

# Zac Manchester

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## Academic Positions

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### Stanford University

*Assistant Professor of Aeronautics and Astronautics*

*Jan 2018 – Present*

### Harvard University

*Postdoctoral Fellow, Agile Robotics Lab*

*Oct 2015 – Dec 2017*

## Education

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### Cornell University

*Ph.D. Aerospace Engineering*

*Dissertation: Centimeter-Scale Spacecraft: Design, Fabrication, and Deployment*

*Advisor: Mason Peck*

**Ithaca, NY**

*2015*

### Cornell University

*M.Eng. Mechanical Engineering*

**Ithaca, NY**

*2010*

### Cornell University

*B.S. Applied Physics*

**Ithaca, NY**

*2009*

## Research Experience

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### Stanford University

*Director, Robotic Exploration Laboratory*

**Stanford, CA**

*Jan 2018–Present*

- Pushing the limits of size, mass, and power in small spacecraft.
- Developing communication, navigation, and control capabilities to enable massively distributed space systems.
- Building motion planning and control algorithms that can reason about uncertainty and contact interactions.

### Harvard University

*Postdoctoral Fellow, Agile Robotics Laboratory*

**Cambridge, MA**

*Oct 2015–Dec 2017*

- Developed novel algorithms for robust motion planning under uncertainty and disturbances.
- Developed a new framework for modeling and controlling robotic systems that experience contact based on discrete mechanics.
- Performed wind tunnel tests to develop a full-flight-envelope model of a small UAV for planning and control of aggressive flight maneuvers.

**Cornell University***Graduate Research Assistant, Space Systems Design Studio***Ithaca, NY***Aug 2010–Sep 2015*

- Pioneered the development of centimeter-scale “ChipSat” spacecraft.
- Founded the KickSat project to launch and deploy 100 ChipSats in low-Earth orbit.
- Raised \$75k through crowd-funding website Kickstarter.
- Awarded launch through NASA’s CubeSat Launch Initiative.
- Developed novel attitude control and inertia estimation algorithms.
- Developed a long-range low-power radio communication protocol for small spacecraft.
- Led a small team to design, build, test, and fly a 3U CubeSat.

**NASA Ames Research Center***Aerospace Engineer***Moffett Field, CA***June 2012–Dec 2013*

- Developed attitude determination and control algorithms for small satellite missions.
- Experimented with rapid prototyping techniques for fabrication of spacecraft components.
- Performed integration and environmental testing for CubeSats.

**Sandia National Laboratories***Research Intern***Albuquerque, NM***Summer 2009*

- Used semiconductor fabrication techniques to build prototype satellite-on-chip devices at Sandia’s Center for Integrated Nanotechnology.

**Cornell University***Undergraduate Research Assistant, Space Systems Design Studio***Ithaca, NY***Jan 2008–July 2010*

- Designed and conducted experiments to measure the capacitance of charged objects in a plasma
- Operated a xenon ion thruster in a vacuum chamber

## Teaching Experience

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**Harvard University***Guest Lecturer and Lab Instructor, Science of the Physical Universe***Cambridge, MA***Spring 2017**Teaching Assistant, Optimization Algorithms for Robotics**Spring 2016**Guest Lecturer, Space Science and Engineering**Fall 2016***Cornell University***Instructor, Spacecraft Engineering***Ithaca, NY***Spring 2012**Teaching Assistant, Feedback Control Systems**Fall 2010*

## Other Professional Experience

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**Breakthrough Starshot***Advisory Committee Member**Feb 2016–Present***Sentinel IC Technologies, Inc.***Software Consultant**Spring 2010*

- Developed high performance mixed-integer optimization code in C for semiconductor design applications

**Analytical Graphics, Inc.***Software Development Intern**2007–2010*

- Developed astrodynamics simulation software
- Developed a C# to Java source-to-source compiler
- Developed an algorithm for calculating rhumb lines on oblate and prolate spheroids that is now part of STK

## Licenses and Certifications

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### Private Pilot

*Single-Engine Land*

2017

### Amateur Radio

*Technician Class*

2011

## Awards

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### Distinction in Teaching Award

*Harvard University*

2016

Awarded for top student reviews while serving as a teaching assistant

### Thomas J. and Joan T. Kelley Prize

*Cornell University*

2010

Awarded for top Aerospace Engineering Master's project

## Publications

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### Preprints.....

1. Z. Manchester and S. Kuindersma, "Robust Direct Trajectory Optimization Using Approximate Invariant Funnels," *Autonomous Robots*, 2018.

### Journal Papers.....

2. J. I. Lipton, R. MacCurdy, Z. Manchester, L. Chin, D. Cellucci, and D. Rus, "Handedness in shearing auxetics creates rigid and compliant structures," *Science*, vol. 360, no. 6389, pp. 632–635, May 11, 2018. DOI: 10.1126/science.aar4586.
3. Z. Manchester and A. Loeb, "Stability of a Light Sail Riding on a Laser Beam," *The Astrophysical Journal*, vol. 837, no. 2, Mar. 7, 2017. DOI: 10.3847/2041-8213/aa619b.
4. Z. Manchester and M. Peck, "Quaternion Variational Integrators for Spacecraft Dynamics," *Journal of Guidance, Control, and Dynamics*, vol. 39, no. 1, pp. 69–76, Jan. 2016. DOI: 10.2514/1.G001176.

### Conference Papers.....

5. J. Lipton, Z. Manchester, and D. Rus, "Planning cuts for mobile robots with bladed tools," in *Robotics and Automation (ICRA), 2017 IEEE International Conference On*, Singapore: IEEE, 2017.
6. Z. Manchester and S. Kuindersma, "DIRTREL: Robust Trajectory Optimization with Ellipsoidal Disturbances and LQR Feedback," in *Robotics: Science and Systems (RSS), Cambridge, MA, Cambridge, MA*, 2017.
7. Z. Manchester and S. Kuindersma, "Variational Contact-Implicit Trajectory Optimization," in *Proceedings of the International Symposium on Robotics Research (ISRR)*, Puerto Varas, Chile, 2017.
8. Z. Manchester, J. Lipton, R. Wood, and S. Kuindersma, "A Variable Forward-Sweep Wing Design for Enhanced Perching in Micro Aerial Vehicles," in *55th AIAA Aerospace Sciences Meeting*, Grapevine, TX, 2017.
9. Z. Manchester and M. Peck, "Recursive Inertia Estimation With Semidefinite Programming," in *AIAA Guidance, Navigation, and Control Conference*, Grapevine, TX, 2017.

10. B. Plancher, Z. Manchester, and S. Kuindersma, "Constrained Unscented Dynamic Programming," in *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Vancouver, BC, 2017.
11. Z. Manchester, "Lyapunov-Based Control for Flat-Spin Recovery and Spin Inversion of Spin-Stabilized Spacecraft," in *AIAA/AAS Astrodynamics Specialist Conference*, Long Beach, CA, 2016.
12. Z. Manchester and S. Kuindersma, "Derivative-free trajectory optimization with unscented dynamic programming," in *Decision and Control (CDC), 2016 IEEE 55th Conference On*, Las Vegas, NV: IEEE, 2016.
13. Z. Manchester, M. Peck, and A. Filo, "Kicksat: A crowd-funded mission to demonstrate the world's smallest spacecraft," in *AIAA/USU Conference on Small Satellites*, Logan, UT, 2013.
14. Z. Manchester and M. Peck, "Stochastic Space Exploration with Microscale Spacecraft," in *AIAA Guidance, Navigation, and Control Conference*, Portland, OR: American Institute of Aeronautics and Astronautics, Aug. 8, 2011. DOI: 10.2514/6.2011-6648.
15. J. Atchison, Z. Manchester, and M. Peck, "Microscale Atmospheric Re-entry Sensors," in *7th International Planetary Probe Workshop*, Barcelona, Spain, 2010.

#### Dissertation.....

16. Z. Manchester, "Centimeter-Scale Spacecraft: Design, Fabrication, and Deployment," Cornell University, Ithaca, NY, 2015.

#### Other.....

17. Z. Manchester, "How Do You Fly to Alpha Centauri in Just 20 Years? Ride a Laser Beam," *IEEE Spectrum*, Jun. 6, 2016.
18. Z. Manchester, "KickSat: Bringing Space to the Masses," *CQ VHF Magazine*, vol. 17, no. 3, pp. 32–38, 2013.
19. Z. Manchester, "Measurement and Analysis of the Capacitance of Charged Objects in a Plasma with Applications to Lorentz-Actuated Spacecraft," Cornell University, Ithaca, NY, M.Eng. Report, 2010.

## Invited Talks and Panels

WORLD.MINDS, Zurich	May 9, 2018
Toyota Research Institute, Technical Talk Series	May 4, 2018
Stanford University, Robotics and Autonomous Systems Seminar	Apr 20, 2018
UC Berkeley, Semiautonomous Seminar Series	Feb 23, 2018
Carnegie Mellon University, ECE Graduate Seminar Series	Feb 8, 2018
DLD Munich 2018	Jan 21, 2018
MIT, Department of Aeronautics and Astronautics	Jul 7, 2017
Harvard-Smithsonian Center for Astrophysics, Observatory Night	May 16, 2017
Breakthrough Discuss Conference, Stanford, CA	Apr 21, 2017
TU Delft, Aerospace Engineering Seminar Series	March 10, 2017
Brown University, Space Horizons 2017	Feb 16, 2017
Upper Canada College, World Affairs Conference	Feb 7, 2017
Harvard-Smithsonian Center for Astrophysics, ITC Seminar Series	Jan 26, 2017

MIT Media Lab, Space Lectures Series	Nov 29, 2016
AIAA SciTech, Plenary Panel	Jan 5, 2016
NSF, Workshop on Engineering and Biology	Oct 16, 2014
Texas Instruments, Dallas, TX	May 30, 2014
Cornell University, Technology for Bootstrapped Entrepreneurship	May 5, 2014
AIAA San Francisco Chapter, Small Payloads Tech Talks	Oct 15, 2012
NASA Goddard Spaceflight Center, Seminar Series	Dec 12, 2011

## Professional Service

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### Co-Organizer.....

- o Progress in Novel Space Propulsion, Breakthrough Discuss Conference 2018

### Journal Reviewer.....

- o AIAA Journal of Guidance, Control, and Dynamics
- o AIAA Journal of Aerospace Information Systems
- o IEEE Transactions on Robotics
- o Journal of Physics Communications
- o Advances in Space Research
- o Aerospace Science and Technology
- o IET Control Theory and Applications

### Conference Reviewer.....

- o Robotics: Science and Systems (RSS 2018)
- o International Symposium on Robotics Research (ISRR 2017)
- o IEEE Conference on Automation Science and Engineering (CASE 2017)
- o International Workshop on the Algorithmic Foundations of Robotics (WAFR 2016)

### External Thesis Committee Member.....

- o Daniel Djordjevski, TU Delft, 2017

## Outreach

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### Clubes de Ciencia

#### Instructor

Planned and taught a one-week workshop on aerospace engineering for freshman and sophomore college students. Topics included satellite subsystems, orbit mechanics, and GPS. Activities included tracking CubeSats with amateur radio equipment and launching a high-altitude balloon.

**Xalapa, Mexico**

*Summer 2016*

### Maker Faire

#### Exhibitor

Awarded "Educators Choice" red ribbon.

**New York, NY**

*September 2014*

### Maker Faire

#### Exhibitor

Awarded "Editor's Choice" blue ribbon.

**Bay Area, CA**

*May 2013*

## Selected Press Coverage

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1. R. Wyss, "Dieser Mini-Satellit soll das All erkunden," *Blick*, May 13, 2018.
2. L. Billings, "Reaching for the Stars, Breakthrough Sends Smallest-Ever Satellites into Orbit," *Scientific American*, Jul. 26, 2017.
3. L. Crane, "Smallest satellite ever paves way for planned interstellar fleet," *New Scientist*, Jul. 26, 2017.
4. N. Davis, "Breakthrough Starshot successfully launch world's smallest spacecraft," *The Guardian*, Jul. 28, 2017.
5. D. Freeman, "World's Smallest Spacecraft Is Prelude to Enormous Voyage," *NBC News*, Sep. 18, 2017.
6. T. Staedter, "Breakthrough Starshot's Interstellar Sail Works Best As a Ball," *Space.com*, Mar. 21, 2017.
7. K. Hartnett, "Teaching satellites to swarm," *The Boston Globe*, Oct. 30, 2016.
8. N. Jones, "Tiny 'chipsat' spacecraft set for first flight," *Nature News*, vol. 534, no. 7605, p. 15, Jun. 2, 2016. DOI: 10.1038/534015a.
9. O. Morton, "Brain Scan: Space Chips," *The Economist*, Aug. 27, 2016.
10. T. Revell, "Disco-ball sail propelled by laser could fly to a nearby star," *New Scientist*, Nov. 10, 2016.
11. *BBC World News*, Sep. 24, 2014.
12. S. Clark, "Crowd-funded stowaway to deploy 104 tiny satellites," *Spaceflight Now*, Apr. 13, 2014.
13. G. Fleishmann, "Nanosats are go!" *The Economist*, Jul. 6, 2014.
14. Q. Hardy, "Space Chips for the Common Man," *The New York Times*, May 4, 2014.
15. N. Hurst, "Q&A: KickSat's Zac Manchester and Andy Filo," *Make Magazine*, Nov. 4, 2014.
16. "Man vs. The Universe," *The Science Channel*, Aug. 2014.
17. C. Seidler, "SpaceX-Flug: Mein Haus, mein Auto, mein Mini-Satellit," *Der Spiegel*, Apr. 14, 2014.
18. R. Hollingham, "How to get to space on the cheap," *BBC Future*, Apr. 16, 2012.
19. *BBC Radio 4*, Oct. 13, 2011.