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*

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

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

Stanford University **Stanford, CA**
Instructor, Spacecraft Design *Fall 2018*
Instructor, Spacecraft Attitude Determination and Control *Spring 2018*

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

Early Career Faculty Award
NASA *2018*
Robust Verification Methods for Precision Entry Guidance

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. J. K. Gupta, K. Menda, Z. Manchester, and M. J. Kochenderfer, "A General Framework for Structured Learning of Mechanical Systems," *(In Review)*, Feb. 2019.
2. B. Landry, J. Lorenzetti, Z. Manchester, and M. Pavone, "Bilevel Optimization for Planning through Contact: A Semidirect Method," in *ISRR 2019 (In Review)*, 2019, p. 15.
3. K. Menda, J. Gupta, J. de Becdelievre, I. Kroo, Z. Manchester, and M. Kochenderfer, "Non-linear System Identification from Partial Observations via Iterative Smoothing and Learning," Jul. 2019.

Journal Papers

4. 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 2018.
5. Z. Manchester and S. Kuindersma, "Robust Direct Trajectory Optimization Using Approximate Invariant Funnels," *Autonomous Robots*, Jul. 2018.
6. Z. Manchester and A. Loeb, "Stability of a Light Sail Riding on a Laser Beam," *The Astrophysical Journal*, vol. 837, no. 2, Mar. 2017.
7. 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.

Conference Papers

8. T. A. Howell, B. E. Jackson, and Z. Manchester, "ALTRO: A Fast Solver for Constrained Trajectory Optimization," in *IROS 2019*, Feb. 2019.

9. B. Landry, Z. Manchester, and M. Pavone, "A Differentiable Augmented Lagrangian Method for Bilevel Nonlinear Optimization," in *Robotics: Science and Systems (RSS)*, Freiburg, Germany, Feb. 2019.
10. N. Doshi, K. Jayaram, B. Goldberg, Z. Manchester, R. J. Wood, and S. Kuindersma, "Contact-Implicit Optimization of Locomotion Trajectories for a Quadrupedal Microrobot," in *Robotics: Science and Systems (RSS)*, Pittsburgh, PA, Jun. 2018, p. 10.
11. 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, Jun. 2017.
12. 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, Jul. 2017.
13. Z. Manchester and S. Kuindersma, "Variational Contact-Implicit Trajectory Optimization," in *Proceedings of the International Symposium on Robotics Research (ISRR)*, Puerto Varas, Chile, Dec. 2017.
14. 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, Jan. 2017.
15. Z. Manchester and M. Peck, "Recursive Inertia Estimation With Semidefinite Programming," in *AIAA Guidance, Navigation, and Control Conference*, Grapevine, TX, Jan. 2017.
16. 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, Sep. 2017.
17. 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, Feb. 2016.
18. 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, Dec. 2016.
19. 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, Aug. 2013.
20. 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. 2011.
21. J. Atchison, Z. Manchester, and M. Peck, "Microscale Atmospheric Re-entry Sensors," in *7th International Planetary Probe Workshop*, Barcelona, Spain, Jun. 2010.

Dissertation

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

Other

23. Z. Manchester, "How Do You Fly to Alpha Centauri in Just 20 Years? Ride a Laser Beam," *IEEE Spectrum*, Jun. 2016.

24. Z. Manchester, "KickSat: Bringing Space to the Masses," *CQ VHF Magazine*, vol. 17, no. 3, pp. 32–38, Apr. 2013.

25. 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, May 2010.

Invited Talks and Panels

University of Aukland, ChipSat Workshop	*Mar 16, 2019*
Brown University, Space Horizons Workshop	*Feb 2, 2019*
MIT, Space Seminar	*Dec 6, 2018*
Caltech, GALCIT Seminar	*Oct 26, 2018*
University of Colorado, Robotics Seminar	*Aug 20, 2018*
Unusual Appendages Workshop, RSS 2018	*Jun 29, 2018*
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	*Mar 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

Co-Organizer

- Progress in Novel Space Propulsion, Breakthrough Discuss Conference 2018

Journal Reviewer

- International Journal of Robotics Research (IJRR)
- AIAA Journal of Guidance, Control, and Dynamics
- IEEE Transactions on Robotics
- IEEE Robotics and Automation Letters

- AIAA Journal of Spacecraft and Rockets
- AIAA Journal of Aerospace Information Systems
- Journal of Physics Communications
- Advances in Space Research
- Aerospace Science and Technology
- IET Control Theory and Applications
- International Journal of Robust and Nonlinear Control

Conference Reviewer

- Robotics: Science and Systems (RSS 2019, RSS 2018)
- International Conference on Intelligent Robots and Systems (IROS 2019)
- International Conference on Robotics and Automation (ICRA 2019)
- 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 — Awarded "Educators Choice" red ribbon. *September 2014*

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

Selected Press Coverage

1. M. Lachmann, *Einstein and Hawking: Unlocking The Universe*, Science Channel, Mar. 2019.
2. J. Shreeve, S. Lowell, and D. Berry, "Who's Out There?" *National Geographic*, pp. 42–75, Mar. 2019.
3. "Daily Planet," *Discovery Channel Canada*, Mar. 2018.
4. M. Harris, "The FCC's Big Problem with Small Satellites," en, *IEEE Spectrum*, Oct. 2018.
5. S. Nadis, "The Tiny Satellites That Might Fly to Another Solar System," *Discover Magazine*, Nov. 2018.
6. R. Wyss, "Zac Manchester will Mini-Satelliten ins All beamen," de, *Blick*, May 2018.
7. L. Billings, "Reaching for the Stars, Breakthrough Sends Smallest-Ever Satellites into Orbit," *Scientific American*, Jul. 2017.
8. L. Crane, "Smallest satellite ever paves way for planned interstellar fleet," *New Scientist*, Jul. 2017.

9. N. Davis, "Breakthrough Starshot successfully launch world's smallest spacecraft," *The Guardian*, Jul. 2017.
10. D. Freeman, "World's Smallest Spacecraft Is Prelude to Enormous Voyage," *NBC News*, Sep. 2017.
11. T. Staedter, "Breakthrough Starshot's Interstellar Sail Works Best As a Ball," *Space.com*, Mar. 2017.
12. K. Hartnett, "Teaching satellites to swarm," *The Boston Globe*, Oct. 2016.
13. N. Jones, "Tiny 'chipsat' spacecraft set for first flight," *Nature News*, vol. 534, no. 7605, p. 15, Jun. 2016.
14. O. Morton, "Brain Scan: Space Chips," *The Economist*, Aug. 2016.
15. T. Revell, "Disco-ball sail propelled by laser could fly to a nearby star," *New Scientist*, Nov. 2016.
16. *BBC World News*, Sep. 2014.
17. S. Clark, "Crowd-funded stowaway to deploy 104 tiny satellites," *Spaceflight Now*, Apr. 2014.
18. G. Fleishmann, "Nanosats are go!" *The Economist*, Jul. 2014.
19. Q. Hardy, "Space Chips for the Common Man," *The New York Times*, May 2014.
20. N. Hurst, "Q&A: KickSat's Zac Manchester and Andy Filo," *Make Magazine*, Nov. 2014.
21. "Man vs. The Universe," *The Science Channel*, Aug. 2014.
22. C. Seidler, "SpaceX-Flug: Mein Haus, mein Auto, mein Mini-Satellit," *Der Spiegel*, Apr. 2014.
23. R. Hollingham, "How to get to space on the cheap," *BBC Future*, Apr. 2012.
24. *BBC Radio 4*, Oct. 2011.