

## EDUCATION

**Ph.D. in Mechanical Engineering**, 2011, Stanford University

Dissertation: *Applications of Model Predictive Control to Vehicle Dynamics for Active Safety and Stability*

**M.S. in Mechanical Engineering**, 2007, Stanford University

**B.S. with Honors in Mechanical Engineering**, 2005, Bucknell University, Summa Cum Laude

Thesis: *Pulse-Width Control Criteria and Evaluation for Serially Connected Flexible Robotic Arms*

## APPOINTMENTS

**Associate Professor**, 2020 – Present

Bucknell University, Department of Mechanical Engineering

**Assistant Professor**, 2012 – 2020

Bucknell University, Department of Mechanical Engineering

Jane W. Griffith Fellow, 2012 – 2015

**Visiting Assistant Professor**, 2011 – 2012

Bucknell University, Department of Mechanical Engineering

**Graduate Teaching Affiliate**, 2010

Stanford University, Department of Mechanical Engineering

**Graduate Fellow**, 2006 – 2008

Stanford University, Department of Mechanical Engineering

## PUBLICATIONS

### Journal Articles

- [J1] H. Haeri, C. E. Beal, and K. Jerath. “Near-optimal Moving Average Estimation at Characteristic Timescales: An Allan Variance Approach.” *IEEE Control Systems Letters*. 6 pages, published early access, November 2020. DOI: <https://doi.org/10.1109/LCSYS.2020.3040111>.
- [J2] M. D. Robinson, C. E. Beal, and S. N. Brennan. “At what cost? How planned collisions with pedestrians may save lives.” *Accident Analysis & Prevention*, volume 141, p. 105492, 2020. ISSN 0001-4575. DOI: <https://doi.org/10.1016/j.aap.2020.105492>.
- [J3] C. Beal and S. Brennan. “Modeling and Friction Estimation for Automotive Steering Torque at Very Low Speeds.” *Vehicle System Dynamics*, volume 59(3), pp. 458–484, 2021. DOI: <https://doi.org/10.1080/00423114.2019.1708416>.
- [J4] C. Beal and S. Brennan. “Friction Detection from Stationary Steering Manoeuvres.” *Vehicle System Dynamics*. 28 pages, published early access, July 2019. DOI: <https://doi.org/10.1080/00423114.2019.1645862>.
- [J5] C. Beal. “Rapid Road Friction Estimation using Independent Left/Right Steering Torque Measurements.” *Vehicle System Dynamics*, volume 58(3), pp. 377–403, 2020. DOI: <https://doi.org/10.1080/00423114.2019.1580377>.

- [J6] C. Beal and C. Boyd. “Coupled Lateral-Longitudinal Vehicle Dynamics and Control Design with Three-Dimensional State Portraits.” *Vehicle System Dynamics*, volume 57(2), pp. 286–313, February 2019. DOI: <https://doi.org/10.1080/00423114.2018.1467019>.
- [J7] C. Bobier-Tiu, C. Beal, J. Kegelmann, R. Hindiyeh, and J. Gerdes. “Vehicle Control Synthesis Using Phase Portraits of Planar Dynamics.” *Vehicle System Dynamics*, volume 57(9), pp. 1318–1337, 2019. DOI: <https://doi.org/10.1080/00423114.2018.1502456>.
- [J8] C. Beal and J. C. Gerdes. “Model Predictive Control for Vehicle Stabilization at the Limits of Handling.” *IEEE Transactions on Control Systems Technology*, volume 21(4), pp. 1258–1269, July 2013. DOI: <https://doi.org/10.1109/TCST.2012.2200826>.

### Peer Reviewed Conference Papers

\* undergraduate student author

- [C1] C. Boyd\* and C. Beal. “Vehicle Stabilization During Critical Cornering Scenarios Using Sliding Surface Control.” In “Proceedings of the 2017 ASME Dynamic Systems and Control Conference, Tyson’s Corner, VA, USA,” ASME DCSD, October 2017. DOI: <https://doi.org/10.1115/DSCC2017-5216>.
- [C2] C. Beal. “Stabilization of a Vehicle Traversing a Short Low-Friction Road Segment.” In “Proceedings of the 2017 IEEE Conference on Control Technology and Applications, Kohala, HI, USA,” pp. 1898–1903. IEEE Control Systems Society, August 2017. DOI: <https://doi.org/10.1109/CCTA.2017.8062733>.
- [C3] C. Beal and J. Orbison. “An Interactive Professional Ethics Case Simulation.” In “Proceedings of the 2017 ASEE Annual Conference and Exposition, Columbus, OH, USA,” ASEE, June 2017. DOI not available.
- [C4] C. Beal. “Miniature Electric Vehicle Laboratory for Introductory and Advanced Coursework.” In “Proceedings of the 2017 American Control Conference, Seattle, WA, USA,” pp. 5349–5354. ASME DCSD, May 2017. <https://doi.org/10.23919/ACC.2017.7963786>.
- [C5] C. Beal. “Independent Wheel Effects in Real Time Estimation of Tire-Road Friction Coefficient from Steering Torque.” In “Proceedings of the 2016 IFAC Symposium on Advances in Automotive Control, Norrkoping, Sweden,” pp. 319–326. International Federation of Automatic Control, Automotive Control TC, June 2016. DOI: <https://doi.org/10.1016/j.ifacol.2016.08.048>.
- [C6] H. Yang\*, D. McBlane\*, C. Boyd\*, C. Beal, and S. Brennan. “Vehicle Road Departure Detection Using Anomalies in Dynamics.” In “Proceedings of the 2016 American Control Conference, Boston, MA, USA,” pp. 6314–6319. ASME DCSD, June 2016. DOI: <https://doi.org/10.1109/ACC.2016.7526662>.
- [C7] L. Giugliano\* and C. Beal. “Dynamic Rear-End Collision Mitigation for a Vehicle About to be Struck.” In “Proceedings of the 2015 ASME Dynamic Systems and Control Conference, Columbus, OH, USA,” ASME DCSD, October 2015. DOI: <https://doi.org/10.1115/DSCC2015-9674>.
- [C8] C. Beal, C. Bobier, and J. C. Gerdes. “Controlling Vehicle Instability Through Stable Handling Envelopes.” In “Proceedings of the 2011 ASME Dynamic Systems and Control Conference, Arlington, Virginia, USA,” pp. 861–868. ASME DCSD, November 2011. DOI: <https://doi.org/10.1115/DSCC2011-6124>.
- [C9] C. Beal and J. C. Gerdes. “A Method for Incorporating Nonlinear Tire Behavior into Linear Model Predictive Control for Vehicle Stability.” In “Proceedings of the 2010 ASME Dynamic Systems

and Control Conference, Boston, Massachusetts, USA,” pp. 157–164. ASME DCSD, October 2010. <https://doi.org/doi:10.1115/DSCC2010-4168>.

- [C10] C. Beal and J. C. Gerdes. “Experimental Validation of a Linear Model Predictive Envelope Controller in the Presence of Vehicle Nonlinearities.” In “2010 IFAC Symposium on Advances in Automotive Control,” pp. 25–30. IFAC Technical Committee on Automotive Control, July 2010. <https://doi.org/10.3182/20100712-3-DE-2013.00041>.
- [C11] C. Beal and J. C. Gerdes. “Predictive Control of Vehicle Roll Dynamics with Rear Wheel Steering.” In “Proceedings of the 2010 American Control Conference,” pp. 1489–1494. IFAC AACC, June-July 2010. DOI: <https://doi.org/10.1109/ACC.2010.5531263>. (Best Presentation in Session Award).
- [C12] C. Beal and J. C. Gerdes. “Enhancing Vehicle Stability Through Model Predictive Control.” In “Proceedings of the 2009 ASME Dynamic Systems and Control Conference, Hollywood, USA,” pp. 197–204. ASME DCSD, October 2009. DOI: <https://doi.org/10.1115/DSCC2009-2659>.
- [C13] C. Beal and J. C. Gerdes. “Rollover Event Prevention Through Predictive Control of Coordinated Actuators.” In “Proceedings of the 21st International Symposium on Dynamics of Vehicles on Roads and Tracks, Stockholm, Sweden,” International Association for Vehicle System Dynamics, August 2009. DOI not available.
- [C14] K. Buffinton, A. Perkins, C. Beal, and M. Berg. “Evaluation of Pulse-Width Controllers for Multi-Link, Revolute-Jointed Robotic Arms.” In “Proceedings of the IASTED International Conference on Robotics and Applications,” pp. 131–139. Oct.-Nov. 2005. DOI not available.

### Conference Poster Presentations

- [CP1] D. Ebenstein, L. F. Perrone, M. Vigeant, D. Sills, C. Beal, and A. Kabalan. “Global Engineering Perspectives Scholars Program (Work in Progress).” In “Proceedings of the 2020 ASEE Virtual Conference,” ASEE, June 2020. DOI not available.
- [CP2] H. Yang\*, S. Brennan, and C. Beal. “Vehicle Road Departure Detection Using Anomalies in Dynamics.” In “Undergraduate Research and Design Exposition at the International Mechanical Engineering Congress and Exhibition (IMECE),” ASME, 2015. Awarded 2nd place.

### PATENTS

- [P1] Beal, Craig and Brennan, Sean. 2019. Method for Estimation of Friction Coefficient from Steering Maneuvers of a Vehicle. U.S. Patent Application 62,823,761, filed July 16, 2019. Patent Pending.

### GRANTS AND PROPOSALS

#### Funded Proposals

- [G1] NSF #1726283: *MRI: Acquisition of Automotive Tire Force and Moment Sensors*. \$154,840, **C. Beal**, sole PI. 9/15/17 – 9/14/19.
- [G2] PA Manufacturing Fellows Initiative: *Product and Manufacturing Innovations for Water Sports Equipment for Gilson Snow, Inc.* \$70,000 (**C. Beal**, N. Siegel - Bucknell), 8/1/19 – 7/31/20.
- [G3] NSF #1932509: *CPS: Medium: Collaborative Research: Automated Discovery of Data Validity for Safety-Critical Feedback Control in a Population of Connected Vehicles*. \$124,143 (**C. Beal** - Bucknell), \$1,195,334 (total), 10/1/19 – 9/31/21.

## **Bucknell Student Support Grants**

- Bucknell Program for Undergraduate Research 2019: Y. Zhou  
*Instantaneous Friction Determination using Combined Steering Torque and Braking Force Measurement*  
(Third-year proposal denied, but funded by BU mechanical engineering department.)
- Bucknell Program for Undergraduate Research 2017: H. Wang  
*Dynamic control paradigm for a 3-D printer resin extruder*
- Bucknell Program for Undergraduate Research 2016: C. Boyd  
*Design of a control system that employs trail braking as a safety maneuver*  
(Second-year proposal denied, but funded by BU mechanical engineering department.)
- Bucknell Program for Undergraduate Research 2015: C. Boyd  
*Trail Braking as a Safety Manuever for Navigating Corners*
- Bucknell Program for Undergraduate Research 2014: L. Giugliano  
*Enhancing the Modern Driver's Perception*
- Bucknell Summer Research Fellowship 2014: D. Lifschitz  
*Automobile Safety Systems: Improvement of a Method to Estimate Tire Friction Coefficients in Passenger Vehicles*
- Bucknell Program for Undergraduate Research 2013: A. Dillon  
*Experimental Estimation of Road Friction Coefficient with an RC Car*
- Bucknell Program for Undergraduate Research 2013: A. Slavitz  
*Development of a Driving Enhancement to Reduce Roadside Accidents Caused by Loss of Handling*

## **INVITED LECTURES**

- Driven: Steering Yourself to a Degree*  
ME201: Dim Sum of Mechanical Engineering Seminar, December 2010, Stanford University
- Staying in Control at the Limits of Handling: A Model Predictive Envelope Controller to Keep You and Your Car Out of Danger*  
Mechanical Engineering Seminar Series, September 2010, Villanova University
- Vehicle Dynamics Principles for Formula SAE*  
July 2008, York College of Pennsylvania

## **CAMPUS LECTURES**

- The Future of the Automobile*  
ASME "Teacher Talks," March 2017, Bucknell University
- Choose your own Engineering Ethics Adventure*  
New Horizons Faculty Lunch Series, February 2017, Bucknell University
- Kickin' the Tires in the Laplace Domain: How Engineers Use Mathematics to Design Great Cars*  
Mathematics Colloquium, April 2014, Bucknell University

## PROFESSIONAL SERVICE

Reviewer - IEEE Transactions on Control System Technology	2019 - Present
Reviewer - Vehicle System Dynamics	2018 - Present
Reviewer - IEEE Transactions on Vehicular Technology	2011 - Present
Reviewer - American Control Conference	2011 - Present
Reviewer - ASME Dynamic Systems and Control Conference	2010 - Present
Reviewer - IEEE Conference on Control Technology and Applications	2018
Associate Editor - ASME/IEEE American Control Conference	2015 - 2018
Associate Editor - ASME Dynamic Systems and Control Conference	2015 - 2018
Reviewer - IFAC World Congress	2017
Reviewer - IEEE Conference on Decision and Control	2017
Reviewer - ASME Journal of Dynamic Systems, Measurement and Control	2013 - 2017
Reviewer - IFAC International Symposium on Advances in Automotive Control	2010, 2016

## RESEARCH EXPERIENCE

**Bucknell University** - Assistant Professor 2012 - Present

*My research focus is in developing high performance human-vehicle interactions to assist drivers in maintaining control of their vehicle at the friction-dependent handling limits. My research also provides foundational knowledge for the development of autonomous systems.*

### **Eliciting Emergency Driver Responses with In-Vehicle Stimuli**

Students: Y. Zhou (UG)

Exploration of the potential for the vehicle to recognize adverse road or environmental situations and use in-vehicle sensory stimuli to provoke a desired and rapid driver reaction.

### **Detection of Road Surface Friction Conditions from Steering Torques**

Faculty Collaborator: S. Brennan (PSU)

Determination of sufficient excitation conditions and development/refinement of algorithms for detecting road surface friction conditions from on-board steering torque measurements.

### **Control of Vehicle Maneuvers on Uncertain Road Surfaces**

Students: C. Boyd (UG/Masters)

Development of systems for responding to changes in road friction, enabling human-driven and autonomous vehicles to maneuver appropriately in adverse or uncertain road conditions.

### **Virtual and Small Scale Vehicle Dynamics Testing**

Students: J. Ferrara (UG), Z. Slavitz (UG), A. Dillon (UG), H. Doherty (UG)

Development of scale vehicles and sensing to create an environment for friction estimation and safe experimentation with limit-handling vehicle control.

**Bucknell University** - Visiting Assistant Professor

2011 - 2012

### **Control of Low Power Compliant Robots**

Students: G. Williams (UG), J. Rivera (UG/Masters)

Faculty Collaborators: C. Kim (MECH), C. Buffinton (MECH), B. Vogel (CHEG), J. Meiser (ARST)

Development of design, manufacturing techniques, and feedback loops for producing and controlling small scale, low power, fluid driven compliant mechanisms.

## MEMBERSHIPS

IEEE and IEEE Control Systems Society	2012 – present
American Society for Engineering Education (ASEE)	2010 – present
Tau Beta Pi National Engineering Honor Society (TBP)	2004 – present
American Society of Mechanical Engineers (ASME)	2003 – present
Society of Automotive Engineers (SAE)	2013 – present

## TEACHING EXPERIENCE

### Courses Taught:

#### **Bucknell University**

Introduction to Engineering: F2015, F2016, approx. 25 students

Graphics for Design and Manufacturing: S2013, S2018, S2019, approx. 42 students

Fundamentals of Electrical and Computer Engineering: F2020, approx. 32 students

Mechanical Design: S2014, S2015, S2017, approx. 25 students

Senior Design Project Advisor: AY2012-2013, AY2014-2015, AY's 2016-2019, approx. 8 students

System Dynamics: F2011-2015, F2017-2018, approx. 25 students

Robotics: F2011, S2014, approx. 18 students

Vehicle Dynamics and Control: S2013, F2014, approx. 18 students

Mechatronics: S2019, approx. 11 students

#### **Stanford University**

Vehicle Dynamics and Control: W2010, approx. 32 students

### Academic Advising

Class of 2021, Bucknell University, BSME (A-K,Y), 16 students

Class of 2017, Bucknell University, BSME (A-K), 15 students

### Theses Supervised

[T1] C. Boyd. *Vehicle Stabilization During Critical Cornering Scenarios Using Sliding Surface Control*. Master's thesis, Bucknell University, 2017.

[T2] D. Lifschitz. *Automobile Safety Systems: Improvement of a Method to Estimate Tire Friction Coefficients in Passenger Vehicles*. Master's thesis, Bucknell University, 2015.

### Thesis Committees

[H1] S. Salinger. *Electric Helicopter Configuration Selection for Urban Air Mobility Requirements*. Undergraduate honors thesis, Bucknell University, May 2019. Committee member.

[H2] J. Ring. *A Passive Brace for the Treatment of Scoliosis Utilizing Compliant Mechanisms*. Master's thesis, Bucknell University, 2017. Committee member.

[H3] J. Rivera. *The Design, Construction, and Experimental Characterization of Spatial Parallel Architectures of Elastofluidic Systems*. Master's thesis, Bucknell University, 2014. Committee member.

### Workshops Attended:

Project Catalyst: How to Engineer Engineering Education, Bucknell University, 2013.

ASEE National Effective Teaching Institute (NETI), Tampa, 2013.