Joseph Breeden

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Attitude Control Systems Engineer
Goddard Space Flight Center, Greenbelt, MD

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SUMMARY

I am an early career engineer interested in designing control systems for challenging satellite guidance, navigation, and control problems. My PhD research focused on developing constrained control laws for provably-safe autonomy, with an emphasis on safety-filtering and space applications. My professional career has provided attitude control and flight dynamics analysis for a range of satellites, including numerous CubeSats and the GPM and OSAM-1 missions.

EDUCATION

Ph.D. Aerospace Engineering, May 2024
Thesis: "Constrained Control and Online Safety Filtering for Autonomous Space Systems", dx.doi.org/10.7302/22843
M.S.E. Aerospace Engineering, April 2022
University of Michigan, Ann Arbor, MI, United States
National Science Foundation Graduate Research Fellow, François Xavier Bagnoud Fellow

Visiting Doctoral Student, October 2023–March 2024
Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS-CNRS), Toulouse, France
Chateaubriand Fellow

B.S. Aerospace Engineering, **B.S. Mathematics**, May 2019
University of Maryland, College Park, MD, United States

PUBLICATIONS

Published Journal Articles

Breeden, J., Zaccarian, L., and Panagou, D. (2024). "Robust Safety-Critical Control for Systems with Sporadic Measurements and Dwell Time Constraints", in *IEEE Control Systems Letters*, vol. 8, pp. 1415-1420, dx.doi.org/10.1109/LCSYS.2024.3410631.

K. Garg, J. Usevitch, J. Breeden, M. Black, D. Agrawal, H. Parwana, and D. Panagou (2024). "Advances in the Theory of Control Barrier Functions: Addressing practical challenges in safe control synthesis for autonomous and robotic systems", in *Annual Reviews in Control*, vol. 57, no. 100945, dx.doi.org/10.1016/j.arcontrol.2024.100945.

Breeden, J., and Panagou, D. (2023). "Safety-Critical Control for Systems with Impulsive Actuators and Dwell Time Constraints", in *IEEE Control Systems Letters*, vol. 7, pp. 2119-2124, dx.doi.org/10.1109/LCSYS.2023.3285141.

Breeden, J., and Panagou, D. (2023). "Autonomous Spacecraft Attitude Reorientation Using Control Barrier Functions", in *AIAA Journal of Guidance, Dynamics, and Control*, vol. 46, iss. 10, pp. 1874-1891, dx.doi.org/10.2514/1.G007456.

Breeden, J., and Panagou, D. (2023). "Robust Control Barrier Functions under High Relative Degree and Input Constraints for Satellite Trajectories", in *Automatica*, vol. 155, no. 111109, dx.doi.org/10.1016/j.automatica.2023.111109.

Breeden, J., and Panagou, D. (2022). "Guaranteed Safe Spacecraft Docking with Control Barrier Functions", in *IEEE Control Systems Letters*, vol. 6, pp. 2000-2005, dx.doi.org/10.1109/LCSYS.2021.3136813.

Breeden, J., Garg, K., and Panagou, D. (2021). "Control Barrier Functions in Sampled-Data Systems", in *IEEE Control Systems Letters*, vol. 6, pp. 367-372, dx.doi.org/10.1109/LCSYS.2021.3076127.

Peer-Reviewed Conference Papers

Breeden, J. and Panagou, D. (2022). "Compositions of Multiple Control Barrier Functions Under Input Constraints", *2023 American Control Conference*, pp. 3688-3695, dx.doi.org/10.23919/ACC55779.2023.10156625.

Breeden, J., and Panagou, D. (2022). "Predictive Control Barrier Functions for Online Safety-Critical Control", *2022 61st IEEE Conference on Decision and Control*, pp. 924-931, dx.doi.org/10.1109/CDC51059.2022.9992926. (**CDC Outstanding Student Paper Award**)

Breeden, J., and Panagou, D. (2021). "High Relative Degree Control Barrier Functions Under Input Constraints", *2021 60th IEEE Conference on Decision and Control*, pp. 6119-6124, dx.doi.org/10.1109/CDC45484.2021.9683705. (**TCAC Outstanding Student Paper Award**)

Breeden, J., and Panagou, D. (2020). "Quadratic Programs for High Relative Degree Spatial Constraints and Spatiotemporal Specifications with Spacecraft Applications", *2020 59th IEEE Conference on Decision and Control*, pp. 1496-1502, dx.doi.org/10.1109/CDC42340.2020.9304162.

PROFESSIONAL EXPERIENCE

Attitude Control Systems Engineer
NASA Goddard Space Flight Center, Greenbelt, MD
Summary: Over five work tours, I provided attitude determination and control system analysis for a variety of satellite missions and proposals. I solved problems in topics such as control system design, trajectory optimization, orbit scheduling, underactuated control, visual navigation, satellite drag analysis, and others. Specific roles include:

Analyst for Dione and OSAM-1	June 2024 - Present
Analyst for TSIS-2, OSAM-1, GTOSat, and LIC Missions	June - Aug. 2022
Failure Response Analyst for GPM Mission	May - Oct. 2020
Analyst for LunarIceCube and SmallSat Rapid Development Pipeline	May - Aug. 2019
Analyst for LunarIceCube and CubeSat Phase A Proposal	Jan. - Aug. 2018

GRADUATE RESEARCH EXPERIENCE

Graduate Student Research Assistant Aug. 2019 - May 2024

- My thesis investigated the application of safety-filtering and control barrier functions to design computationally lightweight and provably-safe constrained control for space applications.
- Emphasis was placed on application to higher-order dynamics, minimizing conservatism, sampled-data effects, robustness, and relevance to space systems.
- Applications simulated included: spacecraft trajectory generation in the presence of moving obstacles with known trajectories, constrained reorientation, spacecraft docking maneuvers, collision avoidance within disimilar orbits, asteroid inspection, and car intersection management.

Project Mentor for ROB590 Independent Research (Robotics) Jan. - April 2023
Teaching Assistant for AERO740: Multi-Agent Control Jan. - April 2022

HONORS AND AWARDS

UM Department of Aerospace Engineering: **Pierre T. Kabamba Award for Excellence in Control Systems**, 2024
UM College of Engineering: **Towner Prize for Distinguished Academic Achievement**, 2024
IEEE Control Systems Society: **CDC Outstanding Student Paper Award**, 2022
IEEE Technical Committee on Aerospace Controls: **Outstanding Student Paper Award**, 2021
NASA Goddard Spaceflight Center: (Team) **Robert H. Goddard Award**, 2021
UMD Aerospace Engineering Department: **Alfred Gessow Academic Achievement Award**, 2019
AIAA Student Conference Region I: (Team) **Third Place Presentation**, 2018
Universities Space Research Association: **John R. Sevier Memorial Scholarship**, 2017
Aerospace States Association: **Edward A. O'Connor Jr. Founder's Scholarship**, 2017
SpaceX Hyperloop Competition: (Team) **Performance and Operations Award**, 2017
NASA Goddard Space Flight Center: **Poster Session Winner**, 2016

UNDERGRADUATE EXPERIENCE

Navigation and Mission Design Academic Collaborator Jan. - Dec. 2017
NASA Goddard Space Flight Center, Greenbelt, MD

- Studied optical navigation algorithms

Imaging, Electronics, and Systems Engineer – RockSat-X Student Team Sep. 2016 - Aug. 2018
University of Maryland Space Systems Lab, College Park, MD

- Designed, built, and delivered a 160 km sounding rocket payload for RockSatX

Attitude Control Systems Engineering Intern June - Aug. 2016
NASA Goddard Space Flight Center, Greenbelt, MD

- Studied miniaturized reaction wheels

Balloon Payload Program Student Team Leader Sep. 2015 - April 2019
University of Maryland Nearspace Lab, College Park, MD

- Designed, constructed, launched, and iterated a high-altitude balloon payload

Pneumatics Subsystem Lead – Student Team Aug. 2015 - Aug. 2017
University of Maryland Hyperloop Team, College Park, MD
- Led subteam in designing pneumatic actuator subsystem for SpaceX Hyperloop Competition

Space Exploration Sector High School Intern Oct. 2014 – May 2015
Johns Hopkins University Applied Physics Lab, Laurel, MD
- Studied structure from motion

UNDERGRADUATE PRESENTATIONS

Breeden, J., Casey, C., Chastain, T., Chen, A., Gabsa, N., Marlin, S., Perumalla, A., Plank, V., Roberts, I., Sahinci, C., Schwenger, S., Stamatakis, N., and Venincasa, J. (2019). "Crewed Habitat for Extended Extraterrestrial Surface Exploration". Capstone Engineering Presentation and Design Review, College Park, MD.

Weinberg, B., Breeden, J., and Abbonizio, J. (2018). "Engineering of a Tribocharging Regolith Simulant Experiment". Presentation given at AIAA Student Conference Region I, Potsdam, NY.

Breeden, J., and Cruz-Ortiz, G. (2018). "Simulating a Multirotor Testbed for Spacecraft Formation Flying". Presentation given at AIAA Student Conference Region I, Potsdam, NY.

Breeden, J., and Bilello, J. (2017). "Optical Relative-Navigation Centroiding Algorithm". Poster presented at NASA Goddard Interns Poster Session, Greenbelt, MD.

Breeden, J., and Bowden, M. (2017). "High Altitude Weather Balloon Venting and Balloon Dynamics". Presentation given at AIAA Student Conference Region I, Charlottesville, VA.

Walker, M., Breeden, J., et al. (2017) "High Altitude Weather Balloon Operations in the Mid-Atlantic". Presentation given at AIAA Student Conference Region I, Charlottesville, VA.

Breeden, J., and Cruz-Ortiz, G. (2016) "Reaction Ring for CubeSat Attitude Control". Poster presented at NASA Goddard Interns Poster Session, Greenbelt, MD.

MENTORSHIP AND SERVICE

Robotics Outreach Ambassador, *UM Robotics Department*, 2023
Science Communication Fellow, *UM Museum of Natural History*, 2023
Outreach Presenter, *Wolverine Pathways Program*, 2021-2022
Common Read Facilitator, *UM College of Engineering*, 2020
Payload Design Mentor, *Balloon Payload Program*, 2016-2018
Engineering Outreach Volunteer, *Space Systems Lab*, May 2017, 2018, 2019