Steven H. Collins

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Faculty Appointments

Associate Professor	**Carnegie Mellon University** (July 2015—present) Department of Mechanical Engineering Robotics Institute (by courtesy)
Assistant Professor	**Carnegie Mellon University** (2010—2015) Department of Mechanical Engineering Robotics Institute (by courtesy)

Education

Postdoctoral Fellow	**Delft University of Technology** (2008—2010) BioMechanical Engineering Supervisor: Martijn Wisse
M.S., Ph.D.	**University of Michigan** (2002—2008) Mechanical Engineering Advisor: Art Kuo
B.S.	**Cornell University** (1997—2002) Mechanical Engineering Research advisor: Andy Ruina

Journal Articles

Papers, videos and other supporting materials available at: www.andrew.cmu.edu/~shc17
Numbers: 26 articles, 13 proceedings, 14 patents, 42 abstracts, 30 podium, 3,500 citations, h-index: 16.
Citation numbers from Google Scholar.

1. Collins, S. H., Wisse, M., Ruina, A. (2001) A three-dimensional passive-dynamic walking robot with two legs and knees. *International Journal of Robotics Research*, **20**:607-615. Cited by 695.

2. Collins, S. H., Ruina, A. L., Tedrake, R., Wisse, M. (2005) Efficient bipedal robots based on passive-dynamic walkers. *Science*, **307**:1082-1085. Cited by 1,387.

3. Adamczyk, P. G., Collins, S. H., Kuo, A. D. (2006) The advantages of a rolling foot in human walking. *Journal of Experimental Biology*, **209**:3953-3963. Cited by 154.

4. Vanderpool, M. T., Collins, S. H., Kuo, A. D. (2008) Ankle fixation need not increase the energetic cost of human walking. *Gait & Posture*, **28**:427-433. Cited by 28.

5. Collins, S. H., Adamczyk, P. G., Ferris, D. P., Kuo, A. D. (2009) A simple method for calibrating force plates and force treadmills using an instrumented pole. *Gait & Posture*, **29**:59-64. Cited by 54.

6. Collins, S. H., Adamczyk, P. G., Kuo, A. D. (2009) Dynamic arm swinging in human walking. *Proceedings of the Royal Society of London B.*, **276**:3679-3688. Cited by 112.

7. van der Krogt, M. M., Bregman, D. J. J., Wisse, M., Doorenbosch, C. A. M., Harlaar, J., Collins, S. H. (2010) How crouch gait can dynamically induce stiff-knee gait. *Annals of Biomedical Engineering*, **38**:1593-1606. Cited by 13.

8. Collins, S. H., Kuo, A. D. (2010) Recycling energy to restore impaired ankle function during human walking. *Public Library of Science ONE*, **5**:e9307. Cited by 88.

9. Bregman, D. J., van der Krogt, M. M., de Groot, V., Harlaar, J., Wisse, M., Collins, S. H. (2011) The effect of ankle foot orthosis stiffness on the energy cost of walking: a simulation study. *Clinical Biomechanics*, **26**:955-961. Cited by 42.

10. Morgenroth, D. C., Segal, A. D., Zelik, K. E., Czerniecki, M. J., Klute, G. K., Adamczyk, P. G., Orendurff, M. S., Hahn, M. E., Collins, S. H., Kuo, A. D. (2011) The effect of prosthetic foot push-off on mechanical loading associated with knee osteoarthritis in lower extremity amputees. *Gait & Posture*, **34**:502-507. Cited by 35.

11. Zelik, K. E., Collins. S. H., Adamczyk, P. G., Segal, A. D., Klute, G. K., Morgenroth, D. C., Hahn, M. E., Orendurff, M. S., Czerniecki, J. M., Kuo, A. D. (2011) Systematic variation of prosthetic foot parameter affects center-of-mass mechanics and metabolic cost during walking. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, **19**:411-419. Cited by 31.

12. Segal, A. D., Zelik, K. E., Klute, G. K., Morgenroth, D. C., Hahn, M. E., Orendurff, M. S., Adamczyk, P. G., Collins, S. H., Kuo, A. D., Czerniecki, J. M. (2012) The effects of a controlled energy storage and return prototype prosthetic foot on transtibial amputee ambulation. *Human Movement Science*, **31**:918-931. Cited by 31.

13. Collins, S. H., Kuo, A. D. (2013) Two independent contributions to step variability during over-ground human walking. *Public Library of Science ONE*, **8**:e73597. Cited by 10.

14. Caputo, J. M., Collins, S. H. (2014) A universal ankle–foot prosthesis emulator for human locomotion experiments. *Journal of Biomechanical Engineering*, **136**:035002. Cited by 20.

15. Caputo, J. M., Collins, S. H. (2014) Prosthetic ankle push-off work reduces metabolic rate but not collision work in non-amputee walking. *Nature Scientific Reports*, **4**:7213. Cited by 10.

16. Malcolm, P., Quesada, R. E., Caputo, J. M., and Collins, S. H. (2015) The influence of push-off timing in a robotic ankle-foot prosthesis on the energetics and mechanics of walking. *Journal of NeuroEngineering and Rehabilitation*, **12**:21. Cited by 5.

17. Collins, S. H., Wiggin, M. B., and Sawicki, G. S. (2015) Reducing the energy cost of human walking using an unpowered exoskeleton. *Nature*, **522**:212-215. Cited by 4.

18. Kim, M., and Collins, S. H. (2015) Once-per-step control of ankle-foot prosthesis push-off work reduces effort associated with balance during human walking. *Journal of NeuroEngineering and Rehabilitation*, **12**:43. Cited by 4.

19. Jackson, R. W., and Collins, S. H. (2015) An experimental comparison of the relative benefits of work and torque assistance in ankle exoskeletons. *Journal of Applied Physiology,* **119**:541-557. Cited by 4.

In review: (available on request)

20. Kim, M., and Collins, S. H., Once-per-step control of ankle push-off work improves balance in a three-dimensional simulation of bipedal walking. **In review**, *Transactions on Robotics*.

21. Zhang, J., Cheah, C. C., and Collins, S. H., Comparison of torque control methods for tethered lower-limb exoskeletons during human walking. **In review**, *The International Journal of Robotics Research*.

22. Wu, M., Adamczyk, P. G., and Collins, S. H., The relationship between effort of walking and amount of walking performed: A pilot study. **In review**, *Journal of Exercise Science & Fitness*.

23. Kim, M., Chen, T., Chen, T., and Collins, S. H., A universal ankle-foot prosthesis emulator with plantarflexion and inversion-eversion torque control for human locomotion experiments. **In review**, *Transactions on Robotics*.

24. Quesada, R. E., Caputo, J. M., and Collins, S. H., Restoring ankle push-off work with a powered prosthesis does not necessarily reduce metabolic rate for trans-tibial amputees. **In review**, *Journal of Biomechanics*.

25. Caputo, J. M., Adamczyk, P. G., and Collins, S. H., Informing ankle-foot prosthesis prescription through haptic emulation of candidate devices. **In review,** *Transactions on Robotics*.

26. Witte, K. A., Jackson, R. W., and Collins, S. H., Universal ankle exoskeleton emulators for human locomotion experiments. **Submitted** to *Transactions on Robotics*.

Peer-Reviewed Conference Proceedings

C1. Pratt, J. E., Krupp, B. T., Morse, C. J., Collins, S. H. (2004) The RoboKnee: an exoskeleton for enhancing strength and endurance during walking. In *Proc. IEEE Int. Conf. Robotics and Automation*, New Orleans, LA, pages 2430-2435. Acceptance rate: 59%. Cited by 353.

C2. Collins, S. H., Ruina, A. (2005) A bipedal walking robot with efficient and human-like gait. In *Proc. IEEE International Conference on Robotics & Automation*, Barcelona, Spain, pages 1983-1988. Acceptance rate: 45%. Cited by 322.

C3. Wiggin, M. B., Sawicki, G. S., Collins, S. H. (2011) An exoskeleton using controlled energy storage and release to aid ankle propulsion. In *Proc. IEEE International Conference on Rehabilitation Robotics*, Zurich, Switzerland. 5 pages. Acceptance rate: 62%. Cited by 30.

C4. Caputo, J. M., and Collins, S. H. (2013) An experimental robotic testbed for accelerated development of ankle prostheses. In *Proc. IEEE International Conference on Robotics and Automation*, Karlsruhe, Germany. pages 2630-2635. Acceptance rate oral: 18%. Cited by 10.

C5. Zhang, J., Cheah, C. C., and Collins, S. H. (2013) Stable human-robot interaction control for upper-limb rehabilitation robotics. In *Proceedings IEEE International Conference on Robotics and Automation*, Karlsruhe, Germany. pages 2201-2206. Acceptance rate oral: 18%. Cited by 5.

C6. Song, S., LaMontagna, C., Collins, S. H., and Geyer, H. (2013) The effect of foot compliance encoded in the windlass mechanism on the energetics of human walking. In *Proceedings International Conference of the IEEE Engineering in Medicine and Biology Society*, Osaka, Japan. pages 3179-3182. Acceptance rate: 40%. Cited by 4.

C7. Kim, M. and Collins, S. H. (2013) Stabilization of a three-dimensional limit cycle walking model through step-to-step ankle control. In *Proceedings IEEE International Conference on Rehabilitation Robotics*, Seattle, WA, USA. 6 pages. Acceptance rate: 62%. Cited by 1.

C8. Collins, S. H. and Jackson, R. W. (2013) Inducing Self-Selected Human Engagement in Robotic Locomotion Training. In *Proceedings IEEE International Conference on Rehabilitation Robotics*, Seattle, WA, USA. 6 pages. Acceptance rate for oral presentations: 11%. Cited by 7.

C9. Zhang, J., Cheah, C., C., and Collins, S.H. (2015) Experimental comparison of torque control methods on an ankle exoskeleton during human walking. In *Proc. IEEE International Conference on Robotics and Automation*, Seattle, WA, USA. pages 5584-5589. Acceptance rate: 41%. Cited by 4.

C10. Witte, K. A., Zhang, J., Jackson, R. W., and Collins, S.H. (2015) Design of two lightweight, high-bandwidth torque-controlled ankle exoskeletons. In *Proc. IEEE International Conference on Robotics and Automation*, Seattle, WA, USA. pages 1223-1228. Acceptance rate: 41%. Cited by 2.

C11. Collins, S. H., Kim, M., Chen, T., and Chen, T. (2015) An ankle-foot prosthesis emulator with control of plantarflexion and inversion-eversion torque. In *Proc. IEEE International Conference on Robotics and Automation*, Seattle, WA, USA. pages 1210-1216. Acceptance rate: 41%. Cited by 6.

C12. Caputo, J. M., Adamczyk, P. G., and Collins, S. H. (2015) Informing ankle-foot prosthesis prescription through haptic emulation of candidate devices. In *Proc. IEEE International Conference on Robotics and Automation*, Seattle, Washington, USA. pages 6445-6450. Acceptance rate for oral presentations: 41%. Cited by 2.

In review:

C13. Diller, S., Majidi, C. and Collins, S. H. A lightweight, low-power electroadhesive clutch and spring for exoskeleton actuation. Submitted to *IEEE International Conference on Robotics and Automation*, Stockholm, Sweden.

Patents

P1. Collins, S. H., Kuo, A. D., Foot prosthesis and method of use. U.S. Provisional Patent 60/705,019, filed August, 2005.

P2. Kuo, A. D., Collins, S. H., Foot prosthesis and method of use. U.S. Patent US2007/0061016A1, filed August, 2006.

P3. Collins, S. H., Vrinceanu, A., Mullins, C., Donelan, J. M., Apparatus for Biomechanical Energy Harvesting. U.S. Provisional Patent 61/175,726, filed May, 2009.

P4. Wiggin, M. B., Sawicki, G. S., and Collins, S. H. Apparatus and clutch for using controlled storage and release of mechanical energy to aid locomotion. U.S. Patent US2013/0046218A1, filed August 2011.

P5. Caputo, J. M., Collins, S. H., and Adamczyk, P. G., Methods, apparatuses, and systems for amputee gait capacity assessment. U.S. Provisional Patent 62/070,134, filed May, 2014.

P6. Collins, S. H., Majidi, C., and Diller, S., Energy-recycling actuator with high-bandwidth force control. U.S. Provisional Patent 62/122,066, filed October, 2014.

P7. Collins, S. H., Kim, M., Chen, T., and Chen, T., An ankle-foot prosthesis emulator with control of plantarflexion and inversion-eversion torque. U.S. Provisional Patent filed May, 2015.

P8. Zhang, J., Cheah, C. C., and Collins, S. H., Torque control of lower-limb exoskeletons and prostheses in walking using model-free, integral-action-free feedback control with iterative learning. U.S. Provisional Patent filed May, 2015.

P9. Witte, K. A., Jackson, R. W., and Collins, S. H., Lightweight, tethered torque-controlled ankle exoskeleton. U.S. Provisional Patent filed May, 2015.

P10. Emanuel, B., and Collins, S. H., A disturbance emulation system for stability and recovery testing. U.S. Provisional Patent filed July, 2015.

P11. Caputo, J. M., Adamczyk, P. G., and Collins, S. H., A remotely actuated and torque-controlled ankle-foot prosthesis. U.S. Provisional Patent filed July, 2015.

P12. Caputo, J. M., Kim, M., Chen, T., Chen, T., Adamczyk, P. G., Collins, S. H., Methods, Apparatuses, and Systems for Amputee Gait Capacity Assessment. U.S. Patent filed August, 2015.

P13. Gabriel, J., Collins, S. H., Kirmayer, R., Spinelli, M., Fox, N., Yasinski, E., Robotic knee prosthesis emulator. U.S. Provisional Patent filed September, 2015.

P14. Collins, S. H., Majidi, C., Diller, S. B., Energy-recycling actuator with high-bandwidth force control. Patent Cooperation Treaty Patent filed October, 2015.

Invited Conference Proceedings

A1. Collins, S. H. (2013) What do walking humans want from mechatronics? In: *Proceedings of the IEEE International Conference on Mechatronics (ICM)*, Vicenza, Italy. pp. 24-27. Cited by 2.

A2. Collins, S. H., Caputo, J. M., and Adamczyk, P. G. (2014) Emulating prosthetic feet during the prescription process to improve outcomes and justifications. In: *Proceedings of the IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, Evanston, IL, USA. pages 127-128.

Conference Abstracts

A3. Collins, S.H., Kuo, A.D. (2003) Control of balance during walking in young and elderly adults. *American Society of Biomechanics*, Toledo OH, USA. September 25-27, 2003.

A4. Collins, S.H., Kuo, A.D. (2005) Controlled energy storage and return prosthesis reduces metabolic cost of walking. *International Society of Biomechanics*, Cleveland OH, USA. July 31 - August 5, 2005.

A5. Collins, S. H., Kuo, A. D. (2006) What can dynamic walking teach us about robots and humans? *Dynamic Walking*, Ann Arbor MI, USA. May 6-8, 2006.

A6. Collins, S. H., Kuo, A. D. (2007) Energetics of arm swinging. *Dynamic Walking*, Åland, Finland, June 24-30, 2007.

A7. Collins, S. H., Kuo, A. D. (2008) A comparison of CESR and conventional prosthetic feet: mechanics and metabolics. *Dynamic Walking*, Delft, The Netherlands, May 26-29, 2008.

A8. Collins, S.H. (2009) When mechanics matter: utilizing passive dynamics to gain energetic benefits in human locomotion. *Society for Experimental Biology*, Glasgow, UK, April 18-22, 2009.

A9. Collins, S. H. (2011) Exploring ankle control strategies with an experimental biomechatronic testbed. *Dynamic Walking,* Jena, Germany, Germany, July 18-21, 2011.

A10. Eicholtz, M. R., Collins, S. H. (2011) Design of a portable, lightweight ankle-foot orthosis (AFO) to reduce metabolic cost of walking. *Dynamic Walking*, Jena, Germany, Germany, July 18-21, 2011.

A11. Caputo, J. M., Collins, S. H. (2011) Externally powered and controlled ankle-foot prosthesis. *Dynamic Walking*, Jena, Germany, July 18-21, 2011.

A12. Kim, M. H., Collins, S. H. (2012) Ankle control design to enhance sagittal stability for lower-limb amputees. *Dynamic Walking*, Pensacola, FL, USA, May 21-25, 2012.

A13. Jackson, R. W., Collins, S. H. (2012) Targeting specific muscles for rehabilitation with an EMG-controlled ankle-foot orthosis. *Dynamic Walking*, Pensacola, FL, USA, May 21-25, 2012.

A14. Eicholtz, M. R., Collins, S. H. (2012) Two-dimensional parameter study to characterize performance of ankle-foot orthosis joint impedance control. *American Society of Biomechanics*, Gainesville, FL, USA, August 15-18, 2012.

A15. Caputo, J. M., Collins, S. H. (2012) An externally powered and controlled ankle-foot prosthesis for use in push-off experiments. *American Society of Biomechanics*, Gainesville, FL, USA, August 15-18, 2012.

A16. Collins, S. H. (2012) Towards tip-top testbeds: Biomechatronics for accelerated development of assistive devices. *Canadian Society of Biomechanics*, Vancouver, BC, Canada, June 6-9, 2014.

A17. Kim, M., Collins, S. H. (2013) Ankle push-off is equally important to foot placement in stabilizing three-dimensional walking. *Dynamic Walking*, Pittsburgh, PA, USA, June 9-13, 2013.

A18. Jackson, R. W., Collins, S. H. (2013) Manipulating self-selected gait patterns with an adaptive exoskeleton. *Dynamic Walking*, Pittsburgh, PA, USA, June 9-13, 2013.

A19. Caputo, J. M., Collins, S. H. (2013) Quantifying the relationship between prosthesis work and metabolic rate. *Dynamic Walking*, Pittsburgh, PA, USA, June 9-13, 2013.

A20. Collins, S. H. (2013) Biomechanics-centered design of robotic lower-limb prostheses and orthoses. *American Society of Biomechanics*, Omaha, NE, USA, September 4-7, 2013.

A21. Malcolm, P., Quesada, R., Caputo, J. M., De Clerq, D., Collins, S. H. (2014) Effect of push-off timing on metabolic cost during walking with a universal ankle-foot prosthesis emulator. *Dynamic Walking*, Zurich, Switzerland, June 10-14, 2014.

A22. Kim, M., Tembulkar, T., Collins, S. H. (2014) Modulating prosthetic ankle push-off work at each step reduces balancing effort during walking. *World Congress of Biomechanics*, Boston, MA, USA, July 6-11, 2014.

A23. Jackson, R. W., Collins, S. H. (2014) The relative benefits of work assistance and torque assistance in ankle exoskeletons. *World Congress of Biomechanics*, Boston, MA, USA, July 6-11, 2014.

A24. Caputo, J. M., Collins, S. H. (2014) The effect of ankle-foot prosthesis push-off work on walking kinetics and overall effort. *World Congress of Biomechanics*, Boston, MA, USA, July 6-11, 2014.

A25. Galle, S., Malcolm, P., Collins, S. H., Speekaert, J., De Clercq, D. (2015) Optimizing robotic exoskeletons actuation based on human neuromechanics experiments: interaction of push-off timing and work. *Adaptive Motion of Animals and Machines*, Boston, MA, USA, June 21-25, 2015.

A26. Collins, S. H. (2015) Optimizing (artificial) ankle function during walking. *Adaptive Motion of Animals and Machines*, Boston, MA, USA, June 21-25, 2015.

A27. Zhang, J., Collins, S. H. (2015) Selecting the best series stiffness and iterative learning gains for exoskeleton torque control. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A28. Wu, M., Adamczyk, P. G., Collins, S. H. (2015) The relationship between effort of walking and amount of walking performed. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A29. Witte, K. A., Collins, S. H. (2015) Design of a comfortable pure moment knee exoskeleton. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A30. Poggensee, K. L., Sreenath, K., Collins, S. H. (2015) Identifying the dynamics of a human-exoskeleton system. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A31. Nuckols, R. W., Collins, S. H., Sawicki, G. S. (2015) An emulator system to characterize optimal elastic ankle exoskeleton stiffness during human walking and running. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A32. Kim, M., Chen, T., Del Sesto, T., Collins, S. H. (2015) Step-to-step ankle in/eversion torque control in a robotic ankle-foot prosthesis may reduce balance-related effort during walking. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A33. Jackson, R. W., Collins, S. H. (2015) Estimated changes in muscle-level dynamics and energetics under different levels of exoskeleton-applied work and torque. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A34. Emanuel, B. J., Collins, S. H. (2015) A disturbance emulation system for stability and recovery testing. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A35. Diller, S., Majidi, C., Collins, S. H. (2015) Clutching with high force, high bandwidth, low mass and low energy consumption using electrostatics. *Dynamic Walking*, Columbus, Ohio, USA, July 21-24, 2015.

A36. Chen, T., Kim, M., Del Sesto, T., Collins, S. H. (2015) Inversion-eversion stiffness of ankle-foot prosthesis affects amputee's balance-related effort during walking. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A37. Caputo, J. M., Adamczyk, P. G., Collins, S. H. (2015) Optimizing prosthesis design to maximize user satisfaction using a tethered robotic ankle-foot prosthesis. *Dynamic Walking*, Columbus, OH, USA, July 21-24, 2015.

A38. Zhang, J., Cheah, C. C., Collins, S. H. (2015) Comparison of torque controllers for an ankle exoskeleton with a series elastic actuator driven by a uni-directional Bowden cable during walking. *American Society of Biomechanics*, Columbus, OH, USA, August 5-8, 2015.

A39. Wu, M., Adamczyk, P. G., Collins, S. H. (2015) Effort-o-meter: The relationship between effort of walking and amount of walking performed. *American Society of Biomechanics*, Columbus, OH, USA, August 5-8, 2015.

A40. Witte, K. A., Collins, S. H. (2015) Design of two lightweight high bandwidth torque-controlled ankle exoskeletons. *American Society of Biomechanics*, Columbus, OH, USA, August 5-8, 2015.

A41. Caputo, J. M., Adamczyk, P. G., Collins, S. H. (2015) Emulating candidate ankle-foot prostheses to inform prescription. *American Society of Biomechanics*, Columbus, OH, USA, August 5-8, 2015.

A42. Collins, S. H. (2015) Prosthetic limbs that reduce the energy cost of walking to below non-amputee levels are possible but hard to discover. *American Society of Biomechanics*, Columbus, OH, USA, August 5-8, 2015.

Podium Presentations and Seminars

1. Control of balance during walking in young and elderly adults. *American Society of Biomechanics*, Toledo Ohio, USA. September 26, 2003.

2. A bipedal walking robot with efficient and human-like gait. *International Conference on Robotics and Automation* 2005, Barcelona, Spain. April 20, 2005.

3. Controlled energy storage and return prosthesis reduces metabolic cost of walking. *International Society of Biomechanics*, Cleveland Ohio, USA. August 3, 2005.

4. *Keynote:* What can dynamic walking teach us about robots and humans? *Dynamic Walking*, Ann Arbor Michigan, USA. May 6, 2006.

5. Energetics of arm swinging. *Dynamic Walking*, Åland, Finland. June 26, 2007.

6. A comparison of controlled energy-storage and return and conventional prosthetic feet: mechanics and metabolics. *Dynamic Walking*, Delft, The Netherlands. May 28, 2008.

7. *Invited:* When mechanics matter: utilizing passive dynamics to gain energetic benefits in human locomotion. *Society for Experimental Biology*, Glasgow, United Kingdom. July 1, 2009.

8. Exploring ankle control strategies with an experimental biomechatronic testbed. *Dynamic Walking*, Jena, Germany. July 19, 2011.

9. Toward tip-top testbeds: Biomechatronics for accelerated development of assistive devices. *Canadian Society of Biomechanics*, Vancouver, British Columbia, Canada. June 8, 2012.

10. What walking robots can tell us about ankle-foot prosthesis control. Joint Biped Locomotion Workshop, Disney Research, Pittsburgh, Pennsylvania, USA. November 3, 2012.

11. Learning to help walk: Developing wearable robots for people with lower-limb disabilities. Department Seminar, Department of Mechanical Engineering, The Ohio State University, Columbus, Ohio, USA. November 9, 2012.

12. *Plenary:* What do walking humans want from mechatronics? *International Conference on Mechatronics*, Vicenza, Italy. March 1, 2013.

13. An experimental robotic testbed for accelerated development of ankle prostheses. *International Conference on Robotics and Automation*, Karlsruhe, Germany. May 8, 2013.

14. A method for harnessing least-effort drives in robotic locomotion training. *International Conference on Rehabilitation Robotics*, Seattle, Washington, USA. June 25, 2013.

15. *Award:* Biomechanics-centered design of robotic lower-limb prostheses and orthoses. *American Society of Biomechanics*, Omaha, Nebraska, USA. September 6, 2013.

16. Universal robotic prosthesis emulators. Mechanical Engineering Colloquium, Department of Mechanical Engineering, Massachusetts Institute of Technology, Boston, Massachusetts, USA. November 8, 2013.

17. Tools for accelerating the development of intelligent prostheses. Center for Bionic Medicine, Rehabilitation Institute of Chicago and Northwestern University, Chicago, Illinois, USA. November 15, 2013.

18. Characterizing human locomotor response to wearable robot functionality. Bioengineering Department & National Center for Simulation in Rehabilitation Research, Stanford University, Palo Alto, California, USA. November 18, 2013.

19. Biomechanics-centered design of robotic lower-limb prostheses. Robotics Institute Seminar, Carnegie Mellon University, Pittsburgh, PA, USA. January 23, 2014.

20. Universal prosthesis emulators for rapid evaluation of human response to intervention. Department Seminar, Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA. April 18, 2014.

21. Emulating ankle-foot prostheses during the prescription process to improve outcomes and justifications. IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO), Evanston, Illinois, USA. September 12, 2014.

22. How to develop wearable robots that make walking easier. Department Seminar, Department of Mechanical Engineering, Harvard University, Boston, Massachusetts, USA. October 15, 2014.

23. What I learned from my wearable robot: the unexpected physiological effects of forceful human-robot interactions. Seminar, School of Applied Physiology, Georgia Institute of Technology, Atlanta, Georgia, USA. November 12, 2014.

24. Improving the development, prescription and tuning of robotic prostheses using versatile emulator systems. Department Seminar, Department of Mechanical Engineering, University of Washington, Seattle, Washington, USA. December 2, 2014.

25. Designing robotic prostheses and exoskeletons that enhance human mobility. BioMedical Engineering Seminar, Department of Mechanical Engineering, University of British Columbia, Vancouver, British Columbia, Canada. March 12, 2015.

26. Human-in-the-loop prosthesis design using versatile robotic emulator systems. Dynamic Systems and Controls Seminar, Department of Mechanical and Aerospace Engineering, University of California, San Diego, San Diego, California, USA. April 24, 2015.

27. *Award:* An ankle-foot prosthesis emulator with control of plantarflexion and inversion-eversion torque. *International Conference on Robotics and Automation*, Seattle, WA, USA. May 24, 2015.

28. *Invited:* Optimizing (artificial) ankle function during walking. *Adaptive Motion of Animals and Machines*, Massachusetts Institute of Technology, Boston, Massachusetts, USA. June 23, 2015.

29. *Invited:* Reducing the energy cost of human walking using an unpowered exoskeleton. *Dynamic Walking*, Columbus, Ohio, USA. July 25, 2015.

30. *Invited:* Prosthetic limbs that reduce the energy cost of walking to below non-amputee levels are possible but hard to discover. *American Society of Biomechanics*, Columbus, Ohio, USA. August 8, 2015.

Grants

Principal Investigator: ($2.4M)

1. Development of an actively-controlled prosthetic foot. National Science Foundation, Phase I STTR. PI, 2006-2007, $100,000.

2. Controlled energy storage and release in an intelligent prosthetic foot. National Science Foundation, Phase I STTR. PI, 2003-2004, $100,000.

3. Field-based gait monitoring system for the elderly. National Institutes of Health, Phase I STTR. PI, 2006-2007, $100,000.

4. Development of prosthetic foot with controlled energy storage and release. National Institutes of Health, Phase II STTR. PI, 2007-2010, $750,000.

5. Collaborative Research: User-optimal robotic prosthesis design. National Science Foundation, CMMI, Engineering and Systems Design. PI, 2013-2016, $216,000.

6. NRI: Small: Rapid exploration of robotic ankle exoskeleton control strategies. National Science Foundation, National Robotics Initiative. PI. 2013-2018, $800,000
7. *Internal:* New measurement capabilities for bio- and neuro-mechanics experiments. Carnegie Mellon University College of Engineering Dean's Equipment Grant. PI, 2014, $32,000.

8. *Internal:* Instrumented treadmill for biomechanics experiments. Carnegie Mellon University College of Engineering Dean's Equipment Grant. PI, 2015, $183,000.

9. Development and comparison of new methods for stabilizing amputee gait. National Science Foundation, CBET, General & Age-Related Disabilities Engineering. PI, 2015-2018, $370,226.

Co-Principal Investigator: ($1.1M)

10. Clinic-based robotic prosthesis emulator for amputee gait assessment. National Institutes of Health, Phase I SBIR. Co-PI (PI: Peter Adamczyk), 2013-2014, $150,000.

11. *Internal:* OptiTrack Motion Capture System. Carnegie Mellon University College of Engineering Dean's Equipment Grant. Co-PI (PI: Sreenath), 2014, $75,000.

12. NRI: Balance recovery control for amputees suing powered leg prostheses. National Science Foundation, National Robotics Initiative. Co-PI (PI: Hartmut Geyer), 2015-2018, $900,000.

Co-Investigator: ($3.2M)

13. MRI: Acquisition of an additive manufacturing machine for 3D metal components for research and education. National Science Foundation. Co-I (PI: Burak Ozdoganlar). 2014, $546,000.

14. *Internal*: Acquisition of Arcam electron beam melting additive manufacturing equipment for direct metal fabrication. College of Engineering. Co-I (PI: Gary Fedder), 2014, $1,164,000.

15. Additive manufacturing research infrastructure. Department of Defense, Defense University Research Instrumentation Program. Co-I (PI: Jack Beuth), 2015, $1,500,000.

Pending Proposals: ($3.3M)

i. Clinic-based parameter optimization system for the design of patient-specific lower-limb prostheses. National Institutes of Health Phase I SBIR, recommended to National Institute of Child Health and Human Development. Co-PI (PI: Josh Caputo), 2015, $150,000.

ii. Clinic-based robotic amputee gait capacity assessment system. National Institutes of Health Phase II SBIR, recommended to National Institute of Child Health and Human Development. Co-PI (PI: Peter Adamczyk), 2015-2017, $1,000,000.

iii. Robotic gait training that increases patient engagement. National Institutes of Health R21, National Institute of Child Health and Human Development. PI, 2015-2017, $391,895.

iv. Optimizing hip, knee and ankle exoskeleton assistance during walking and running at various speeds and loads. Invited white paper, U.S. Army, NSRDEC. PI, 2016-2018, $1,627,700.

v. Ankle exoskeletons that make recreational runners faster. Contract under negotiation with a major U.S. corporation. PI, 2016-2017, $260,000.

Professional Awards

1. McManus Design Award. Mechanical Engineering, Cornell University, 2002. The graduate or undergraduate student with the most outstanding solution to a design problem.

2. Department Fellowship. Mechanical Engineering, University of Michigan, 2002-2003.

3. NASA Fellowship. National Aeronautics and Space Administration Graduate Student Researchers Program, 2004-2005.

4. Struminger Faculty Teaching Fellow. Department of Mechanical Engineering, 2012.

5. Young Scientist Award, Post-Doctoral. *American Society of Biomechanics*, 2013.

6. Professor of the Year. Awarded by Mechanical Engineering Senior Class of 2014.

7. Best Medical Robotics Paper Award, *International Conference on Robotics and Automation*, Seattle, WA, USA, May 2015. One of eight awards from among 2,275 papers submitted.

Courses Taught

Faculty Course Evaluation (FCE) scores are on a scale of 1 to 5.

Course #	Course Title	Units	Class	Offered	Students	FCE Crse	FCE Instr
24-370	Design I	12	Jun	Spring 11	99	4.3	4.2
24-674	Biomechatronics	12	Gr	Fall 11	30	3.9	3.9
24-370	Design I	12	Jun	Spring 12	109	3.8	3.7
24-674	Biomechatronics	12	Gr	Fall 12	47	4.2	4.1
24-370	Design I	12	Jun	Spring 13	118	4.4	4.3
24-674	Biomechatronics	12	Gr	Fall 13	45	4.0	4.1
24-370	Design I	12	Jun	Spring 14	123	4.0	3.9
24-674	Biomechatronics	12	Gr	Fall 14	37	4.1	4.0
24-370	Design I	12	Jun	Spring 15	123	3.8	3.7
24-674	Biomechatronics	12	Gr	Fall 15	49	-	-
24-370	Design I	12	Jun	Fall 15	110	-	-

Educational Initiatives:

1. *Overhaul of a core Junior-level course:* 24-370, Engineering Design I: Skills and Methods
   a. *Primary actions:*
      i. Added three projects with physical prototyping
      ii. Flipped classroom
      iii. Developed new Topic Readings as substitute for textbook
   b. *Results:*
      i. FCEs increased by about 0.6 points
      ii. Many students report this is their favorite course at Carnegie Mellon
2. *Developed new core Sophomore-level course:* 24-202 Introduction to Computer Aided Design
   a. *Primary actions:*
      i. Developed syllabus and format
      ii. Recruited and trained adjunct faculty
   b. *Results:*
      i. Strong FCEs (about 4.0)
      ii. Students report being better prepared for internships and later courses

3. *Developed new graduate elective:* 24-674 Design of Biomechatronic Systems
   a. *Actions:*
      i. Introduced new graduate course
      ii. Developed semester-long project format
      iii. Weekly one-hour meetings with each project team
   b. *Results:*
      i. Well-subscribed, enrollment between 30 and 50
      ii. Strong FCEs (about 4.0).
      iii. Students often continue research independently.
      iv. Recent topics, selected from among 34 teams in the past three years, include:
         1. Steadigam: Experiments on balance-enhancing prosthesis control
         2. Stumblr: A block-dropping robot to induce trips

3. Tripod: A three-degree-of-freedom active prosthesis
4. Superknee: A high-performance tethered knee prosthesis
5. Muscle-Vision: Automated ultrasound fascicle tracking
6. Featherweight: Autonomous ankle exo with selectable stiffness
7. Sprint-Knee: Tethered knee exoskeleton for fast running
8. Pack-Man: Adjustable prosthesis socket using granular packing

4. *Developed New Graduate Seminar:* 24-892 Bipedal Locomotion Seminar
   a. *Actions:*
      i. Founded CMU Bipedal Locomotion Seminar, brought together collabroators
      ii. Organize weekly speakers, manage locations, website, and mailing list
   b. *Results:*
      i. Well-attended, with about 30 participants from about 7 labs at 3 Institutions

5. *Infrastructure development:* College of Engineering machine shop reorganization
   a. *Actions:*
      i. Gathered shop usage information across the College
      ii. Developed new usage plans and draft floor plans for architects
      iii. Participated in fundraising activities
   b. *Results:*
      i. Fundraising ongoing for planned Design and Innovation Center

6. *High-school outreach education:* Pittsburgh SciTech High School projects, 2013—2015
   a. *Actions:*
      i. Mentor high school team of 4-5 students each year
      ii. Lead weekly one-hour meetings
      iii. Organize separate weekly meetings with Carnegie Mellon Senior undergraduates
   b. *Results:*
      i. All past students have gone on to STEM studies in college
7. *Planned introduction of new graduate elective:* 24-675 Human Biomechanics Experimentation
   a. *Actions:*
      i. Developed planned syllabus and format, to be introduced in Fall 2016

Student Advising and Mentoring

PhD Students supervised: (8 total, 1 graduated)

1. Joshua M. Caputo, Ph.D., Department of Mechanical Engineering, Fall 2010—Spring 2015
   Bertucci Fellow

2. Juanjuan Zhang, Department of Mechanical Engineering, Fall 2010—present
   NTU Fellow. Dual-degree with NTU, Assoc. Prof. C. C. Cheah

3. Rachel W. Jackson, Department of Mechanical Engineering, Fall 2011—present
   NSF Fellow

4. Myunghee Kim, M.S., Department of Mechanical Engineering, Fall 2011—present

5. Stuart B. Diller, Department of Mechanical Engineering, Fall 2013—present
   Bertucci Fellow. Co-advised with Assistant Professor Carmel Majidi

6. Katherine L. Poggensee, Department of Mechanical Engineering, Fall 2014—present
   NSF Fellow. Luce Fellow. Co-advised with Assistant Professor Koushil Sreenath

7. Kirby A. Witte, Department of Mechanical Engineering, Fall 2014—present
   NSF Fellow

8. Vincent Chiu, Department of Mechanical Engineering, Fall 2015—present

Postdoctoral researchers supervised: (3 total)

1. Philippe Malcolm, Ph.D., Department of Mechanical Engineering, Summer 2014
   Now a postdoc at Harvard

2. Joshua M. Caputo, Ph.D., Department of Mechanical Engineering, Fall 2015—present
   Now President of Human Motion Technologies, L.L.C.

3. Pieter Fiers, Ph.D., Department of Mechanical Engineering, Spring 2016—present

Master's Project Students Supervised: (24 total)

Lowie van Zijl (T.U. Delft), Laurent Huberty (T.U. Delft), Michiel Plooij (T.U. Delft), Matthew Glisson, Kanchi Nayaka, Ben Matzke, Jaan Warnaars (T.U. Delft), Jackie Yang, Tianyao Chen, Winton Zheng, Mailing Wu, Kirby Witte, Tanuf Tembulkar, Roberto Quesada, Biju Obi, Rohan Krishnan, Tianjian Chen, Zach Batts, Russell Kirmayer, Kyle Rawding, James Gabriel, Blair Emanuel, Evan Dvorak, Tyler Del Sesto

Undergraduate Research Students Supervised: (25 total)

Jonathan Boerner, Sarah Kunka, Lizmarie Comenencia-Ortiz, Matthew Stanton, Jessica Lee, Pace Nalbone, Robert Wojno, Mark Erazo, Steven Pepin, Jayon Wang, Ruthika, Eli Zauner, Patrick Sumner, Elena Yasinski, Eric Volk, Mike Spinelli, Faith Quist, Alvan Mbongo, Noah Fox, Stephanie Chen, Alec Assaad, Sean Archie, Michelle Mann, Hannah Lyness, Wentao He

Other Students Mentored: (16 total)

Doctoral: Marjolein van der Krogt, Daan Bregman, Sjoerd Bruijn, Vrije Universiteit Amsterdam; Tomas de Boer, Erik Schuitema and Daniël Karssen, Delft University of Technology; Karl Zelik, Shawn O'Connor, Peter Adamczyk and John Rebula, University of Michigan; Bruce Wiggin, North Carolina State University. *Undergraduate and Master's:* Karin Griffoen, Delft University of Technology; Matthew Vanderpool and Andrew Chang, University of Michigan; Chaim Garfinkel and Jerry Chien, Cornell University

Other Teaching Experience

1. Guest lecturer, MAE 225, Mechanical Synthesis, Cornell University, 2001—2002

2. Teaching assistant, Physics 101. Cornell University, 1999—2001

Other Professional Appointments

1. Mechanical design engineer, Yobotics Inc., Boston, Massachusetts, 2000—2001
   Supervisor: Jerry Pratt, Ph.D.

2. President and founder, Intelligent Prosthetic Systems L.L.C., Ann Arbor, MI, 2003—2010

3. Consultant, Bionic Power Inc., Vancouver, British Columbia, Canada, 2008—2010
   Supervisor: J. Maxwell Donelan, Ph.D.

Academic Service

Conference organizing:

1. Conference aide: Dynamic Walking, Ann Arbor, MI, May 2006.
   Conference with about 60 attendees.

2. Scientific board: Dynamic Walking, June 2008-present.
   Assist with speaker recruitment, reviews, and high-level organization of an annual conference.

3. Co-organizer, co-host: Dynamic Walking 2008, Delft, the Netherlands.
   Conference with about 200 attendees.

4. Co-organizer, scientific program lead: Dynamic Walking 2009, Vancouver, Canada.
   Conference with about 200 attendees.

5. Lead organizer, co-host: Dynamic Walking 2013, Pittsburgh, PA, USA.
   Conference with about 200 attendees. www.cmu.edu/dynamic-walking

6. Symposium organizer: World Congress of Biomechanics 2014, Boston, MA, USA.
   Two sessions with nine invited speakers.

7. Session organizer: American Society of Biomechanics 2015, Columbus, OH, USA.
   Moderated one interactive session with five speakers selected from submitted abstracts.

8. Workshop organizer: Int. Conference on Robotics and Automation 2016, Stockholm, Sweden.
   Proposed, 14 speakers. biomechatronics.cit.cmu.edu/ActiveProsthetics---ICRA2016.html

Peer review: (121 reviews for 31 journals and conferences)

9. Referee: *Proceedings of the National Academy of Sciences, Proceedings of the Royal Society of London Interface, Nature Scientific Reports, Public Library of Science ONE, Journal of Biomechanics, Journal of Experimental Biology, Journal of Biomechanical Engineering, International Journal of Robotics Research, Transactions on Neural Systems & Rehabilitation Engineering, Journal of Theoretical Biology, Experimental Brain Research, Journal of NeuroEngineering and Rehabilitation, Robotics and Automation Letters, Robotics & Autonomous Systems, Intelligent Autonomous Systems, Autonomous Robots, Human Movement Science, Humanoids, Robotics & Automation Magazine, Transactions on Robotics, Robotica, Journal of Medical Devices, European Journal of Applied Physiology, Mechatronics, Annual Meeting of the American Society of Biomechanics (ASB), International Conference on Robotics and Automation (ICRA), International Conference on Robotics and Biomimetics (ROBIO), International Conference on Intelligent Robots and Systems (IROS), Dynamic Systems and Control Conference (DSCC).*

Service to home institution:

10. Qualifying Exams proctor: Mechanical Engineering, Fall 2010—present.
    (reigning champion for number of exams administered, with 82 in the last 6 cycles)

11. Member: Mechanical Engineering Undergraduate Education Committee, Fall 2010—present

12. Coordinator: Mechanical Engineering Undergraduate Teaching Fellow program, Fall 2011—present

13. Member: Mechanical Engineering Robotics Strategic Planning Committee, Fall 2013—2015

14. Member: Mechanical Engineering Shop Reorganization Committee, Fall 2013—present

15. Member: College of Engineering Manufacturing Facilities Committee, Spring 2014—present

16. Ph.D. Committee member:
    a. Siddharth Sanan, Robotics Institute, CMU, 2010-2013.
    b. Sehyuk Yim, Mechanical Engineering, CMU, 2012.
    c. Mohamed Saleh, Mechanical Engineering, CMU, 2013-2015.
    d. Matthew Woodward, Mechanical Engineering, CMU, 2014-present.
    e. Alexander Schepelmann, Robotics Institute, CMU, 2014-present.

Other Academic and Societal Service:

17. Booth: American Association for the Advancement of Science (AAAS) Family Science Days, Washington DC, USA. February, 2005

18. Ph.D. Committee member: Karl E. Zelik, University of Michigan, 2009-2012

19. Ph.D. Thesis Committee member: Sjoerd Bruijn, Vrije Universiteit Amsterdam, 2010

20. Session leader: SWE High School Days, Carnegie Mellon University, Pittsburgh, PA, 2010—2013

21. Co-Organizer: Amp Up! Pittsburgh Amputee Support Group, 2011—2012

22. Judge: Bennett Conference, Carnegie Mellon University, Pittsburgh, PA, 2011

23. Judge: FIRST Robotics competition, National Robotics Engineering Center, Pittsburgh, PA, December 2011

24. Ph.D. Committee member: Bruce Wiggin, North Carolina State University, 2012—2014

25. Mentor: SciTech High School project team. Weekly one-hour meetings. Fall 2013—present

26. Judge: Sweepstakes buggy design competition, Carnegie Mellon University, Pittsburgh, PA, April 2013

27. Guest Lecture: How to design robotic prostheses, Ellis School for girls, Pittsburgh, PA, October 30, 2013

28. Poster at: American Orthotics and Prosthetics Association National Assembly, Las Vegas, NV, USA. Sept. 4-7 2014

29. Reviewer: CMU Robotics Minor program, Spring 2014-present

30. Guest lecture: Applied Physiology 6202, Clinical Gait Analysis, Young-Hui Chang, Georgia Institute of Technology, Altanta, GA, 12 November, 2014

31. Guest lecture: Integrative Physiology 6660, Biomechanics and Energetics of Locomotion Rodger Kram, University of Colorado, Boulder, 19 November 2014

Professional memberships

1. Member, American Society of Biomechanics (ASB), 2003—present

2. Member, Institute of Electrical and Electronics Engineers (IEEE), 2012—present

3. Member, American Physiological Society (APS), 2014—present

4. Member, Robotics and Automation Society (RAS), 2015—present

Popular press and other reviews

1. Efficient walking robot work is reviewed in: Alexander, R. M. (2005) Perspective: Walking made simple. *Science*, **308**(5718):58-59.

2. Efficient walking robot research was reported by the following popular press outlets:
   a. AP (February 2005)
   b. AFP (February 2005)

c. BBC (February 2005)
d. Der Spiegel (February 2005)
e. Discover Magazine (January 2006)
f. Discovery Channel Canada (February 2005)
g. The Guardian (February 2005)
h. The Independent (February 2005)
i. Machine Design (March 2005)
j. Nature News (February 2005)
k. The New Scientist (February 2005)
l. NPR's Day to Day (February 2005)
m. New York Times (February 2005)
n. Popular Mechanics (June 2005)
o. Reuters (February 2005)
p. Science News (August 2005)
q. Science Channel (February 2005)
r. Scientific American (February 2005)
s. The Telegraph (February 2005)
t. The Times (London, February 2005)
u. The World (BBC/PRI, February 2005)
(hundreds of additional news outlets internationally)

3. Arm swinging work is reviewed in: Gillis, G. B. (2009) Outside JEB: Getting into the swing of walking. *J. Experimental Biology*, **212**:V.

4. Arm swinging work was reported by the following popular press:
   a. AFP (August 2009)
   b. Discovery Channel Magazine (January 2010)
   c. The Guardian (August 2009)
   d. The Independent (August 2009)
   e. Radio Nacional de Columbia (August 2009)
   f. Reuters (August 2009)
   g. Scientific American (August 2009)
   h. The Telegraph (August 2009)

5. Energy-recycling artificial foot work was reported by the following popular press
   a. CBC Radio's As It Happens (February 2010)
   b. New Scientist (February 2010)
   c. Popular Science (February 2010)
   d. NRC Handelsblad (February 2010)

6. Robotic emulator system work reported by the following popular press:
   a. Site Selection Magazine (September 2014)
   b. Newsmax (March 2014)

7. Unpowered ankle exoskeleton work is reviewed in:
   a. Castelvecchi, D. (2015) News: Exoskeleton boots improve on evolution – Unpowered mechanical design lowers the energetic costs of walking. *Nature*, **doi**:10.1038/nature.2015.17237

b. Nature Editorial Board (2015) Editorial: Walking 2.0 – A passive device that augments calf muscles improves on natural selection's best effort. *Nature*, 520:6, **doi**:10.1038/520006a.
c. Conover, E. (2015) ScienceShot: Exoskeleton boot reduces cost of walking by 7%. *Science*, **doi**:10.1126/science.aab0409
d. NIH National Institutes of Nursing Research News & Notes, April 23, 2015
e. NSF Press Release 15-031, April 1, 2015

8. Unpowered ankle exoskeleton work reported by the following popular press:
   a. The New York Times (USA, April, 2015)
   b. The Washington Post (USA, April, 2015)
   c. NPR's Science Friday (USA, April, 2015)
   d. NBC News (USA, April, 2015)
   e. The Associated Press (USA, April, 2015)
   f. CBC's Quirks & Quarks (Canada, April, 2015)
   g. The Economist (United Kingdom, April, 2015)
   h. BBC News (United Kingdom, April, 2015)
   i. The Guardian (United Kingdom, April, 2015)
   j. The Independent (United Kingdom, April, 2015)
   k. Der Spiegel (Germany, April, 2015)
   l. Agence France-Presse (France, April, 2015)
   m. El País (Spain, April, 2015)
   n. NRC Handelsblad (The Netherlands, April, 2015)
   o. ORF1's Wissen Aktuell (Austria, April, 2015)
   p. Correio Braziliense (Brazil, April 2015)
   q. Popular Mechanics (USA, April 2015)
   r. Popular Science (USA, April 2015)
   s. Wired, Discovery News, Gizmodo, Engadget, Fusion, etc. (April 2015)
   t. Fox's Earth 2050 (September 2015)
   (hundreds of additional news outlets internationally)