium*, Capetown, South Africa, July 2019.
5. Scheidt, M., Major, J., Ge, J., Godwin, A., Chen, J., Self, B., Widmann, J., Berger, E., "Exploring the relationship between non-cognitive and affective (NCA) factors and first-year retention of undergraduates in engineering," 2019 Frontiers in Education Conference, Cincinnati, OH, October 2019.

6. Chen, J., Janzen, D., McGaughey, K., and Widmann, J., "Tracking learning engagement at the student level," 2019 Frontiers in Education Conference, Cincinnati, OH, October 2019.
7. Janzen, D., Chang, R., and Chen, J., "Development of mobile applications to study engineering students' patterns of learning," 2019 Frontiers in Education Conference, Cincinnati, OH, October 2019.
8. Krest, L., Major, J., Scheidt, M., Ge, J., Self, B., Chen, J., Widmann, J., Godwin, A., and Berger, E., "Examining the importance of non-cognitive and affective (NCA) factors for engineering student success," *Proceedings of the 2020 ASEE Annual Conference*, Montreal, Canada (virtual conference), June 2020.
9. Chen, J., Landy, J., Chambers, C., Grigorian, C., Kerfs, M., Self, B., Scheidt, M., Major, J., Ge, J., Godwin, A., Berger, E., and Widmann, J., "Learning in clusters: Exploring the association between non-cognitive and affective profiles of engineering students and academic performance," *Proceedings of the 2020 ASEE Annual Conference*, Montreal, Canada (virtual conference), June 2020.
10. Major, J., Scheidt, M., Godwin, A., Berger, E., Chen, J., "Effects of Test Anxiety on Engineering Students' STEM Success," *Proceedings of the 2020 ASEE Annual Conference*, Montreal, Canada (virtual conference), June 2020.

Note: Three additional conference papers and presentations were not published or presented due to the conferences being cancelled as a result of the coronavirus pandemic.

Student Impact

Supervision of student projects

- Camaryn Chambers, Christina Grigorian, Michelle Kerfs and Jenna Landy (undergraduate ME, BME and Statistics students, Cal Poly): Co-advised and -supervised these four undergraduates during the 2019-20 academic year for work described in the Bently proposal. Specifically, these students administered the surveys of engineering students, read research papers in support of the project, conducted statistical analyses and participated in the creation and delivery of four conference papers and presentations.

Proposals and other Leverage

Active awards during the period of support

1. **National Science Foundation** (PI: John Chen, co-PIs: David Janzen (CSC), Karen McGaughey (Statistics), Jennifer Teramoto Pedrotti (Psychology & Child Development), Jim Widmann (ME))
Oct. 1, 2014 to Sept. 30, 2017 (extended to Sept. 30, 2019); $200,000
***Title*:** Actively Building the Drive to Achieve through Everyday Engineering Learning. ***Aims*:** Grit – defined as passion and perseverance for long-term goals – is likely to be important to individuals trying to achieve the challenging, long-term goal of attaining an engineering degree, which requires not only talent but also its focused and sustained application over a long period. This proposed project will investigate the role of active learning in building grit. A longitudinal observational research design will be implemented to answer this question. California Polytechnic State University is an ideal place to conduct this study for several reasons: It is a large, state-supported, undergraduate-focused university typical of other large engineering programs; it has a diverse engineering student population; and it prides itself on the quality of the student experience, including many small, personalized classes and a

"learn by doing" culture. As a result of their natural progression through the curricula, students will have widely varying experiences along the active-learning continuum, from low quantity and quality, to high. This highly diverse engineering-learning ecology presents a unique opportunity to study the association between active learning and grit growth. ***Status:*** Submitted Feb. 4, 2014, and project ended in September 2019.

2. **National Science Foundation** (PI: John Chen, co-PIs: David Janzen (CSC), Karen McGaughey (Statistics), Jennifer Teramoto Pedrotti (Psychology & Child Development), Jim Widmann (ME))
June 1, 2016 to May 31, 2019 (extended to May 31, 2020); $499,275
Title**:** Does Active Learning Build Grit? ***Aims*****:** The study uses a quasi-experimental design with treatment and control groups to determine if active learning, which acts as a proxy for deliberate practice, builds the character trait of grit in students while they learn in the domain of mechanics. A second research question is whether increased grit leads to other success outcomes such as retention in major and progress toward degree. These questions are investigated through a direct intervention that includes intensive, peer-based, active-learning experiences, along with activities designed to boost optimism and endorsement of growth mindset. A control group will also undertake learning activities to improve its mechanics learning, but in ways that do not meet the definition of deliberate practice. Grit is likely to be important to individuals trying to achieve the challenging, long-term goal of attaining an engineering degree. ***Status:*** Submitted Sept. 10, 2015, and project was extended to May 31, 2021 to study the impacts of the coronavirus pandemic on students' patterns of learning.

3. **National Science Foundation** (PI: Jim Widmann, co-PIs: John Chen, Brian Self)
Oct. 1, 2016 to Sept. 30, 2020; $479,351
Title**:** IUSE:EHR: Collaborative Research: The Role of Non-Cognitive and Affective (NCA) Factors in Engineering and Computing Student Academic Performance. ***Aims*****:** Understanding the ways in which students succeed and fail in STEM majors, and developing powerful ways to support them, will pay dividends for our students, our institutions, and our nation. Predictive models for student academic performance largely rely upon cognitive measures of achievement such as high school GPA, SAT scores, and similar measures of past performance. These models have consistently demonstrated that only a reasonably small part ($R^2 \sim 0.25$) of the total variance in predicted academic performance is explainable using cognitive factors. More recent work includes non-cognitive and affective (NCA) variables (such as mindset) to improve the predictive power of academic performance models. Nonetheless, there remain substantial gaps in our understanding of how NCA profiles of STEM students can be used to support their academic success. The central intellectual contribution of this research-to-practice project is the development, implementation, and evaluation of NCA-based interventions for diverse STEM students in multiple settings. This multi-institution research team engages student affairs practitioners in the development and delivery of NCA-based interventions. The unique coalescence of expertise and experience among the team strongly promotes the multiple perspectives that are required to deploy interventions with diverse students in different settings. Importantly, the student affairs collaborations allow access to information about life events ("obstacles") faced by students, and this research explicitly connects student academic performance to such obstacles, as mediated by the NCA profile. This obstacle data, and its connection to both NCA profile and academic performance, represents a truly

unique and deeply valuable contribution of this research program. ***Status:*** Submitted Jan. 13, 2016, and project was extended for one additional year to September 2021.

Proposals submitted during the period of support

None.

Lauren Cooper, Assistant Professor, New Hire Assigned Time, 6 WTUs Awarded

Awardee

Lauren Cooper, Assistant Professor, Mechanical Engineering, lcoope06@calpoly.edu

Award

4.8 WTU in 2019 Summer quarter

Summary of Accomplishments

This summer, thanks to the generous support of the Bently Center, I was able to invest a substantial amount of time in developing my research plans (including gaining IRB approval) for AY 2019-2020. I took the lead in developing three pilot studies related to engineering education, each of which will be implemented with a different research team. The first study is focused on the role of mindfulness and mental health in engineering students. This research is expected to begin in January 2020 with a group of 50 engineering students. Dr. Anuraj Dhillon (faculty in Communications Studies), Dr. Andrew Danowitz (faculty in Electrical Engineering), and I will investigate the impact of mindfulness on engineering students' mental health. We recently submitted a research abstract to the Engineering and Research Methods Division of American Society of Engineering Education (ASEE), and we hope for the opportunity to present our work-in-progress at this year's annual conference in June 2020.

My second research project is a small pilot study taking place in ME470: Rehabilitation Engineering. This research is being carried out with Dr. Brian Self and visiting Ph.D. student Amanda Johnston from Purdue. We are investigating the impact of participating in ME470 on students' development of empathy and attitudes toward people with disabilities.

My third research project is a larger study involving about 80 students in Mechanical and Materials Engineering. This research is being carried out with Dr. Trevor Harding and Dr. Nicole Johnson-Glauch, and we are investigating the relationship between goal setting and students' self-efficacy beliefs. One of the unique aspects of this research is that we are collaborating with Ipse, a startup in the Accelerator Program at the Cal Poly Hothouse. Ipse is developing an app that uses crowdsourcing and machine learning to help students achieve goals in ways that best suit them. This collaboration ties in nicely to my research interests and provides exposure to real-world innovation and entrepreneurship.

I am still working to publish the results of my Ph.D. dissertation in project-based learning and student motivation. This past summer I finalized a manuscript draft that I intend to submit for potential journal publication this year.

Student Impact

Supervision of student projects

This summer I also worked devoted time to graduate student advising. I am currently the chair of two graduate committees:

- Project title: Dual Crystal Backlighter Imager
  Student: Nicholas Nguyen
  Expected graduation: May 2020

- Project title: Hybrid III 95th Male Finite Element Model Neck Alteration
  Student: Eric Day
  Expected graduation: December 2019

Stephen M. Klisch, Professor, "New Scholarly Directions for Cal Poly's Human Motion Biomechanics Lab", 12 WTUs Awarded

Awardee

Stephen M. Klisch, Professor, Mechanical Engineering, sklisch@calpoly.edu

Award

12 units (6 in 2019 Summer quarter, 2 in 2019 Fall quarter, 2 in 2020 Winter quarter, 2 in 2020 Spring quarter).

Summary of Accomplishments

As stated in the original proposal, the **primary objectives** of the assigned time were 1) proposal development and 2) conduct interdisciplinary research with students and faculty. To accomplish those objectives, I worked closely with a large, interdisciplinary team of Cal Poly students and faculty. That team included 14 Cal Poly students (11 ME, 3 BMED) and 5 Cal Poly Faculty members: Scott Hazelwood (Biomedical Engineering), Christie O'Hara (Kinesiology & Public Health), Scott Reaves (Food Science & Nutrition), Jeff Sklar (Statistics), and Suzanne Phelan (Kinesiology & Public Health). During the period of support, my primary activities included

- mentoring students as they worked on pitching, sports, and exercise biomechanics projects focused on injury & disease prevention;
- mentoring current and former students as they developed 4 peer-reviewed journal papers (2 published, 2 in review);
- mentoring current and former students as they submitted and/or presented 7 peer-reviewed conference papers;
- developing and/or submitting 9 research proposals (3 external to Cal Poly); and
- maintaining 2 IRB protocols for pitching and exercise biomechanics research.

Publications and other Deliverables (Cal Poly students in bold)

Peer-reviewed journal papers

1. **Jennings DJ**, Reaves SK, Sklar J, Brown C, McPhee J, Hazelwood SJ, Klisch SM. 3-D inertial parameter calculations from body composition imaging and overweight-related indices for youth pitching arm kinetics. *Journal of Applied Biomechanics,* in review, 2020.
2. **Skaro J**, Hazelwood SJ, Klisch SM. Knee angles after crosstalk correction with principal component analysis in gait, cycling, and elliptical training. *ASME Journal of Biomechanical Engineering*, in review, 2020.
3. **Sterner JA**, Reaves SK, Aguinaldo AL, Hazelwood SJ, Klisch SM. Inverse dynamics analysis of youth pitching arm kinetics using body composition imaging. *Sports Biomechanics*, March, 2020. https://doi.org/10.1080/14763141.2020.1715470
4. **Orekhov G**, Robinson AM, Hazelwood SJ, Klisch SM. Knee joint biomechanics in transtibial amputees in gait, cycling, and elliptical training. *PLOS One*, 14(12): e0226060 2019. https://doi.org/10.1371/journal.pone.0226060

Peer-reviewed conference papers

1. **Fernandez R**, **Biglari S**, O'Hara C, Hazelwood SJ, Klisch SM. Knee joint contact compressive force of transtibial amputee and control participants in gait, cycling, and elliptical. *Southwest American College of Sports Medicine Regional Chapter Annual Meeting*, 2019.
2. **Tucker SL**, **Weinhardt S**, O'Hara C, Hazelwood SJ, Klisch SM. Knee kinematics for the contralateral knee of transtibial amputees in gait and cycling. *Southwest American College of Sports Medicine Regional Chapter Annual Meeting*, 2019.
3. **Jennings DJ**, **Rose JM**, Reaves SK, Brown C, McPhee J, Hazelwood SJ, Klisch SM. Full DXA-driven inverse dynamic analysis of youth pitching arm kinetics. *Congress of the International Society of Biomechanics and Annual Meeting of the American Society of Biomechanics,* 2019.
4. **Fernandez R**, **Biglari S**, Hazelwood SJ, Klisch SM. Knee kinetics using DXA-mass driven inverse dynamics in gait, cycling, and elliptical training. *Congress of the International Society of Biomechanics and Annual Meeting of the American Society of Biomechanics,* 2019.
5. **Biglari S**, **Fernandez R**, Hazelwood SJ, Klisch SM. Knee adduction moments of normal weight, overweight, and obese participants in gait, cycling, and elliptical exercises. *Congress of the International Society of Biomechanics and Annual Meeting of the American Society of Biomechanics,* 2019.
6. **Biglari S**, **Stobaugh JR**, **Fernandez R**, Hazelwood SJ, Klisch SM. Lumbar spine compressive loads in simulated strawberry picking using OpenSim. *Congress of the International Society of Biomechanics and Annual Meeting of the American Society of Biomechanics,* 2019.
7. **Wash BR**, Self BP, Hazelwood SJ, Klisch SM. Verification of Opensim pelvic residuals in seated cycling with handlebar and seatpost load cells. *Congress of the International Society of Biomechanics and Annual Meeting of the American Society of Biomechanics,* 2019.

Student Impact

Supervision of M.S. students

1. Sterner, J. Smartphone-tape method for calculating body segment inertial parameters for analysis of pitching arm kinetics. *M.S. Thesis, Cal Poly,* June, 2020.
2. Jennings, D. Use of body composition image to calculate 3D inertial parameters for inverse dynamic analysis of youth pitching arm kinetics. *M.S. Thesis, Cal Poly,* March, 2020.
3. Stearns, J. Subject specific finite element models of the human knee for transtibial amputees to analyze tibial cartilage pressure for gait, cycling, and elliptical training. *M.S. Thesis, Cal Poly*, March, 2020.
4. Palumbieri, A. Comparative analysis of models for the assessment of tibiofemoral contact loads during cycling and gait trials. *M.S. Thesis, Politecnico di Milano, Milan, Italy,* September, 2019.
5. Sam Tucker (MS, non-thesis research, expected graduation Fall 2020).
6. Kaila Lawson (MS thesis research, expected graduation Spring 2021).
7. Carlos Soto (MS thesis research, expected graduation Spring 2021).
8. Ali Yazdkhasti (MS thesis research, expected graduation Spring 2021).

Supervision of B.S. students

1. Shaida Biglari (BMED, BS research, Spring 2018-Fall 2019)
2. Reymil Fernandez (ME, BS research, Spring 2018-present)
3. Ryan Sax (ME, BS research, Winter 2019-present)
4. Marissa Martinez (BMED, BS research, Spring 2018-present)
5. Karthik Padmanabhan (ME, BS research, Winter 2019-present)
6. Christina Fong (ME, BS research, Winter 2019-present)

7. Hunter Morse (ME, BS research, Winter 2019-present)

Proposals and other Leverage

Proposals submitted during the period of support

1. **NIH Academic Research Enhancement Award (AREA)** (PI Klisch).
4/1/21-3/31/24; $420,900 (total costs).
Title: Youth pitching biomechanics: DXA-driven analysis, obesity, and coaching intervention. *Submitted June, 2020*. *Status:* ***in review***.

2. **NIH Academic Research Enhancement Award (AREA)** (PI Klisch).
7/1/20-6/30/23; $415,500 (total costs).
Title: DXA-driven analysis of overweight- and injury-related youth pitching biomechanics. *Submitted October 2019*. *Status:* ***not funded***.

3. **Cal Poly BEACoN Mentors Program** (PI Klisch).
1/1/20-6/30/20; $5,000 (total costs inclusive of student and faculty stipends).
Title: Injury prevention biomechanics: pitching and gait. *Submitted October 2019. Status:* ***funded***.

4. **Cal Poly CENG R-IDC** (PI Klisch).
1/1/20-12/31/20; $5,000 (total costs).
Title: HMB Lab pitching and gait biomechanics: undergraduate student research support. *Submitted November 2019. Status:* ***funded***.

5. **Cal Poly Strategic Initiatives** (PI Klisch, Co-PIs Hazelwood, Espinoza-Wade, Reaves, O'Hara, Sklar, Delagrammaticas).
4/1/20-3/31/21; $494,422 (total costs for 1 year).
Title: Cal Poly's Human Motion Biomechanics (HMB) Lab: inclusive hub for excellence in undergraduate research and serving central coast students. *Submitted January 2020. Status:* ***not funded***.

6. **CSU Program for Education and Research in Biotechnology (CSUPERB)** (PI Klisch, Co-PI Reaves).
6/1/20-11/30/21; $14,973 (total costs).
Title: Effects of diet and coaching interventions on youth baseball and softball biomechanics. *Submitted January 2020*. *Status:* ***not funded***.

7. **Research, Scholarly, and Creative Activities Program (Cal Poly)** (PI Klisch).
Summer 2020 – Spring 2021; 8 WTUs assigned time.
Title: Bridge funding for renewing external support for Cal Poly's Human Motion Biomechanics Lab. *Submitted February 2020*. *Status:* ***not funded***.

8. **Donald E. Bently Center for Engineering Innovation** (PI Klisch).
Fall 2020 – Spring 2021; 8 WTUs assigned time. *Title*: Bridge funding: renewing external support for Cal Poly's Human Motion Biomechanics Lab. *Submitted February 2020*. *Status:* ***funded***.

9. **Cal Poly CENG Summer Undergraduate Research Program (SURP)** (PI Klisch).
6/20-9/20; $12,000 (total costs inclusive of student and faculty stipends).
Title: Injury prevention biomechanics. *Aim*: To mentor summer undergraduate students working on 2 research projects: baseball/softball pitching biomechanics and gait biomechanics. *Submitted March 2020. Status:* ***funded***.

Active awards during the period of support (external awards only)

1. **W.M. Keck Foundation** – Undergraduate Education Program, Phase II Application (PI Klisch; Co-PIs Hazelwood, Self, Clark, O'Hara).

1/1/16-6/30/20; $350,000 (direct costs). *Title*: Human Motion Biomechanics Lab: Integrating Research and Education in an Interdisciplinary Setting.

2. **US Army Medical Research and Materiel Command Broad Agency Announcement (AMRMC BAA)** (PI Klisch, Co-PIs Hazelwood, Self).

3/15/16-3/14/20; $513,645 (total costs). *Title*: Joint loads and cartilage stresses in intact joints of military transtibial amputees: enhancing quality of life.

Patrick Lemieux – "Windturbine LifeLine and Improving Internal Combustion Engines with Compressed Air Energy Storage", 10 WTUs Awarded

Awardee

Patrick Lemieux, Professor, Mechanical Engineering, plemieux@calpoly.edu

Award

10 units (2 Sm19 / 3 F19 / 1 W20 / 1 S20 / 3 Sm20)

Summary of Accomplishments

The original Bently release time proposal focused on two general areas of research:

I. *"Distributed Windturbine LifeLine".*

II. *"CAES: Improving Internal Combustion Engines with Compressed Air Energy Storage".*

The award specifically approved the first project, for 10 units. Therefore, my research focus over much the period of performance reported here has been on the Windturbine LifeLine, although this award has also afforded me the resources to work in parallel, from the Summer of 2019 through Winter 2020, on the recommissioning the hybrid rocket test stand in the Engines Lab. I chose to dedicate some time to this project, because of the significant interest shown by students, especially from our overseas partners. This year, 3 graduate students from the Politecnico di Torino (Polito) (Gaspare , Landi, and Quartararo) came to Cal Poly to work on this project, and much progress was made on the system – including a hot firing, the first one in more than 5 years, and 3 abstract submitted (and accepted) for paper presentations at the 2020 AIAA Propulsion and Energy Conference. Unfortunately, all that work stopped suddenly, the 3 MS students were forced to return to Italy without completing their research in our lab in early March, and the papers were never completed, all due to the COVID-19 pandemic. However, I am pleased to report than I was able to attend the successful PhD defense of another hybrid rocket student working, out of Polito, just prior to the pandemic outbreak. I expect that our collaborative work will resume once the pandemic is over, and hope that the Bently Center will consider funding this important research again.

The rest of this report focuses on the Windturbine LifeLine project.

Windturbine LifeLine PCM System Development

Downtime, troubleshooting, and maintenance remain substantial components of wind energy costs, limiting locations where wind power can compete. Sophisticated remote monitoring systems can increase reliability; however, the investment commitments required prevent their widespread use with distributed wind (DW) turbines. The goal of this project is to develop an inexpensive prognostic condition monitoring (PCM) system with a base material manufacturing production price targeted at around $100. Expected to streamline maintenance and provide feedback on field performance, the

concept was embraced by leading American and international manufacturers. Specific goals for the PCM device include:

1. Minimize the number of sensors and subsystems on the PCM device, and monitor only the most critical components of the machine. The selection of the sensors is based on problems identified in extensive surveys and studies of existing commercial systems, with leading manufacturers. Initially, our plans was to focus on two instruments: a single accelerometer (3-axes) and a shaft speed encoder; no other wind energy generator (WEG)-based PCM system uses so few instruments. In the past year, we have added wind speed to the cluster, for more direct fault correlation with this important environment parameter, but the above comments remain true nonetheless;
2. Focus on three basic root causes of failure: turbine overspeed, tower instabilities, and blade imbalance (again, based on our industry surveys);
3. Leverage "Internet of Things" (IoT) technology to interface with installers, operators, owners and manufacturers.

Work on the development of the PCM prototype started about two years ago, with the help of both undergraduate and graduate students (Gabriel Kardener and Ryan Takatsuka were 2 notably significant students in this period). At the beginning of this performance period, our prototype development had progressed to achieve 2 important milestones:

1) Validated a basic algorithm and a method (both designed at Cal Poly) for detecting trends, using a very simple acceleration monitoring algorithm;

2) Demonstrated its capability to successfully and reliably detected acceleration anomalies, and issue wireless-cellular alerts describing the event.

Our focus since then has been on securing external funding to take the system to a commercial level, and secure IP protection for the university, as outlined in this Bently proposal. Unfortunately, all external sources of funding aimed at supporting our wind energy projects applied for in the past several years have failed. With this in mind, at the very beginning of the period or performance reported here, our focus shifted from grant development to carrying out more fundamental engineering research on the system. Specifically to:

1. characterize more rigorously the performance of the Cal Poly Wind Turbine;
2. develop new, optimized fault-detection algorithms;
3. improve the instrument cluster on our prototypes;
4. tie-in the LifeLine to the control system of our own turbine itself (although in the long run, the LifeLine will need to adapt to a wide variety of different control systems, or be 'system agnostic').

Leveraging our involvement with highly motivated seniors and graduate students in my ME 488 and ME 542 classes, and John Ridgely's Mechatronics classes, and highlighting the potential of this system, we attracted a new crop of exceptionally talented students this year, notably John Cunningham, Luke Costello and Ryan Zhan, who signed on to help push our wind research to the next level, and help us tackle these goals over the past year. We were able to reach three important benchmarks this year: a) we completed the characterization of the Cal Poly wind turbine's in-field power curve, and discovered an important Reynolds Number effect on the Annual Energy Output (AEO) of the turbine, an effect previously unreported; b) We developed a stronger technical basis for the LifeLine's fault detection core, one scalable to multiple fault paths. The new algorithm research focuses on recently published Fault Detection and Diagnostic/ Fault Diagnostic Isolation (FDD/FDI) control methods applied specifically to large WEGs. We also adapted a fault detection method used in military helicopters. Both methods are showing very promising results, and both are certain to improve the competitiveness of our system in future grant application. We expect that a LifeLine system based on either (or both) of these algorithms will be more scalable (and thus 'forward compatible') and could form the basis of a significant, long-term competitiveness improvement in the Distributed Wind segment of the industry. And, c) we streamlined the hardware used in the LifeLine prototype to improve it power consumption, while adding two channels of data (wind speed and rotor speed) *directly* in the box.

All the while, the constraints on achieving these three goals included:

1. minimizing all costs of development (all hardware expenses were supported either by faculty professional-development moneys, or by internal grants from the university (e.g., CENG R-IDC);
2. include as many students as possible, focusing on student success (MS, Sr Projects, reports, etc), even at the cost of slowing down the project progress.

I am glad to report that this strategy has worked quite well. Even though our results have not been submitted for publication yet, I anticipate several conference and journal articles to come out of this years results. Finally, a side benefit of this approach is that our group appears to have reached a new critical mass: new students are now rushing to the project, providing a continuity of research that we have not seen before. I look forward to report to you the continuing success of the Wind Turbine LifeLine in the future, and of many more student involvement in these projects.

Once again, I thank you and the Donald E. Bently Center for Engineering Innovation for your continuing support of our research and our students.

Sincerely,

Patrick Lemieux

Ben Lutz, Assistant Professor, New Hire Assigned Time, 6 WTUs

Awardee

Ben Lutz, Assistant Professor, Mechanical Engineering, blutz@calpoly.edu

Award

6 WTUs in summer 2019

Summary of Accomplishments

During summer 2019, I focused on two primary objectives: 1) submitting manuscripts to journals and conferences and 2) preparing materials for a new class preparation.

In terms of the first objective, I was able to submit two different manuscripts, draft one conference paper, and make significant revisions to an article previously rejected from *The Journal of Engineering Education*. One article was submitted to *Engineering Studies* and focused on the school-to-work transition for recent mechanical engineering graduates. Another article was submitted to *Studies in Engineering Education* and focused on engineering students' conceptualizations of diversity and their expectations for diversity-focused learning in an engineering context. Finally, the conference paper emerged out of my CREATE undergraduate research group and is focusing on some current research we are doing around gender, creativity, and innovation. The conference paper will be submitted to the American Society for Engineering Education.

In terms of the second objective, I devoted significant time to preparing to teach a new class, ME 328: Design for Strength and Stiffness. The class is relatively far outside my expertise and training in engineering education, so I needed to spend time getting familiar with the material again and develop lesson plans and learning modules for the upcoming quarter. I was able to develop my syllabus and map out my entire course before the class began and I am well-positioned to facilitate student learning at a high level in this class in the fall 2019 quarter.

Publications and other Deliverables

Peer-reviewed conference papers

11. Cuellar[1], E., Osman[1], A., Gius[1], G., Lutz, B. (2019, under review) *Exploring the Influence of Activity Structure on Ideation Effectiveness in Mechanical Engineering Teams*. Paper under review for the American Society of Engineering Education Annual Conference in Montreal

Peer-reviewed journal papers

1. **Lutz, B.** and Paretti, M. C. (2019, under review) Unpacking the Content of Learning Experiences of Recent Engineering Graduates during the School-to-Work Transition. Manuscript under review in *Engineering Studies*

[1] Indicates undergraduate research assistant

2. Lee, W. C., **Lutz, B.** (2019, under review) Incorporating Diversity in the Engineering Curriculum: A Qualitative Investigation of Student Motivation. Manuscript under review in *Studies in Engineering Education.*

Student Impact

My work impacts students both in terms of research and learning in the classroom. In terms of research, my CREATE research group has gained valuable skills in performing qualitative analysis (and data collection in the fall) and writing scientific literature. Although the journal articles arose from prior collaboarations with other researchers, my undergraduate researchers have been helpful in reviewing and offering insight into the manuscripts I submitted.

In terms of the classroom, my ability to take time to fully prepare and internalize the concepts central to ME 328 has made me a more effective teacher than would have been possible without dedicated time during the summer.

Russel Westphall, Professor, "BLDS TO FTDS Initiative", 10 WTUs Awarded

Awardee

Russell V. Westphall, rvwestph@calpoly.edu

Award

10 WTU (18 requested; actual WTU used: 4 in Summer 2019, 3 in Fall 2019, 3 in Winter 2020)

Summary of Accomplishments

Restatement of Original Proposal Summary Paragraph (verbatim).

TITLE: BLDS to FTDS Initiative It is proposed to use the requested 18 WTU Bently Center release time award to greatly expand the Boundary Layer Data System concept. The re-imagined BLDS will be called FTDS—Flight Test Data System—and its capabilities will be expanded well beyond those of the existing BLDS to enable it to perform a much broader range of measurement tasks. The current BLDS was conceived specifically to measure quasi-static characteristics of the flow very near the surface, within the boundary layer, on the surface of an aircraft (or aircraft-borne model) in flight. In its various configurations, the existing BLDS can acquire skin friction, 1-, 2-, and 3-component velocity, and 16-probe rake (or other pressure) measurements. An opportunity to re-imagine BLDS as a more general tool for flight test data acquisition is made possible by recent advances in low-power electronics, digital sensors, wireless communications, high-capacity memory, and miniaturization. Current BLDS client Boeing, as well as prospective client General Atomics, have communicated needs for dynamic data including non-flow measurements of strain and acoustic data that cannot be accommodated by the existing BLDS, but would be within the capabilities of the envisioned FTDS. The proposer has demonstrated the ability to make effective use of Bently Center awards, having employed 4 previously completed and one currently in-progress Bently projects to write proposals resulting in 11 external awards valued at over $500 K to date. These projects have supported work involving dozens of students, significantly enhancing the value of their education and directly impacting their job placement. Overall, the proposer has the Department's most successful track record of maintaining continuous external support for his work: since fall 2008, the project has received several dozen awards totaling roughly $1.5 M in external sponsorship including providing to the ME Department over 50 WTU direct support from sponsored contracts. It is acknowledged that an award of at least 12 WTU would include the honor and privilege of using the title "Donald E. Bently Professor".

It has been my privilege to employ the Bently Center award of 10 WTU during summer 2019 through winter 2020 to support the proposed effort "BLDS to FTDS Initiative." The technical goals of the project have been attained through the conception, design, and development of a family of prototypes of the new Flight Test Data System, and some external support has been attained for its further development and deployment. **The award supported development of BLDS-related proposals that have already resulted in one new award, with a value of $13.1 K, and an $8.4 K augmentation of an ongoing project. Two internal proposals were submitted for funds from the BEACoN and R-IDC programs; the former was not awarded while the latter was funded for $2 K. Three additional formal "white paper"**

pre-proposals were submitted (two to USAF, one for the internal Strategic Initiatives) with ROM budgets totaling $775K; two of these were not awarded and one remains under consideration**.**

Aside from the preparation of written proposals, other outreach to cultivate prospective clients for sponsored research has been supported. In September, the PI presented a formal telecon "Flight Test/Boundary Layer Data System" for staff from General Atomics. In October, the PI travelled to the Redondo Beach offices of Northrop Grumman for an invited presentation to the company's acoustics group. The meeting explored mutual interests in acoustic measurements and the possible application of the next-generation BLDS paradigm for the company's acoustic measurement requirements.

The proposer has continued to strengthen the underpinning for the proposed work through publication of two papers which were completed and presented at peer-reviewed American Institute of Aeronautics and Astronautics meetings this summer. The first of these was presented by student co-author Isabel Jellen at AIAA AVIATION on June 18, 2019 (Bently Center support formally acknowledged in the final paper). The second was presented by student co-author Steven Waal at the AIAA Joint Propulsion and Energy Conference in August 2019.

Engagement of students, supported using sponsored contract, discretionary, SURP, Baker-Koob, and COE R-IDC funds has been key to the project. For the third consecutive year, students doing BLDS-related projects were mentored with the support of the COE's Summer Undergraduate Research Program during summer 2019. Three students prepared and presented posters describing the next-gen BLDS-related research they conducted on October 22 2019; one of them, Rachel Potratz, was awarded second place at the Symposium.

The project funded by a Baker-Koob award to student Andy Wu was completed during summer 2019. A project was proposed and awarded from the College R-IDC fund to support pre-proposal work by student Max Emerick; that project is currently underway.

Publications and other Deliverables (students in bold)

Peer-reviewed conference papers

12. **Jellen, I.**, **Wilson, Z.,** and Westphal, R. V. "A Next-Generation Modular Boundary Layer Data System", AIAA-2019-3228, *AIAA Aviation 2019*, Dallas, TX, 17-21 June 2019
13. **Dick, S. C., Ng, P., Gnagy, S. L., Waal, S. R**., and Westphal, R. V. "Compressible Isolated Actuator Disk Theory Solutions," AIAA-2019-3827, *AIAA 2019 Propulsion and Energy Forum,* Indianapolis, IN, 19–22 August 2019

Peer-reviewed journal papers

None.

Competition entry

1. Wu, A. (adviser: Westphal, R. V.) "BLDS-A: A Next-Generation Boundary Layer Data System for Acoustic Measurements", 8 page manuscript submitted in support of nomination for *34th CSU Statewide Student Research Competition*

Internet/newsletter articles

1. "A Tale of Two Schlierens: A Legacy of Prof. Hal Gascoigne," by R. Westphal; *https://www.ceng.calpoly.edu/connection/2019/09/a-tale-of-two-schlierens-a-legacy-of-prof-hal-gascoigne/*
2. "Cal Poly Autonomous Flight Lab Conducts First Flight of Next-Generation Flight Test Data System," by A. Drake & R. Westphal; *https://www.ceng.calpoly.edu/connection/2019/10/cal-poly-autonomous-flight-lab-conducts-first-flight-of-next-generation-flight-test-data-system/*

Formal Presentations

1. **Potratz, R.**, and Westphal, R. V. "Silicone Manifold for the Boundary Layer Data System" poster presentation at the Summer Undergraduate Research Symposium, Oct. 11, 2019.
2. **Wu, A**. and Westphal, R. V. "A Next-Generation Boundary Layer Data System for Unsteady Pressure Diagnostics With MEMS Microphones" poster presentation at the Summer Undergraduate Research Symposium, Oct. 11, 2019.
3. **Costello, L.**, and Westphal, R. V. "Rake Design for the Boundary Layer Data System" poster presentation at the Summer Undergraduate Research Symposium, Oct. 11, 2019.
4. **Jellen, I.** , **Wilson, Z**., and Westphal, R. V. "A Next-Generation Modular Boundary Layer Data System" AIAA-2019-3228, presented by student I. Jellen at AIAA AVIATION, June 18 2019
5. **Dick, S. C., Ng, P., Gnagy, S. L., Waal, S. R**., and Westphal, R. V. "Compressible Isolated Actuator Disk Theory Solutions," AIAA-2019-3827, presented by student S. R. Waal at *AIAA 2019 Propulsion and Energy Forum,* Indianapolis, IN, 19–22 August 2019
6. Westphal, R. V. "Flight Test/Boundary Layer Data System," teleconference presented for flight test and aerodynamics staff, hosted by General Atomics, Sept. 27, 2019.
7. Westphal, R. V. "BLDS for Acoustic Measurements," invited presentation for the Northrop Grumman acoustics group, Redondo Beach, CA Oct. 22, 2019
8. **Wu, A.** (adviser: Westphal, R. V.) "BLDS-A: A Next-Generation Boundary Layer Data System for Acoustic Measurements", paper presented for Cal Poly internal selection competition for 34 CSU Statewide Research Competition, Feb. 22, 2020

Student Impact

Supervision of student projects (all students listed paid hourly except as noted)

1. **Marc Goupil** (ME master's thesis—completed Dec. 2019; paid through COE R-IDC grant)
2. **Sean Casteel** (ME undergrad—fall 2019-winter 2020; paid sponsored project work)
3. **Charlie Refvem** (ME master's student, paid project work—summer 2019)
4. **Nathan Hoyt** (ME master's thesis—summer 2019, thesis defense June 27 2019)
5. **Zach Wilson** (ME master's thesis—completed Dec. 2019).
6. **Andy Wu** (ME undergrad—summer 2019 through winter 2020; paid sponsored project, SURP, Baker-Koob).
7. **Steven Waal** (ME undergrad—paper presentation, paid travel, summer 2019, *unpaid*)
8. **Isabel Jellen** (CptSci grad—paper presentation, paid travel, summer 2019, *unpaid*)
9. **Max Emerick** (ME undergrad—paid project work, summer 2019, winter 2020)
10. **Owen Basham-Clair** (ME undergrad—paid project work, summer 2019)
11. **Luke Costello** (ME undergrad—SURP student; Symposium poster co-author)
12. **Rachel Potratz** (MATE undergrad—SURP student; Symposium poster co-author)
13. **Makenzie Kamei** (ME undergrad—ME 400 project *unpaid*)

Proposals and other Leverage

Active awards during the period of support

Boeing Commercial Airplane Company (R. V. Westphal, PI, A. G. Drake, co-PI)

Dec. 2018-Aug. 2020; $23.4 K (extended and augmented during summer-fall 2019)
Title*:** Oil Flow Dispensing System ***Aims*:** Develop and apply BLDS for oil flow dispensing for 777/ GE9X engine flight test. ***Status: submitted Nov. 2018, **funded**, in progress.

Cal Poly Mech. Engr. Donald E. Bently Center for Engrg Innovation (R. V. Westphal, PI)

Summer 2019-Summer 2020; 18 WTU
Title: BLDS to FTDS Initiative ***Aims:*** Provide PI release time for effort to expand BLDS to a comprehensive Flight Test Data System (FTDS)
Status: submitted Feb 2019, 10 WTU (approx. value $40 K) **awarded**

Northrop Grumman Corp. (R. V. Westphal, PI)

Dec. 2018-Dec. 2019; $30 K
***Title*:** Engine Inlet Diagnostics ***Aims*:** Investigate novel approaches to engine inlet flow diagnostics.
Status: unrestricted grant/gift received Dec. 2018, **funded**, in progress.

Cal Poly College of Engrg 2019 Summer Undergrad. Research Prog. (R.V. Westphal, PI)

June 2019-August 2019; value approx. $16 K in student and faculty stipends
Title: BLDS Project ***Aims:*** Involve more students in BLDS-related non-proprietary project work
Status: BLDS project (4 students) **funded**, completed.

Cal Poly Baker-Koob fund (R. V. Westphal, PI)

Jan 2019-July 2019; $0.5 K for materials and supplies
Title: Noise Sensing Version of the Boundary Layer Data System ***Aims:*** support project costs for student Andy Wu
Status: awarded Dec 2018, **completed Sept 2019**

Proposals submitted and other funding initiated during the period of Bently support

1. **Otto Aviation** (R. V. Westphal, PI)
   Fall 2019-Summer 2020; $13.1 K + options
   Title: Boundary Layer Diagnostics Flight Test ***Aims:*** flight test of Otto aircraft using BLDS
   Status: awarded Sept 2019, **funded**, in progress
2. **US Air Force Research Laboratory** (R. V. Westphal, PI, A. Drake, co-PI)
   Fall 2019 – Fall 2021; $175 K ROM budget
   Title: Low-Cost Flight Test Instrumentation and Consortium ***Aims:*** develop flight-capable next-gen BLDS prototype with input and evaluation of user consortium
   Status: invited formal white paper submitted June 2019 not funded
3. **US Air Force Research Laboratory** (A. Drake, PI, R. V. Westphal, co-PI)
   Fall 2019 – Fall 2022; $450 K ROM budget
   Title: Cal Poly Aging Aircraft Fuel Efficiency Initiative ***Aims:*** Employ Autonomous Flight Lab resources and BLDS team to improve USAF fleet fuel economy
   Status: invited formal white paper submitted July 2019 not funded
4. **Cal Poly College of Engineering R-IDC fund** (R. V. Westphal, PI)

Jan 2020-May 2020; $4 K for student salary & hardware ($2 K awarded)
Title: BLDS-T ***Aims:*** support student Max Emerick for next-gen BLDS temperature measurement
Status: awarded Dec 2019 **funded,** in progress

5. **Cal Poly Strategic Initiatives** (R. V. Westphal, PI, A. Drake, co-PI)
   June 2020-June 2022; $150 K
   Title: BLISTERS: A Paradigm for Tiny, Autonomous Aircraft Devices ***Aims:*** initiate work on radically smaller/lighter/low-power version of FTDS
   Status: submitted Jan 28, 2020; under review
6. **BEACoN** (R. V. Westphal, PI/mentor)
   Winter-spring 2020; $5 K
   Title: BLDS-T ***Aims:*** Provide an opportunity for a BEACoN sponsored student to work with the BLDS project team.
   Status: submitted October 4, 2019; not awarded

Xi Wu, Professor, "Data Acquisition Card for Bently Rotor Kit", 3 WTUs Awarded

Awardee

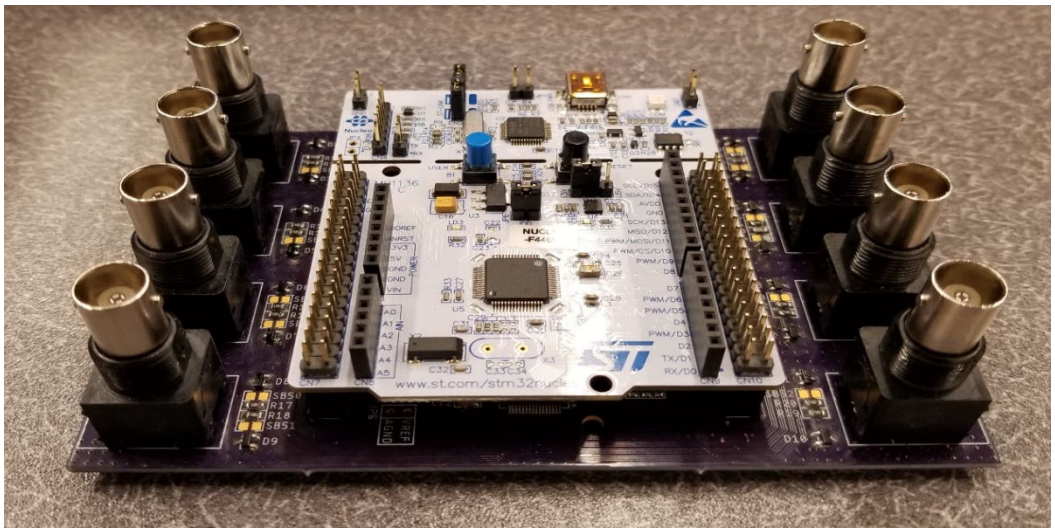
Xi Wu, Professor, Mechanical Engineering, xwu@calpoly.edu

Award

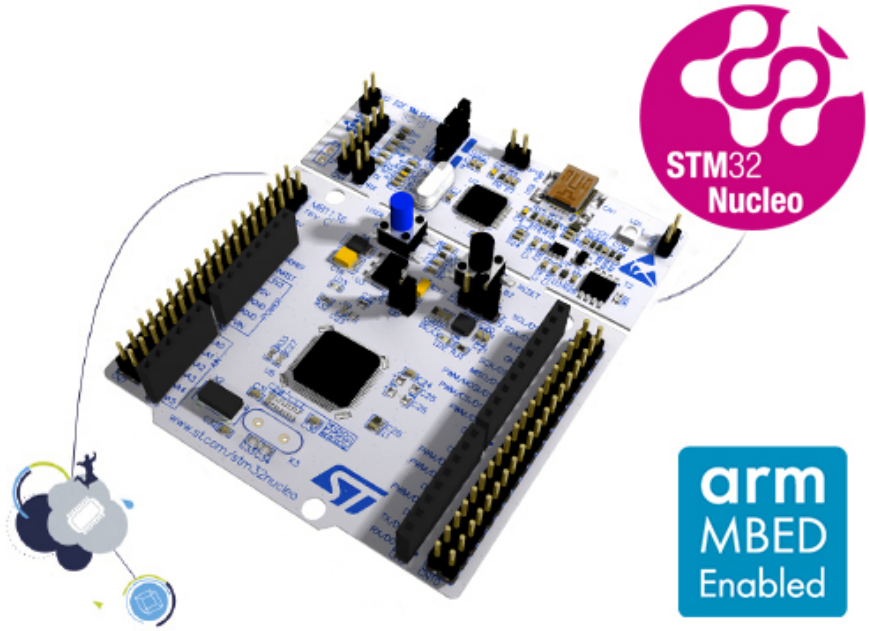
Total 3 WTUs.

Summary of Accomplishment

As the proposal stated, we have successfully designed and developed hardware Data Acquisition Card for Bently rotor kit using mechatronics knowledge based on the use of a STM32 microcontroller. **This brand-new DAQ is creatively designed by Cal Poly and its function is compatible to National Instruments cDAQ-9174 module with lower cost.** Its purpose is to provide a transparent and low-cost alternative to commercially available DAQs, providing instructors a means to teach students about the process through which data are collected as well as the uses of collected data. The DAQ was designed to collect data from rotating machinery spinning at a speed up to 10,000 RPM and send this data to a computer through a USB 2.0 full-speed connection. Multitasking code was written for the DAQ to allow for data to be simultaneously collected and transferred over USB. Additionally, a console application was created to control the DAQ and read data, and MATLAB code written to analyze the data. The DAQ was compared against a custom assembled National Instruments CompactDAQ system. Using a Bently-Nevada RK 4 Rotor Kit, data was simultaneously collected using both DAQs. Analysis of this data shows the capabilities and limitations of the low cost DAQ compared to the custom CompactDAQ. Please refer to the thesis for detail.



STM32 USB DAQ Hardware. STMicroelectronics line of Nucleo boards provide access to a power 32-bit Arm based microcontroller. These boards provide easy access to the microcontroller's GPIO pins and include an on board STLink programmer and debugger. This, along with the low cost of the board, make these microcontrollers suitable for use as a low-cost, transparent DAQ.



STM32 Nucleo-F446RE: Nucleo-64 development board; 180 MHz frequency; USB 2.0 Full-Speed core

Student Impact

Based on the outstanding contribution, we are preparing to publish peer-reviewed journal paper

Master's Thesis. Gregory Pellegrino, " DESIGN OF A LOW-COST DATA ACQUISITION SYSTEM FOR ROTORDYNAMIC DATA COLLECTION", 2019.

These objectives provide a learning experience not only to the students that design the DAQ, but also to those who use the device in the future, as they will be able to see and learn about the steps necessary for accurately collecting vibrational data. This new hardware DAQ is the first data acquisition system designed by Cal Poly. It will eventually replace the old ADRE208 in Vibration Lab which can only work properly with Windows XP, which is not supported by Microsoft anymore. The Bently rotor kits are extensively used for teaching **the required undergraduate class ME318 and graduate-level class ME518**. **Replacing the outdated data acquisition system with the new DAQ will bolster our program as a whole. Every student from ME will benefit from this project.**

Other Leverage

Because of our excellent research, Bently Nevada GE keeps supporting our research and teaching program. In the past year, Bently Nevada have hired two graduate students from Cal Poly. They have

also donated the most current equipment and software: (1). 4701 and 2300 machinery monitoring system Bently Nevada (hardware). (2). expensive System1 software (allow us to free download in future 10 years). The total value is more than $120,000.