

# Jake Welde

PhD Candidate | Researcher in Robotics, Dynamics, and Control  
University of Pennsylvania, GRASP Laboratory

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## RESEARCH FOCUS

My work addresses planning and control for mechanical systems. I'm interested in rigorous geometric approaches which leverage strong properties of these control systems and scale gracefully with system complexity, tackling challenges associated with underactuation and non-Euclidean geometry. Such structural properties can inform mechanism and controller design for real-world robots and enable the deployment of robots that more closely parallel the incredible examples in nature that provide the ultimate inspiration.

## EDUCATION

**PhD Candidate in Mechanical Engineering and Applied Mechanics**

*University of Pennsylvania, GRASP Laboratory*

2019 - present

*Philadelphia, PA*

**Advisor:** Dr. Vijay Kumar

My ongoing work exploits symmetry, Riemannian geometry, and dynamical systems theory to develop a constructive approach to geometric control for underactuated mechanical systems, such as aerial and space robots.

**Master of Science in Engineering, Robotics**

*University of Pennsylvania*

2020

*Philadelphia, PA*

**Bachelor of Science in Engineering, Mechanical Engineering and Applied Mechanics**

*University of Pennsylvania*

2019

*Philadelphia, PA*

Minor in French and Francophone Studies

## PUBLICATIONS

### JOURNAL ARTICLES

1. “Dynamically Feasible Task Space Planning for Underactuated Aerial Manipulators”,  
Jake Welde, James Paulos, and Vijay Kumar.  
*IEEE Robotics and Automation Letters*, 2021.  
*Finalist for Best Paper in Unmanned Aerial Vehicles* at ICRA 2021.
2. “Autonomous Flight for Detection, Localization, and Tracking of Moving Targets With a Small Quadrotor”,  
Justin Thomas, Jake Welde, Giuseppe Loianno, Kostas Daniilidis, and Vijay Kumar.  
*IEEE Robotics and Automation Letters*, 2017.

### REFEREED CONFERENCE PROCEEDINGS

1. “The Role of Symmetry in Constructing Geometric Flat Outputs for Free-Flying Robotic Systems”,  
Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.  
*IEEE International Conference on Robotics and Automation*, 2023.

2. “Trajectory Planning for the Bidirectional Quadrotor as a Differentially Flat Hybrid System”, Katherine Mao, Jake Welde, M. Ani Hsieh, and Vijay Kumar.  
*IEEE International Conference on Robotics and Automation*, 2023.
3. “Coordinate-Free Dynamics and Differential Flatness of a Class of 6DOF Aerial Manipulators”, Jake Welde and Vijay Kumar.  
*IEEE International Conference on Robotics and Automation*, 2020.

## PREPRINTS

1. “A Compositional Approach to Certifying the Almost Global Asymptotic Stability of Cascade Systems”, Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.  
*IEEE Control Systems Letters (Under Review)*, 2023.

## PRESENTATIONS

### EXTERNAL AND INVITED TALKS

1. “A Principal Bundle Perspective on Differential Flatness in Complex Robotic and Biological Systems”, Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.  
Contributed Talk, *Robophysics Focus Session*, APS March Meeting, 2023.
2. “The Role of Symmetry in Constructing Geometric Flat Outputs for Free-Flying Robotic Systems”, Jake Welde, Matthew D. Kvalheim, and Vijay Kumar.  
Invited Talk, *Daniilidis Lab Research Seminar*, University of Pennsylvania, 2022.
3. “Planning and Control for Multirotor Aerial Vehicles and Manipulators”, Jake Welde and Vijay Kumar.  
Guest Lecture, *MEAM 543: Performance, Stability, and Control of UAVs*, University of Pennsylvania, 2019.

## POSTERS

1. “Towards Automatic Identification of Globally Valid Geometric Flat Outputs via Numerical Optimization”, Jake Welde and Vijay Kumar.  
*Geometric Representations Workshop*, International Conference on Robotics and Automation, 2023.
2. “Some Aerial Manipulators Can Exactly Track Arbitrary Smooth End-Effector Trajectories in 6 Degrees of Freedom”, Jake Welde and Vijay Kumar.  
*Northeast Robotics Colloquium*, University of Pennsylvania, 2019.

## HONORS AND AWARDS

Outstanding Teaching Assistant Award, Mechanical Engineering, University of Pennsylvania	Fall 2021
Finalist for Best Paper in Unmanned Aerial Vehicles, International Conference on Robotics and Automation	2021
National Science Foundation Graduate Research Fellowship	2019
Couloucondis Prize for Best Presentation, Mechanical Engineering Senior Design, University of Pennsylvania	2019
Second Place, School of Engineering Senior Design Competition, University of Pennsylvania	2019
Student Travel Grant Award, IEEE International Conference on Intelligent Robots and Systems	2017

## TEACHING

### PEDAGOGICAL TRAINING

Certificate in College and University Teaching, Center for Teaching and Learning	2023
<i>Multipart teaching preparation and credential for university instruction</i>	<i>University of Pennsylvania</i>

Preparation consists of participation in teaching seminars held by current faculty, expert observation of a teaching demonstration, and exploration and development of personal teaching philosophy through interaction with expert teachers and scholars.

**Course in College Teaching**, Center for Teaching and Learning Fall 2022  
*Semester-long seminar covering course design, active learning, and engaging teaching practices* *University of Pennsylvania*

**Inclusive and Equitable Teaching Mini-Course**, Center for Teaching and Learning Spring 2023  
*Month seminar on scholarly research and primary sources on inclusive and equitable instruction* *University of Pennsylvania*

## INSTRUCTIONAL EXPERIENCE

**MEAM 520 / CIT 520: Introduction to Robotics** Fall 2020 / Spring 2021 / Fall 2021  
*Teaching Assistant for Professors Cynthia Sung, Vijay Kumar, and M. Ani Hsieh* *University of Pennsylvania*

Led development of written and laboratory assignments to achieve key pedagogical objectives across theory and practice, covering forward and inverse kinematics, motion planning, rigorous testing, and simulation-to-reality workflow. Worked closely with students in office hours, recitations, and hands-on lab sessions. Led the creation and introduction of a final capstone competition in which students implement a complete manipulation solution on industrial robot hardware. Recognized with the **Outstanding TA Award**.

**MEAM 211: Engineering Mechanics, Dynamics** Spring 2021  
*Teaching Assistant for Professor Michael Posa* *University of Pennsylvania*

Conducted interactive problem-solving recitations with undergraduates. Developed new computational assignments for the course, in which students implement a multibody dynamics simulator via step-by-step weekly modules, putting concepts into practice.

## EXPERIENCE

### ACADEMIA

**Research in Aerial Robotics, Dynamics, and Control** *GRASP Laboratory, University of Pennsylvania*  
*Undergraduate Research Assistant* 2015 - 2019

*Graduate Research Fellow* 2019 - present

- Contributed to onboard sensing, estimation, and motion planning pipeline enabling a quadrotor to autonomously track dynamically moving targets without violating the vehicle's coupled sensor and actuation constraints
- Demonstrated differential flatness of underactuated aerial manipulators and developed algorithm to plan trajectories which will achieve a desired trajectory for the end effector while respecting system's underactuation
- Achieved insight into longstanding open questions regarding the role of symmetry in differential flatness, simplifying the discovery of flat outputs and enabling efficient and effective control of underactuated robotic systems.

**SharpShooter: an Invisible Tripod via Reaction Wheels** 2018 - 2019  
*Senior Design Project, Mechanical Engineering at the University of Pennsylvania* *Philadelphia, PA*

Development of a novel reaction wheel stabilizer for ergonomic, handheld long-exposure still photography with team of peers

- Developed motor system identification pipeline to enable precise application of corrective torques
- Implemented gyroscope bias observer to enable accurate and precise attitude estimation during exposures
- Packaged estimation, control, and camera integration system in tightly-integrated prototype of consumer device
- Quantitative stabilization performance exceeded all other commercially available handheld stabilizers

### INDUSTRY

**Exyn Technologies** Summer 2018  
*Robotics: Software and Algorithms Intern* *Philadelphia, PA*

Software engineering at aerial robotics startup delivering trustworthy autonomy in challenging environments

- Evaluated and integrated range of technologies for barcode decoding and localization for autonomous warehouse inventory
- Contributed mission-critical modules to integrate low-level sensors with high-level flight software stack
- Developed and implemented novel algorithm for extrinsic calibration of any number of rigidly connected inertial measurement units, cameras, and LIDARs using only a single physical calibration target accomodating all sensing modalities

## MEDIA

GRASP Lab Presents: "MEAM 520 Class Breakdown"	2022
Penn Engineering Today: "Virtual Robots: Taking Risks in an Online Classroom"	2021
National Geographic's Breakthrough: "Game of Drones"	2017
34th Street Magazine: "Penn Students Create Gingerbread Replica of Fisher Fine Arts Library"	2017

## SERVICE

### OUTREACH

<b>Science Olympiad at the University of Pennsylvania</b>	2017 - present
• <b>Event Supervisor</b> , <i>Penn Invitational Tournament</i> . Coordinating a team of student volunteers to run a yearly engineering challenge for high school students, with over 100 students competing.	
• <b>Placement Leader</b> , <i>Urban Initiative</i> . Site supervisor for several student volunteers in affiliated outreach and mentoring program. Making weekly visits to a Philadelphia public high school to work directly with students exploring science and engineering topics.	

### MENTORING STUDENT RESEARCHERS

*Undergraduate and masters student(s) I have supervised directly and doctoral student(s) with whom I have worked closely as a mentor.*

#### Doctoral Students

• Katie Mao, University of Pennsylvania (Mechanical Engineering)	2022
<i>"Trajectory Planning for the Bidirectional Quadrotor as a Differentially Flat Hybrid System"</i>	

#### Masters Students

• Saibernard Yogendran, University of Pennsylvania (Robotics)	Fall 2022 - present
<i>"Brushless Motor Dynamic Response Characterization and Aerial Vehicle Design"</i>	

#### Undergraduate Students

• Nicole Luna, Cal Poly Pomona (Mechanical Engineering and Physics)	Summer 2021
<i>"Aerial Manipulator Mechanical Design"</i>	
• Natasha Dilamani, University of Pennsylvania (Mechanical Engineering)	Summer 2020
<i>"Dynamic Modeling of the Sphero, a Highly Nonholonomic System"</i>	

### ACADEMIC AND PROFESSIONAL

<b>Treasurer, Mechanical Engineering Graduate Association</b> , University of Pennsylvania	2020-2021
Managed finances while planning and executing programming to support the professional, social, engagement, and inclusion needs of the graduate student community in our department.	

#### Review Activities for International Journals and Conferences

• Springer Autonomous Robots	2023
• IEEE Robotics and Automation Letters	2021 - 2023
• ASME Journal of Dynamic Systems, Measurement and Control	2022 - 2023
• IEEE International Conference on Robotics and Automation	2022 - 2023
• Robotics: Science and Systems	2022
• IEEE Transactions on Automatic Control	2022
• IEEE Transactions on Robotics	2021 - 2022
• IEEE International Conference on Intelligent Robots and Systems	2020 - 2021
• IEEE International Conference on Automation Science and Engineering	2020