Zac Manchester

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Academic Positions

Stanford University
Assistant Professor of Aeronautics and Astronautics — *Jan 2018 – Present*

Harvard University
Postdoctoral Fellow, Agile Robotics Lab — *Oct 2015 – Dec 2017*

Education

Cornell University — **Ithaca, NY**
Ph.D. Aerospace Engineering — *2015*
Dissertation: *Centimeter-Scale Spacecraft: Design, Fabrication, and Deployment*
Advisor: Mason Peck

Cornell University — **Ithaca, NY**
M.Eng. Mechanical Engineering — *2010*

Cornell University — **Ithaca, NY**
B.S. Applied Physics — *2009*

Research Experience

Stanford University — **Stanford, CA**
Director, Robotic Exploration Laboratory — *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 — **Cambridge, MA**
Postdoctoral Fellow, Agile Robotics Laboratory — *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 **Ithaca, NY**
Graduate Research Assistant, Space Systems Design Studio *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 **Moffett Field, CA**
Aerospace Engineer *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 **Albuquerque, NM**
Research Intern *Summer 2009*
- Used semiconductor fabrication techniques to build prototype satellite-on-chip devices at Sandia's Center for Integrated Nanotechnology.

Cornell University **Ithaca, NY**
Undergraduate Research Assistant, Space Systems Design Studio *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

Harvard University **Cambridge, MA**
Guest Lecturer and Lab Instructor, Science of the Physical Universe *Spring 2017*
Teaching Assistant, Optimization Algorithms for Robotics *Spring 2016*
Guest Lecturer, Space Science and Engineering *Fall 2016*

Cornell University **Ithaca, NY**
Instructor, Spacecraft Engineering *Spring 2012*
Teaching Assistant, Feedback Control Systems *Fall 2010*

Other Professional Experience

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

Private Pilot
Single-Engine Land *2017*

Amateur Radio
Technician Class *2011*

Awards

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

Preprints

1. Z. Manchester and S. Kuindersma, "Robust Direct Trajectory Optimization Using Approximate Invariant Funnels," *Autonomous Robots*, In Review.
2. J. Lipton, R. MacCurdy, Z. Manchester, L. Chin, D. Celluci, and D. Rus, "Handedness in Shearing Auxetics for Rigid and Compliant Structures," *Science*, To Appear.

Journal Papers

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

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

Journal Reviewer

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

Conference Reviewer

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

External Thesis Committee Member

- Daniel Djordjevski, TU Delft, 2017

Outreach

Clubes de Ciencia **Xalapa, Mexico**
Instructor *Summer 2016*
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.

Maker Faire **New York, NY**
Exhibitor *September 2014*
Awarded "Educators Choice" red ribbon.

Maker Faire **Bay Area, CA**
Exhibitor *May 2013*
Awarded "Editor's Choice" blue ribbon.

Selected Press Coverage

1. "Daily Planet," *Discovery Channel Canada*, Mar. 14, 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.