



## Research Interests:

- Small Spacecraft
- Unmanned Aircraft
- Robotics
- Optimization
- Control Systems
- Nonlinear Dynamics
- Estimation and Filtering
- Low-Power Radio Communication and Navigation

## Education:

<b>2015</b>	<b><i>Ph.D.</i></b>	<b><i>Aerospace Engineering</i></b>	<b><i>Cornell University</i></b>
		<ul style="list-style-type: none"><li>• Dissertation: “Centimeter-Scale Spacecraft: Design, Fabrication, and Deployment”</li><li>• Advisor: Mason Peck</li></ul>	
<b>2014</b>	<b><i>M.S.</i></b>	<b><i>Aerospace Engineering</i></b>	<b><i>Cornell University</i></b>
<b>2010</b>	<b><i>M.Eng.</i></b>	<b><i>Mechanical Engineering</i></b>	<b><i>Cornell University</i></b>
<b>2009</b>	<b><i>B.S.</i></b>	<b><i>Engineering Physics</i></b>	<b><i>Cornell University</i></b>

## Research Experience:

- 2015-Present** ***Harvard University***
- Developing optimization-based algorithms for motion planning, robust control, and system identification with applications to agile fixed-wing aircraft and legged robots.
- 2009-Present** ***Cornell University***
- Pioneered the development of centimeter-scale (ChipSat) spacecraft
  - Founded the KickSat project to launch and deploy over 100 centimeter-scale spacecraft from a CubeSat “mothership” in low Earth orbit
  - Raised \$74,586 through crowd-funding website Kickstarter
  - Awarded launch through NASA’s CubeSat Launch Initiative
  - Developed long-range, low-power radio communication protocol for small spacecraft
  - Developed novel attitude control and inertia estimation algorithms
  - Led a small team to design, build, test, and fly a 3U CubeSat
- 2012-2013** ***NASA Ames Research Center***
- 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
- 2009** ***Sandia National Laboratories***
- Used semiconductor fabrication techniques to build prototype satellite-on-chip devices at Sandia’s Center for Integrated Nanotechnology
- 2006-2007** ***CU-24 Unmanned Aerial Vehicle Team***
- Integrated onboard computer, autopilot, and communication systems for a UAV



## Teaching Experience:

### *Spring 2017 Lab Instructor – Science of the Physical Universe – Harvard*

- Gave a lecture on spacecraft engineering and designed and taught a week of lab sections for an introductory science class for non-science majors at Harvard University.

### *Summer 2016 Instructor – Clubes de Ciencia México*

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

### *Spring 2016 Teaching Assistant – Optimization Algorithms for Robotics – Harvard*

- Gave guest lectures and held weekly office hours for a graduate course in optimal control and optimization-based motion planning for robotic systems
- Overall student evaluation: 4.9/5

### *Spring 2012 Lecturer – Spacecraft Engineering – Cornell*

- Taught a junior-level undergraduate course (73 students) covering spacecraft orbital and attitude dynamics and space mission design

### *Fall 2010 Teaching Assistant – Feedback Control Lab – Cornell*

- Ran the lab portion of a senior-level undergraduate course on feedback control systems where controllers were designed and implemented on electromechanical laboratory systems

## Other Professional Experience:

### *2016-Present Breakthrough Foundation*

- Member of the advisory committee and consultant for the Breakthrough Starshot project

### *2010 Sentinel IC Technologies, Inc.*

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

### *2007-2010 Analytical Graphics, Inc.*

- Developed astrodynamics (orbital and attitude dynamics) simulation software
- Developed an algorithm for calculating rhumb lines on oblate and prolate spheroids that is now part of the Systems Tool Kit (STK) software
- Developed a C# to Java source-to-source compiler

## Awards:

### *2016 Distinction in Teaching Award*

- Awarded for top student reviews while serving as a Teaching Assistant at Harvard

### *2010 Thomas J. and Joan T. Kelley Prize*

- Awarded for the top Master of Engineering project in Aerospace Engineering at Cornell



### **Journal Publications:**

1. Z. Manchester and A. Loeb. "Stability of a Light Sail Riding on a Laser Beam," *The Astrophysical Journal Letters*, Vol. 837, No. 2, 2017.
2. Z. Manchester and M. Peck. "Quaternion Variational Integrators for Spacecraft Dynamics," *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 39, No. 1, 2016, pp. 69-76.

### **Conference Publications:**

1. Z. Manchester and S. Kuindersma. "DIRTREL: Robust Nonlinear Direct Transcription with Ellipsoidal Disturbances and LQR Feedback," Robotics: Science and Systems (RSS), July 12-16, 2017.
2. B. Plancher, Z. Manchester, and S. Kuindersma. "Constrained Unscented Dynamic Programming: A Sampling-Based DDP Algorithm for Trajectory Optimization with State and Input Constraints," IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), September 24-28, 2017.
3. J. Lipton, Z. Manchester, and D. Rus. "Planning Cuts for Mobile Robots with Bladed Tools," IEEE International Conference on Robotics and Automation (ICRA), Singapore, May 29-June 3, 2017.
4. Z. Manchester, J. Lipton, R. Wood, and S. Kuindersma. "A Variable Forward-Sweep Wing Design for Enhanced Perching in Micro Aerial Vehicles," 55<sup>th</sup> AIAA Aerospace Sciences Meeting, Grapevine, Texas, January 9-13, 2017.
5. Z. Manchester and M. Peck. "Recursive Inertia Estimation with Semidefinite Programming," AIAA Guidance, Navigation, and Control Conference, Grapevine, Texas, January 9-13, 2017.
6. Z. Manchester and S. Kuindersma. "Derivative-Free Trajectory Optimization with Unscented Dynamic Programming," IEEE Conference on Decision and Control, Las Vegas, Nevada, December 12-14, 2016.
7. Z. Manchester. "Lyapunov-Based Control for Flat-Spin Recovery and Spin Inversion of Spin-Stabilized Spacecraft," AIAA/AAS Astrodynamics Specialist Conference, Long Beach, California, September 13-16, 2016.
8. Z. Manchester, M. Peck, and A. Filo. "KickSat: A Crowd-Funded Mission To Demonstrate The World's Smallest Spacecraft," AIAA/USU Conference on Small Satellites, Logan, Utah, August 12-16, 2013.
9. Z. Manchester and M. Peck. "Stochastic Space Exploration with Microscale Spacecraft," AIAA Guidance, Navigation, and Control Conference, Portland, OR, August 8-11, 2011.
10. J. Atchison, Z. Manchester, and M. Peck. "Microscale Atmospheric Reentry Sensors," 7th International Planetary Probe Workshop, Barcelona, Spain, June 14-18, 2010.

### **Dissertations and Theses:**

1. Z. Manchester. "Centimeter-Scale Spacecraft: Design, Fabrication, and Deployment," Ph.D. Dissertation, Cornell University, Ithaca, NY, August 2015.
2. Z. Manchester. "Measurement and Analysis of the Capacitance of Charged Objects in a Plasma with Applications to Lorentz-Actuated Spacecraft," M.Eng. Report, Cornell University, Ithaca, NY, May 2010.



## Other Publications:

1. Z. Manchester. "How Do You Fly to Alpha Centauri in Just 20 Years? Ride a Laser Beam," *IEEE Spectrum*, June 6, 2016.
2. Z. Manchester. "KickSat: Bringing Space to the Masses," *CQ VHF Magazine*. Vol. 17, no. 3, pp. 32-38, 2013.

## Invited Talks:

1. "Engineering Tiny Space Systems," MIT Department of Aeronautics and Astronautics, July 7, 2017.
2. "First Probe to the Stars," Observatory Night, Harvard-Smithsonian Center for Astrophysics, May 16, 2017.
3. "How to Ride a Laser Beam," Breakthrough Discuss Conference, Stanford, California, April 21, 2017.
4. "KickSat: Crowdfunding the World's Smallest Spacecraft," Aerospace Engineering Seminar Series, TU Delft, Delft, The Netherlands, March 10, 2017.
5. "Starship Engineering," Space Horizons 2017, Brown University, Providence, RI, February 16, 2017.
6. "Democratizing Space," World Affairs Conference, Upper Canada College, Toronto, ON, February 7, 2017.
7. "How to Ride A Laser Beam," Institute for Theory and Computation, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, January 26, 2017.
8. "KickSat: The World's Smallest Spacecraft," Space Lectures Series, MIT Media Lab, Cambridge, MA, November 29, 2016.
9. "Aerospace Generations: Lessons Learned from a Half Century of Innovation in Aerospace Technology," AIAA SciTech Conference Plenary, San Diego, January 5, 2016.
10. "CubeSat Constellations for Wildlife Tracking and Monitoring," National Science Foundation Workshop on Engineering and Biology at the Frontier of Environmental and Organismal Sensing, Washington, D.C., October 16, 2014.
11. "KickSat: The World's Smallest Spacecraft," Texas Instruments, Dallas, TX, May 30, 2014.
12. "KickSat: Crowd-Funding Space," Technology for Bootstrapped Entrepreneurship, Cornell University School of Hotel Administration, May 5, 2014.
13. "ChipSats: Centimeter-Scale Spacecraft and How They Will Change Atmospheric Science," NASA Ames Research Center, October 24, 2012.
14. "KickSat: Kick Starting the Personal Space Age," AIAA San Francisco Chapter Small Payloads Tech Talks, October 15, 2012.
15. "The Sprite Project: Satellite on a Chip," NASA Goddard Spaceflight Center, December 12, 2011.
16. "Demonstration of a Prototype 'Sprite' ChipSat," ChipSat Workshop, Brown University, Providence, RI, February 18, 2010.



**Outreach:**

1. Clubes de Ciencia Mexico 2016
2. Maker Faire NYC 2014
3. Maker Faire Bay Area 2013

**Professional Service:**

1. External Thesis Committee Member, TU Delft, 2017
2. Reviewer, AIAA Journal of Guidance, Control, and Dynamics
3. Reviewer, AIAA Journal of Aerospace Information Systems
4. Reviewer, IEEE Transactions on Robotics (Journal)
5. Reviewer, Journal of Physics Communications
6. Reviewer, Advances in Space Research (Journal)
7. Reviewer, Aerospace Science and Technology (Journal)
8. Reviewer, IET Control Theory and Applications (Journal)
9. Reviewer, 18<sup>th</sup> International Symposium on Robotics Research (ISRR 2017)
10. Reviewer, 13<sup>th</sup> IEEE Conference on Automation Science and Engineering (CASE 2017)
11. Reviewer, 12<sup>th</sup> International Workshop on the Algorithmic Foundations of Robotics (WAFR)



## Selected Press Coverage:

1. D. Freeman. "World's Smallest Spacecraft Is Prelude to Enormous Voyage," *NBC News*. September 18, 2017. <https://www.nbcnews.com/mach/science/world-s-smallest-spacecraft-prelude-enormous-voyage-ncna797866>
2. L. Billings. "Reaching for the Stars, Breakthrough Sends Smallest-Ever Satellites into Orbit," *Scientific American*. July 26, 2017. <https://www.scientificamerican.com/article/reaching-for-the-stars-breakthrough-sends-smallest-ever-satellites-into-orbit/>
3. L. Crane. "Smallest satellite ever paves way for planned interstellar fleet," *New Scientist*. July 26, 2017. <https://www.newscientist.com/article/2141956-smallest-satellite-ever-paves-way-for-planned-interstellar-fleet/>
4. N. Davis. "Breakthrough Starshot successfully launch world's smallest spacecraft," *The Guardian*. July 28, 2017. <https://www.theguardian.com/science/2017/jul/28/breakthrough-starshot-successfully-launch-worlds-smallest-spacecraft>
5. T. Staedter. "Breakthrough Starshot's Interstellar Sail Works Best As A Ball," *Space.com*. March 21, 2017. <http://www.space.com/36146-breakthrough-starshot-interstellar-laser-sail-ball.html>
6. K. Hartnett. "Teaching satellites to swarm," *The Boston Globe*. October 30, 2016.
7. T. Revell. "Disco-ball sail propelled by laser could fly to a nearby star," *New Scientist*. October 11, 2016. <https://www.newscientist.com/article/2108650-disco-ball-sail-propelled-by-laser-could-fly-to-a-nearby-star/>
8. O. Morton. "Brain scan: Space chips," *The Economist*. August 27, 2016. <http://www.economist.com/technology-quarterly/2016-25-08/space-2016#Panel01>
9. N. Jones. "Tiny 'chipsat' spacecraft set for first flight," *Nature*. Vol. 534, no. 7471, pp. 15-16, 2016. <http://www.nature.com/news/tiny-chipsat-spacecraft-set-for-first-flight-1.20006>
10. BBC World News: Interviewed as part of a segment on low-cost space exploration, September 24, 2014.
11. The Science Channel, *Man vs. The Universe*. Episode 2, August 2014.
12. G. Fleishmann. "Nanosats are go!" *The Economist*. June 7, 2014.
13. C. Seidler. "SpaceX-Flug: Mein Haus, mein Auto, mein Mini-Satellit." *Der Spiegel*. April 14, 2014.
14. S. Clark. "Crowd-funded stowaway to deploy 104 tiny satellites." *Spaceflight Now*. April 13, 2014. <http://spaceflightnow.com/falcon9/009/140413kicksat>
15. N. Hurst. "Q&A: KickSat's Zac Manchester and Andy Filo." *Make Magazine*. April 11, 2014. <http://makezine.com/2014/04/11/how-to-kick-a-sat/>
16. Q. Hardy. "Space Chips for the Common Man." *The New York Times Bits Blog*. April 5, 2014. <http://bits.blogs.nytimes.com/2014/04/05/space-chips-for-the-common-man>
17. R. Hollingham. "How to get to space on the cheap." *BBC Future*. April 16, 2012. <http://www.bbc.com/future/story/20120412-how-to-get-to-space-on-the-cheap>
18. BBC Radio 4: Interviewed about the KickSat project, October 13, 2011.

