

MASSACHUSETTS INSTITUTE OF TECHNOLOGYSchool of Architecture and Planning Faculty Personnel Record

Date: August 23, 2004

Full Name: Hugh Miller Herr**Department:** Program in Media Arts and Sciences**1. Date of Birth:**

10/25/64

2. Citizenship:

U.S.

3. Education:

<u>School</u>	<u>Degree</u>	<u>Date</u>
Millersville University of Pennsylvania	B.A. Physics	1990
MIT	M.S. Mechanical Eng.	1993
Harvard University	Ph.D. Biophysics	1998

4. Title of Thesis for Most Advanced Degree:

A Model of Mammalian Quadrupedal Running

5. Principal Fields of Interest:

Professor Herr conducts research in the fields of biomechanics and biological motion control, and applies that knowledge to the design of human rehabilitation and augmentation technology

6. Name and Rank of Other Departmental Faculty in Same Field:

None.

7. Name and Rank of Faculty of Other Departments in Same Field:

Neville Hogan, Professor, Mechanical Engineering, MIT.

8. Non-MIT Experience (including military service):

<u>Employer</u>	<u>Position</u>	<u>Beginning</u>	<u>Ending</u>
Harvard Medical School	Instructor	1999	2003
Health Sciences & Tech.	Instructor	1999	2003
Harvard Medical School	Assistant Professor	2003	2004
Health Sciences & Tech.	Assistant Professor	2003	2004

9. History of MIT Appointments:

<u>Rank</u>	<u>Beginning</u>	<u>Ending</u>
Postdoctoral Fellow	1998	1999
Assistant Professor	2004	Present

10. Consulting Record:

<u>Firm</u>	<u>Beginning</u>	<u>Ending</u>
Flex-Foot, Inc.	2001	2002
Össur, Inc.	2002	2003

11. Department and Institute Committees, Other Assigned Duties:

<u>Activity</u>	<u>Beginning</u>	<u>Ending</u>
HMS Native American Student Program	2002	2003
HST BioMatrix Mentoring Program	2002	Present
EECS Women's Technology Program	2003	Present

12. Government and Other Outside Committees, Service, etc.:

<u>Committee</u>	<u>Beginning</u>	<u>Ending</u>
National Institute on Disability and Rehabilitation Research (NIDRR); Scientific Merit Review Board for Rehabilitation Center Grants	2000	2001
National Institute of Health (NIH); Scientific Merit Review Board for Small Business Innovation Research Program	2002	2002
Department of Veterans Affairs (VA); Scientific Merit Review Board for Rehabilitation Research and Development Service	2002	2005
Editorial Board: ad hoc reviewer; Book: Biologically Inspired Intelligent Robots	2002	2002

Editorial Board: ad hoc reviewer; Proceedings of the Royal Society: Biological Sciences	2003	Present
Editorial Board: ad hoc reviewer; IEEE Transactions on Biomedical Engineering	2003	Present
Editorial Board: ad hoc reviewer; International Journal of Robotics Research	2003	Present
Editorial Board: ad hoc reviewer; Book: Machines Called Robots	2003	2003
Editorial Board: ad hoc reviewer; Journal of Experimental Biology	2003	Present
Associate Editor; Journal of NeuroEngineering and Rehabilitation	2003	Present

13. Awards Received:

<u>Award</u>	<u>Date</u>
Sports Hall of Fame	1989
Young American Award	1990
United States College Academic Team	1990
Office of Naval Research Fellow	1992
Who's Who of American Inventors	1996
Howard R. Thranhardt Lecture Honorarium	2001

14. Current Organization Membership:

<u>Organization</u>	<u>Date</u>
The Society of Experimental Biologists	2000 - Present
The American Academy of Orthotists and Prosthetists	2001 - Present
Electrical and Electronics Engineers (IEEE)	2004 - Present

15. Patents and Patent Applications Pending:

1. Gosthnian B., Herr H., inventors; Inflatable Limb Prosthesis with Preformed Inner Surface. US patent 4,923,475. 1990.
2. Gamow I., Herr H., inventors; Shoe and Foot Prosthesis with a Coupled Spring System. US Patent 5,367,790. 1994.
3. Herr H., inventor; Crutch with Elbow and Shank Springs. US Patent 5,458,143. 1995.
4. Herr H., Gamow I., inventors; Shoe and Foot Prosthesis with Bending Beam Spring Structures. US Patent 5,701,686. 1997.
5. Herr H., Gamow I., inventors; Shoe and Foot Prosthesis with Bending Beam Spring Structures. US Patent 6,029,374. 2000.
6. Deffenbaugh B., Herr H., Pratt G., Wittig M., inventors; Electronically Controlled Prosthetic Knee. US Patent 6,764,520. 2001.
7. Herr H., Wilkenfeld A., Olaf B., inventors; Speed-Adaptive and Patient-Adaptive Prosthetic Knee. Pending. 2001.
8. Seyfarth A., Geyer H., Herr H., inventors; A Speed-Adaptive Control Scheme for Legged Running Robots. Pending. 2003.
9. Herr H., Blaya J., Pratt G., inventors; Adaptive Control of a Variable-Impedance Ankle-Foot Orthosis to Assist Drop Foot Gait. Pending. 2003.
10. Herr H., inventor; Variable-Mechanical-Impedance Artificial Legs. Pending. 2003.
11. Farahat W., Herr H., inventors; An Apparatus for Generalized Characterization and Control of Muscle. Pending 2004.

16. Professional Registration:

None.

17. Projects:

Built:

1. Inflatable Limb Prosthesis with Preformed Inner Surface. 1990.
2. Shoe and Foot Prosthesis with a Coupled Spring System. 1994.
3. Crutch with Elbow and Shank Springs. 1995.
4. A human-powered, endurance amplifier for cyclic anaerobic activities. 1997.

- *5. Electronically Controlled Prosthetic Knee. 2001.
- 6. A Swimming Robot Actuated by Living Muscle Tissue. 2002.
- 7. A Variable-Impedance Ankle-Foot Orthosis to Assist Drop Foot Gait. 2003.
- 8. An Apparatus for Generalized Characterization and Control of Muscle. 2003.
- 9. A Dynamic Bioreactor for the Characterization and Control of Tissue-Actuated Swimming Robots. 2003.
- 10. A Low-Cost, Body Orientation Sensor. 2004.

Under Construction:

- 1. A Variable-Impedance, Foot-Ankle Prosthesis with Electromyographic Control. Expected completion 2005.
- 2. A Variable-Impedance, Knee Prosthesis with Electromyographic Control. Expected completion 2005.
- 3. A Leg Exoskeleton for Locomotory Endurance Amplification. Expected completion 2005.
- 4. An Autonomous, Variable-Impedance Ankle-Foot Orthosis to Assist Drop Foot Gait. Expected completion 2005.

Unbuilt:

- 1. A Robust and Controllable, Swimming Robot Actuated by Living Muscle Tissue. Construction to begin 2005.
- 2. A Powered Leg Prosthesis for Running. Construction to begin 2005.
- 3. An Upper Extremity Exoskeleton for Climbing Augmentation. Construction to begin 2005.

18. Symposia Organized:

None.

* The Electronically Controlled Prosthetic Knee developed by Professor Herr's research group is being sold commercially to the benefit of transfemoral amputees worldwide.

Teaching Experience of Hugh Herr

<u>Term</u>	<u>Sub. No.</u>	<u>Title</u>	<u>Role</u>	<u>Enrollment</u>
ST 99	Harvard, ES 149	Muscles, Reflexes and Locomotion	Lecturer	20
FT 99- Present	Harvard Medical School, HST 010	Human Functional Anatomy	Lecturer, Prosector, and Dissector	50

Publications of Hugh Herr

1. Books:

None.

2. Papers in Refereed Journals:

1. Herr H, Langman N. Optimization of Human-Powered Elastic Mechanisms for Endurance Amplification. *Journal of the International Society for Structural and Multidisciplinary Optimization (ISSMO)*. 1997; 13:65-7.
2. Hu J, Pratt J, Chew C, Herr H, Pratt G. Virtual Model Based Adaptive Dynamic Control of a Biped Walking Robot. *International Journal on Artificial Intelligence Tools*. 1999; 8:337-48.
3. Herr H, McMahon T. A Trotting Horse Model. *International Journal of Robotics Research*. 2000; 19:566-81.
4. Herr H, McMahon T. A Galloping Horse Model. *International Journal of Robotics Research*. 2000; 20:26-37.
- *5. Kerdok A, Biewener A, McMahon T, Weyand P, Herr H. Energetics and Mechanics of Human Running on Surfaces of Different Stiffnesses. *J Appl Physiol* 2001; 92:469-78.
6. Herr H, Huang G, McMahon T. A Model of Scale Effects in Mammalian Quadrupedal Running. *J. Exp. Biol.* 2002; 205:959-67.

* Outgrowth of supervised thesis

Publications of Hugh Herr

- *7. Hofmann A, Popovic M, Herr H. Humanoid Standing Control: Learning from Human Demonstration. *J Automatic Control* 2002; 12:16-22.
- *8. Herr H, Wilkenfeld A. User-Adaptive Control of a Magnetorheological Prosthetic Knee. *Industrial Robot: An International Journal* 2003; 30: 42–55.
- *9. Seyfarth A, Geyer H, Herr H. Leg Retraction: A Simple Control Strategy for Stable Running. *The Journal of Experimental Biology* 2003; 206: 2547-2555.
- *10. Blaya J., Herr H. Adaptive Control of a Variable-Impedance Ankle-Foot Orthosis to Assist Drop Foot Gait. *IEEE Transactions on Neural Systems & Rehabilitation Engineering* 2004; 12(1): 24-31.
- 11. Herr H., Dennis B. A Swimming Robot Actuated by Living Muscle Tissue. *Journal of NeuroEngineering and Rehabilitation*. 2004 (In press).
- *12. Farahat W., Herr H. An Apparatus for Generalized Characterization and Control of Muscle. *IEEE Transactions on Neural Systems & Rehabilitation Engineering* 2004 (In press).

3. Papers in Refereed Conference Proceedings:

- 1. Hu J., Pratt J., Chew C., Herr H., Pratt G. Adaptive Virtual Model Control of a Bipedal Walking Robot. *Proceedings of IEEE International Joint Symposia on Intelligence and Systems*; 1998 May; Dallas, Texas 245-51.
- 2. Herr H., Pratt G., Dennis B., Rosenthal N., Marsh R. From Swimming to Walking: Examples of How Biology is Helping us Design Better Machines. *Second International Congress on Motion Systems*; 2001 July; University of Jena, Jena, Germany.
- *3. Herr H., Wilkenfeld A., Blaya J. Patient-Adaptive Prosthetic and Orthotic Leg Systems. *Proceedings of the 12th Nordic Baltic Conference on Biomedical Engineering and Medical Physics*; 2002 June; Reykjavik, Iceland; 123-128.
- *4. Popovic M., Hofmann A., Herr H. Angular Momentum Regulation during Human Walking: Biomechanics and Control. *International Conference on Robotics & Automation*; 2004 April; New Orleans, LA; 123-128.
- 5. Herr H., Kornbluh R. New horizons for orthotic and prosthetic technology: artificial muscle for ambulation. *Smart Structures and Materials: Electroactive Polymer Actuators and Devices*; 2004 March; San Diego, CA.

* Outgrowth of supervised thesis

Publications of Hugh Herr

- *6. Hofmann A., Massaquoi S., Popovic M., Herr H. A Sliding Controller for Bipedal Balancing Using Integrated Movement of Non-Contact Limbs. IEEE/RSJ International Conference on Intelligent Robots and Systems; 2004 October; Sendai, Japan; pp. 1952-1959.
7. Popovic M., Englehart A., Herr H. Angular Momentum Primitives for Human Walking: Biomechanics and Control. IEEE/RSJ International Conference on Intelligent Robots and Systems; 2004 October; Sendai, Japan; pp. 1685-1691.
- *8. Popovic M., Hofmann A., Herr H. Zero Spin Angular Momentum Control: Definition and Applicability. IEEE-RAS/RSJ International Conference on Humanoid Robots; 2004 November; Santa Monica, Los Angeles, CA, USA; (In press).

4. Other Major Publications:

Refereed Book Chapters:

1. Herr H., Whiteley G., Childress D. "Cyborg Technology--Biomimetic Orthotic and Prosthetic Technology," *Biologically Inspired Intelligent Robots*, Bar-Cohen, Y. and C. Breazeal, Eds., SPIE Press; Bellingham, Washington; 2003.
2. Krebs H.I., Hogan N., Durfee W., Herr H. Rehabilitation Robotics, Orthotics, and Prosthetics; Chapter 48; In M.E. Selzer, S. Clarke, L.G. Cohen, P.W. Duncan, F.H. Gage (Eds); *Textbook of Neural Repair and Rehabilitation*; Cambridge University Press 2004.

Internal Memoranda:

1. Herr H., Wilkenfeld A. Biologically Inspired Adaptive Control of an External Knee Prosthesis. MIT AI Lab Abstracts. 1998, pp. 93-94.
2. Wilkenfeld A., Herr H. Smooth Gait Control of an External Knee Prosthesis. MIT AI Lab Abstracts. 1999, pp. 187-188.
3. Seyfarth A., Hartmut G., Herr H. Leg Design and Control for Fast Locomotion. MIT AI Lab Abstracts. 2001, pp. 255-256.
4. Palmer M., Riley P., Herr H. Characterization of the Human Foot/Ankle System During Normal Walking Gait. MIT AI Lab Abstracts. 2001, pp. 253-254.

* Outgrowth of supervised thesis

Publications of Hugh Herr

5. Huang G., Herr H. Toward a Three-Dimensional Forward Model of Human Walking. MIT AI Lab Abstracts. 2001, pp. 245-246.
6. Popovic M., Gu W., Herr H. Conservation of Angular Momentum During Human Locomotion. MIT AI Lab Abstracts. 2002, pp. 231-232.
7. Blaya J., Newman D., Herr H. Active Ankle Foot Orthoses (AAFO). MIT AI Lab Abstracts. 2002, pp. 219-220.
8. Dennis R., Herr H. An Actin-Myosin Machine. MIT AI Lab Abstracts. 2002, pp. 221-222.

Progress Reports:

1. Herr H. An Actin-Myosin Machine. Quarterly Darpa Report. Aug., 2001.
2. Herr H. An Actin-Myosin Machine. Quarterly Darpa Report. Nov., 2001.
3. Herr H. An Actin-Myosin Machine. Final Darpa Report. Feb., 2002.
4. Kirchner F., Pratt G., Herr H. Intelligent Hexapod Robot. Quarterly Darpa Report. May, 2002.
5. Herr H. Engineered Muscle Actuators: Cells and Tissues. Feb., 2003.
6. Dennis R., Herr H. Engineered Muscle Actuators: Cells and Tissues. Quarterly Darpa Report. May, 2003.
7. Dennis R., Herr H. Engineered Muscle Actuators: Cells and Tissues. Quarterly Darpa Report. Aug., 2003.
8. Dennis R., Herr H. Engineered Muscle Actuators: Cells and Tissues. Quarterly Darpa Report. Nov., 2003.
9. Dennis R., Herr H. Engineered Muscle Actuators: Cells and Tissues. Final Darpa Report. March, 2004.
10. Herr H. Control of a Liquid Crystal Elastomer. Quarterly Darpa Report. Feb., 2003.
11. Herr H. Control of a Liquid Crystal Elastomer. Quarterly Darpa Report. May, 2003.
12. Herr H. Control of a Liquid Crystal Elastomer. Quarterly Darpa Report. Aug., 2003.

Publications of Hugh Herr

5. Invited Lectures and Seminars:

1. American Academy of Orthotists and Prosthetists, Annual Meeting, Dallas, Texas, 2001.
2. The National Institute of Health, State of Rehabilitation Meeting, Arlington, VI, 2001.
3. Second International Congress on Motion Systems, University of Jena, Germany, 2001.
4. State of Science Meeting in Orthotics and Prosthetics, Chicago, IL, 2002.
5. Second International Conference on Advanced Prosthetics, City, CA, 2002.
6. The IVth World Congress of Biomechanics, Calgary, Alberta, 2002.
7. Physical Medicine and Rehabilitation, National Assembly, Orlando, FL, 2002.
8. American Orthotic and Prosthetic Association. Annual Meeting, Reno, NV, 2003.
9. ZIF International Conference on Walking Machines, Bielefeld, Germany, 2003.
10. Highlands Forum XXII: Life Sciences, Complexity, and National Security, Maryland, 2003.
11. International Conference on Advanced Prosthetics II. Manchester, England, 2003.
12. Smart Structures and Materials: Electroactive Polymer Actuators and Devices, San Diego, CA, 2004.
13. Canadian Association of Prosthetists and Orthotists, Ottawa, Canada, 2004.
14. A personal invitation from Richard Saul Wurman & The Wall Street Journal to the TEDMED Conference, Charleston, SC, 2004.

Theses Supervised by Hugh Herr

Summary:

	<u>Total</u>	<u>Completed</u>	<u>In Progress</u>
<u>S.B.</u>	2	2	0
<u>S.M.</u>	9	5	4
<u>Ph.D</u>			
Supervisor	4	0	4
Reader	1	1	0

S.B. Theses:

1. Sylvan Clarke Magnetic Suspension Assist System for Prosthetic Leg Socket 2000 (Harvard, DEAS)

2. Jianwen Wendy Gu The Regulation of Angular Momentum During Human Walking 2003 (MIT, Physics)

S.M. Theses:

1. Amy Kerdok Energetics and mechanics of human running on surfaces of different stiffnesses 2000 (Harvard, DEAS)

2. Michael Lars Palmer Sagittal Plane Characterization of Normal Human Ankle Function Across a Range of Walking Gait Speeds 2002 (MIT, Mech. Eng.)

3. Sneha Thakkar Energy Economy Gait Analysis of an Auto-Adaptive Prosthetic Knee 2002 (MIT, Physics)

4. Matt Malchano Biologically-Plausible Six-Legged Running: Control and Simulation 2003 (MIT, EECS)

5. Joaquin Blaya Adaptive Control of a Variable-Impedance Ankle-Foot Orthosis to Assist Drop-Foot Gait 2003 (MIT, Mech. Eng.)

6. Goutam Reddy A Low-Cost, Body Orientation Sensor 2004 (MIT, EECS)

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| 7. | Andrew Valiente | Mechanism and Control of a Powered Hip Exoskeleton to Assist Human Walking | 2005 (MIT, Mech. Eng.) |
| 8. | Conor Walsh | Mechanism and Control of a Leg Exoskeleton to Assist Human Walking | 2005 (MIT, Mech. Eng.) |
| 9. | Benjamin Swilling | The Effects of Weight Carrying on Body Angular Momentum in Human Walking | 2005 (MIT, Mech. Eng.) |

Doctoral Theses, Supervisor:

- | | | | |
|----|-----------------|--|------------------------|
| 1. | Daniel Paluska | A Simple Actuation and Control Model of Human Walking and Implications for the Design of Prosthetics, Orthotics and Exoskeletons | 2005 (MIT, Mech. Eng.) |
| 2. | Andreas Hofmann | Control Rules for Biomimetic Human Bipedal Locomotion Based on Biomechanical Principles | 2005 (MIT, EECS) |
| 3. | Waleed Farahat | Identification and Control of Muscle-Actuated Systems | 2005 (MIT, Mech. Eng.) |
| 4. | Samuel Au | A Myoelectric, Variable Impedance, External Prosthetic Foot-Ankle System | 2006 (MIT, Mech. Eng.) |

Doctoral Theses, Reader:

- | | | | |
|----|----------------|--|------------------|
| 1. | Ari Wilkenfeld | Biologically Inspired Auto-adaptive Control of a Knee Prosthesis | 2000 (MIT, EECS) |
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