

Ian W. Hunter

HATSOPOULOS PROFESSOR OF MECHANICAL ENGINEERING

MECHANICAL ENGINEERING
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Professor Ian Hunter is the Hatsopoulos Professor of Mechanical Engineering and runs the BioInstrumentation Lab (<http://bioinstrumentation.mit.edu>) at the Massachusetts Institute of Technology. Ian was born in New Zealand and had an early interest in science, engineering and instrumentation which continues to the present. He started his first company when he was 9, by the age of 10 he had published his first paper (a design of a miniaturized single transistor radio) and by age 14 had built a fully functional gas liquid chromatograph (hydrogen flame ionization type) for chemical analysis. After graduating from the University of Auckland with BSc, MSc and PhD degrees he completed a Post-Doctoral Fellowship in the Department of Biomedical Engineering at McGill University, Canada. He then joined the faculty of McGill University and advanced to tenured Associate Professor in the Department of Biomedical Engineering. In 1994 Ian moved his lab to the Department of Mechanical Engineering at MIT.

His main areas of research are instrumentation, micro-robotics, medical devices and biomimetic materials. Over the years he and his students have developed many instruments and devices including: confocal laser microscopes, scanning tunneling electron microscopes, miniature mass spectrometers, new forms of Raman spectroscopy, needle free drug delivery technologies, nano- and micro-robots, micro-surgical robots, robotic endoscopes, high performance Lorentz force motors, and micro-array technologies for massively parallel chemical and biological assays. Ian is also working on a new approach to the development of instrumentation and devices using systems whose components (actuators, energy storage, sensors, wires etc) are grown out of conducting polymers. As a result of his research, Ian has over 335 refereed publications. He also invents instruments and devices based on this research. This has led to over 130 issued and pending patents. Finally Ian's inventions have been used by numerous companies and in addition he has founded or co-founded over 20 companies.

Ian loves teaching and has been the recipient of several teaching awards at MIT including the Keenan Award for Innovation in Undergraduate Education, the Amar Bose Award for Excellence in Teaching and the Den Hartog Distinguished Educator Award.

IAN W. HUNTER

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DEPARTMENT OF MECHANICAL ENGINEERING
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Education

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| University of Auckland, New Zealand | BSc | 1974 |
| University of Auckland, 1st class honors | MSc | 1975 |
| University of Auckland | DCP | 1976 |
| University of Auckland | PhD | 1980 |

Selected Appointments

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| McGill University, Postdoctoral Fellow | 1980-1981 |
| Canadian Muscular Dystrophy Assoc., Postdoctoral Fellow | 1980-1983 |
| McGill University, Research Fellow | 1984-1985 |
| McGill University, Associate Member | 1985-1994 |
| McGill University, Assistant Professor | 1985-1989 |
| Canadian Inst. Advanced Research, Scholar | 1985-1990 |
| McGill Research Centre for Intelligent Machines, Member | 1986-1994 |
| Inst. for Robotics & Intelligent Systems, Project Director | 1989-1994 |
| McGill University, Associate Professor | 1990-1994 |
| MIT Associate Professor | 1994-1996 |
| MIT Co-director, Information Systems and Technology Laboratory | 1995-present |
| MIT Full Professor | 1996-present |
| MIT Professor of Bioengineering | 1996-2004 |
| MIT Hatsopoulos Professor | 1996-present |

Selected Awards:

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| Canadian Muscular Dystrophy Association Fellowship | 1981 |
| Medical Research Council of Canada Scholarship | 1984 |
| Canadian Institute for Advanced Research Scholarship | 1987 |
| General Motors Fellowship | 1990 |
| Outstanding Young Canadian Biomedical Engineer of the Year Award | 1990 |
| Canadian Institute for Advanced Research Fellowship | 1991 |
| d'Arbeloff Scholar | 1994 |
| General Motors R&D Academic Research Fellow | 1995 |
| Hatsopoulos Professor (personal chair) | 1996 |
| Fellow of the American Institute for Medical and | |

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| Biological Engineering | 1999 |
| Honorary Professor, Bio-Engineering Institute, University of Auckland, New Zealand | 2003 |
| Keenan Award for Innovation in Undergraduate Education | 2004 |
| Amar Bose Award for Excellence in Teaching | 2004 |
| Den Hartog Distinguished Educator Award | 2007 |

Ian Hunter Patents

Selected Patents and Patents Pending from total of over 150 (including foreign filings)

- Hunter, I.W. "Gas jet actuator using Coanda effect," US Patent 5,067,509, November 1991.
- Hunter, I.W. and S. Lafontaine. "Shape memory alloy fibers having rapid twitch response," US Patent 5,092,901, March, 1992.
- Hunter, I.W., Lafontaine, S.R., and Madden, J.D., "Three dimensional microfabrication by localized electrodeposition and etching," US patent 5,641,391, June 24, 1997.
- Martel, S., Lafontaine, S.R. and Hunter, I.W., "Dynamically reconfigurable hardware system for real-time control of processes," US Patent 5,887,165 issued March 23, 1999.
- Galiana, H.L., Hunter, I.W., Jones, L.A. and Tangorra, J., "Apparatus and Method for Measuring Vestibulo-ocular Reflex Function," US Patent 5,942,954, August 24, 1999.
- Hunter, I.W., Brenan, C.J.H. and Lafontaine, S.R., "Active thermal control of surfaces by steering heating beam in response to sensed thermal radiation," US Patent 5,998,768, December 7, 1999.
- Hunter, I.W. and Brenan, C.J.H., "Rapid high resolution image capture system," US Patent 5,999,209, December 7, 1999.
- Korenberg, M.J., Brenan, C. J.H., and Hunter, I.W., "Non-uniform sampling for spectral and related applications," US Patent 6,005,664, December 21, 1999.
- Brenan, C.J.H., Lafontaine, S.R., and Hunter, I.W., "Contractile actuated bellows pump," US Patent 6,059,546, May 9, 2000.
- Hunter, I.W., Lafontaine, S.R. and Madden, J.D., "Conducting polymer driven rotary motor," US Patent 6,084,321, July 4, 2000.
- Brenan, C.J.H., and Hunter, I.W., "Three-dimensional light absorption spectroscopic imaging," US Patent No. 6,088,100, July 11, 2000.
- Galiana, H.L., Hunter, I.W., Jones, L.A., and Tangorra, J.L., "Drowsiness/alertness monitor," US Patent No. 6,091,334, July 18, 2000.
- Hunter, I.W. and Charette, P.G., "Apparatus and method for rapid 3D image parametrization," US Patent No. 6,101,269, August 8, 2000.

Hunter, I.W., Lafontaine, S.R. and Madden, J.D., "Conducting polymer generator-actuator with energy storage/recovery," US Patent No. 6,157,113, December 5, 2000.

Madden, P., Madden, J. and Hunter, I.W., "Method of manufacture of polymer transistors with controllable gap," U.S. Patent No. 6,207,034, March 27, 2001.

Madden, J.D., Kanigan, T.S., Lafontaine, S.R., and Hunter, I.W., "Conducting Polymer Actuator," U.S. Patent 6,249,076, June 19, 2001.

Hunter, I.W., "Apparatus for droplet microchemistry," US Patent No. 6,309,600, October 30, 2001.

Hunter, I.W., "Method and apparatus for performing microassays," US Patent No. 6,387,331, May 14, 2002.

Hunter, I.W., "Method for performing microassays," US Patent No. 6,743,633, June 1, 2004.

Ozbal, C., Hunter, I.W., and Linton, J., "System and method for high throughput sample preparation and analysis using column chromatography," US Patent 6,812,030, November 2, 2004.

Hunter, I.W., Brenan, C.J.H. and Kanigan, T.S., "Methods for screening substances in a microwell array," US Patent 6,893,877, May 17, 2005.

Ozbal, C., Hunter, I.W. and Linton, J., "System for high throughput sample preparation and analysis using column chromatography," US Patent 6,932,939, August 23, 2005.

Angel, A.B., and Hunter, I.W., "Needleless injector," US Patent 6,939,323, September 6, 2005.

Angel, A.B., Hunter, I.W., and Hansen, P., "Transdermal transport device with suction," US Patent No. 7,066,922, June 27, 2006.

Anquetil, P.A., Hunter, I.W., Madden, J.D., Madden, P.G., Pullen, A.E., Swager, T.M., Xu, B., Yu, H.-h., "Molecular actuators, and methods of use thereof," US Patent 7,138,075 B2, November 21, 2006.

Donoghue, J.P., Hatsopoulos, N.G., Martel, S.M., Fofonoff, T.A., Dyer, R.J., Hunter, I.W., "Microstructured arrays for cortex interaction and related methods of manufacture and use," US Patent 7,212,851, issued May 1, 2007.

Anderson, R.R., Hunter, I.W., Brenan, C.J.H., Lim, K.H., Sebern, E., "Apparatus and method for laser treatment with spectroscopic feedback," US Patent 7,217,266 issued May 15, 2007.

Hunter, I.W. and Madden, J.D., "High power-to-mass ratio actuator," US Patent 7,256,529, issued August 14, 2007.

Angel, A.B., Hunter, I.W., "Microneedle transdermal transport device," US Patent 7,364,568 B2, issued April 29, 2008.

Angel, A.B., Hunter, I.W., "Needleless injector," US Patent 7,425,204 B2, issued September 16, 2008.

Angel, A.B., Hunter, I.W., "Microneedle Transport Device," US Patent 7,429,258 B2, issued September 30, 2008

Hunter, I.W. and Madden, J.D., "High power-to-mass ratio actuator," US Patent 7,432,630 B2, issued October 7, 2008.

Garcia-Webb, M., Hunter, I.W., Taberner, A.J., "Microscopic Dynamic Mechanical Analyzer," US Patent 7,485,100 B2, issued February 3, 2009.

Hunter, I.W., "Measuring Properties of an Anatomical Body," US Patent 7,530,975 B2, May 12, 2009.

Brenan, C.J., Hunter, I.W., and Kanigan, T.S., "Methods for Filling a Sample Array by Droplet Dragging," U.S. Patent 7,547,556, June 16, 2009.

Hunter, I.W., David, R., "Liquid Expansion Thermometer and Microcalorimeter," U.S. Patent 7,642,096 B2, January 5, 2010.

Angel, A.B., Hunter, I.W., Proctor, L.L., Tangorra, J., "Impedance Sensor," U.S. Patent No. 7,645,263 B2, issued January 12, 2010.

Angel, A.B., Hunter, I.W., "Microneedle Transport Device," U.S. Patent No. 7,651,475, issued January 26, 2010.

Llinas, R. R., Hunter, I.W., Ruddy, B.P. "Conducting Polymer Nanowire Brain-machine Interface Systems and Methods," U.S. Patent 7,818,065 B2, issued October 19, 2010.

Hunter, I.W., Taberner, A.J., Hemond, B.D., Wendell, D.M., Ball, N.B., Hogan, N.C., "Controlled Needle-Free Transport," U.S. Patent 7,833,189 B2, issued November 16, 2010.

Angel, A.B., and Hunter, I.W., "Needleless Injector," Canada Patent No. 2,464,954, issued December 21, 2010.

Anderson, R.R., Brenan, C.J., Hunter, I.W., Lim, K.H, and Sebern, E.L., "Microsurgical Laser Scalpel Based on Spectroscopic Feedback: The "Smart Scalpel," U.S. Patent 7,967,016, issued July, 2011.

Hunter, I.W. Brenan, C.J., Kanigan, T.S., "Systems for Filling a Sample Array by Droplet Dragging," U.S. Patent 8,029,745 B2, issued October 4, 2011.

Hunter, I.W., "Measuring Properties of an Anatomical Body," U.S. Patent 8,105,270 B2, January 31, 2012.

Hunter, I.W., Hemond, B.D., Wendell, D.M., Hogan, N.C., Taberner, A.J., Ball, N.B., "Needle-Free Injector Device with Autoloading Capability," U.S. Patent 8,172,790 B2, May 8, 2012.

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Hunter, I.W., Taberner, A.J., Hemond, B.D., Wendell, D.M., Hogan, N.C., Ball, N.B., "Controlled Needle-Free Transport," U.S. Patent 8,328,755, issued December 11, 2012.

Hunter, I.W., "Electric Generator," U.S. Patent 8,362,660 B2, issued January 29, 2013.

Hunter, I.W., Taberner, A.J., Hogan, N.C., "Method & Apparatus for Extraction of a Sample from a Sample Source," US Patent 8,398,583, issued March 19, 2013.

Angel, A.B., Hunter, I.W., "Microneedle Transport Device," Canada Patent 2464483, issued April 2, 2013.

Hunter, I.W., Hemond, B.D., Wendell, D.M., Hogan, N.C., Taberner, A.J., and Ball, N.B., "Needle-free Injector Device with Autoloading Capability," Japan Patent 5284962, issued June 7, 2013.

Hunter, I.W., "Electric Motor," U.S Patent 8,519,575, issued August 27, 2013.

Hunter, I.W., "Tunable Pneumatic Suspension," U.S Patent 8,585,062, issued November 19, 2013.

Hunter, I.W., Fofonoff, T., "Electric Coil and Method of Manufacture," U.S. Patent 8,624,699, issued January 7, 2014.

Banik, M.S., Boulais, D.R., Couvillon, Jr., L.A., Chin, A.C., Hunter, I.W., "Articulation Joint," US Patent 8,622,894 B2, issued January 7, 2014.

Publications of Ian W. Hunter
(from total of over 350 refereed publications)

Papers in Refereed Journals:

Hunter, I.W. and Kearney, R.E., "Dynamics of human ankle stiffness: variation with mean ankle torque," *Journal of Biomechanics*, 15, 747-752, 1982.

Kearney, R.E. and Hunter, I.W., "Dynamics of human ankle stiffness: variation with displacement amplitude," *Journal of Biomechanics*, 15, 753-756, 1982.

Hunter, I.W. and Kearney, R.E., "Two-sided linear filter identification," *Medical and Biological Engineering and Computing*, 21, 203-209, 1983.

Weiss, P.L., Hunter, I.W. and Kearney, R.E., "Reduction of physiological signal contamination by a combined experimental and computational approach," *Medical and Biological Engineering and Computing*, 21, 521-524, 1983.

Kearney, R.E. and Hunter, I.W., "System identification of human triceps surface stretch reflex dynamics," *Experimental Brain Research*, 51, 117-127, 1983.

Kearney, R.E., Hunter, I.W., Weiss, P.L. and Spring, K., "A tilt-table/ankle actuator system for the study of vestibulospinal reflexes," *Medical and Biological Engineering and Computing*, 21, 301-305, 1983.

Hunter, I.W. and Kearney, R.E., "Invariance of ankle dynamic stiffness during fatiguing muscle contractions," *Journal of Biomechanics*, 16, 985-991, 1983.

Hunter, I.W. and Kearney, R.E., "Generation of random sequences with jointly specified probability density and autocorrelation functions," *Biological Cybernetics*, 47, 141-146, 1983.

Hunter, I.W. and Kearney, R.E., "NEXUS: a computer language for physiological systems and signal analysis," *Computers in Biology and Medicine*, 14, 385-401, 1984.

Kearney, R.E. and Hunter, I.W., "System identification of human stretch reflex dynamics: tibialis anterior," *Experimental Brain Research*, 56, 40-49, 1984.

Hunter, I.W. and Davison, M.C., "Determination of a behavioral transfer function: white noise analysis of session to session response ratio dynamics on concurrent VI VI schedules," *Journal of the Experimental Analysis of Behavior*, 43, 43-59, 1985.

Selected Publications of Ian W. Hunter

- Weiss, P.L., Kearney, R.E. and Hunter, I.W., "Position dependence of ankle dynamics-I. Passive mechanics," *Journal of Biomechanics*, 19, 727-735, 1986.
- Weiss, P.L., Kearney, R.E. and Hunter, I.W., "Position dependence of ankle dynamics-II. Active mechanics," *Journal of Biomechanics*, 19, 737-751, 1986.
- Weiss, P.L., Kearney, R.E. and Hunter, I.W., "Position dependence of stretch reflex dynamics at the human ankle," *Experimental Brain Research*, 63, 49-59, 1986.
- Hunter, I.W. and Korenberg, M.J., "The identification of nonlinear biological systems: Wiener and Hammerstein cascade models," *Biological Cybernetics*, 55, 135-144, 1986.
- Korenberg, M.J. and Hunter, I.W., "The identification of nonlinear biological systems: LNL cascade models," *Biological Cybernetics*, 55, 125-134, 1986.
- Hunter, I.W., Jones, L.A., and Kearney, R.E., "Estimation of the conduction velocity of muscle action potentials using phase and impulse response function techniques," *Medical and Biological Engineering and Computing*, 25, 121-126, 1987.
- Bates, J.H.T., Hunter, I.W., Sly, P.D., Okubo, S., Filiatrault, S. and Milic-Emili, J., "Effect of valve closure time on the determination of respiratory resistance by flow interruption," *Medical and Biological Engineering and Computing*, 25, 136-140, 1987.
- Kearney, R.E. and Hunter, I.W., "Nonlinear identification of stretch reflex dynamics," *Annals of Biomedical Engineering*, 16, 79-94, 1988.
- Weiss, P.L., Hunter, I.W. and Kearney, R.E. Human ankle joint stiffness over the full range of muscle activation levels. *Journal Biomechanics*, 21, 539-544, 1988.
- Genadry, W., Kearney, R.E. and Hunter, I.W. Dynamic relationship between EMG and torque at the human ankle: variation with contraction level and modulation. *Medical and Biological Engineering and Computing*, 26, 489-496, 1988.
- Bates, J.H.T., Janssens, S., Jiang, T.X., Hunter, I.W., "and Decramer, M., "A subtractive method for decomposing muscle tension into individual twitches," *Computer and Biomedical Research*, 21, 570-578, 1988.
- Rababy, N., Kearney, R.E. and Hunter, I.W., "Method for EMG conduction velocity estimation which accounts for input and output noise," *Medical and Biological Engineering and Computing*, 27, 125-129, 1989.

Selected Publications of Ian W. Hunter

- Korenberg, M.J. and Hunter, I.W., "The identification of nonlinear biological systems: Wiener kernel approaches," *Annals of Biomedical Engineering*, 18, 629-654, 1990.
- Jones, L.A. and Hunter, I.W., "Influence of the mechanical properties of a manipulandum on human operator dynamics: 1. elastic stiffness," *Biological Cybernetics*, 62, 299-307, 1990.
- Hunter, I.W., Lafontaine, S., Nielsen, P.M.F., Hunter, P.J. and Hollerbach, J.M., "Manipulation and dynamic mechanical testing of microscopic objects using a tele-micro-robot system," *IEEE Control Systems Magazine*, 10, 3-9, 1990.
- Kearney, R.E. and Hunter, I.W., "System identification of human joint dynamics," *CRC Critical Reviews of Biomedical Engineering*, 18, 55-87, 1990.
- Xu, Y., Hunter, I.W., Hollerbach, J.M. and Bennett, D.J., "An airjet actuator system for identification of the human arm joint mechanical properties," *IEEE Transactions on Biomedical Engineering*, 38, 1111-1122, 1991.
- Bennett, D.J., Hollerbach, J.M., Xu, Y. and Hunter, I.W., "Time-varying stiffness of human elbow joint during cyclic voluntary movement," *Experimental Brain Research*, 88, 433-442, 1992.
- Jones, L.A. and Hunter, I.W., "Changes in pinch force with bidirectional load forces," *Journal of Motor Behavior*, 24, 157-164, 1992.
- Hunter, P.J., Nielsen, P.M.F., Smaill, B.H., LeGrice, I.J. and Hunter, I.W., "An anatomical heart model with applications to myocardial activation and ventricular mechanics," *Critical Reviews in Biomedical Engineering*, 20(5,6), 403-426, 1992.
- Charette, P.G., Hunter, I.W. and Brenan, C.J.H., "A complete high performance heterodyne interferometer displacement transducer for micro-actuator control," *Review of Scientific Instruments*, 63, 241-248, 1992.
- Brenan, C.J.H., Charette, P.G. and Hunter, I.W., "An environmental isolation platform for microrobot system development," *Review of Scientific Instruments*, 63, 3492-3498, 1992.
- MacNeil, J.B., Kearney, R.E. and Hunter, I.W., "Identification of time-varying biological systems from ensemble data," *IEEE Transactions on Biomedical Engineering*, 39, 1213-1225, 1992.

Selected Publications of Ian W. Hunter

- Doukoglou, T.D., Hunter, I.W. and Kearney, R.E., "Non-parametric two-dimensional point spread function estimation for biomedical imaging," *Medical & Biological Engineering & Computing*, 31, 277-283, 1993.
- Brenan, C.J.H., Doukoglou, T.D., Hunter, I.W. and Lafontaine, S., "Characterization and use of a novel optical position sensor for microposition control of a linear motor," *Review of Scientific Instruments*, 64, 349-356, 1993.
- Jones, L.A. and Hunter, I.W., "Influence of the mechanical properties of a manipulandum on human operator dynamics: 2. Viscosity," *Biological Cybernetics*, 69, 295-303, 1993.
- Hunter, I.W., Doukoglou, T.D., Lafontaine, S., Charette, P.G., Jones, L.A., Sagar, M., Mallinson, G.D. and Hunter, P.J., "A teleoperated microsurgical robot and associated virtual environment for eye surgery," *Presence*, 2, 265-280, 1993.
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- Hunter, I. W., Jones, L.A., Sagar, M., Lafontaine, S.R. and Hunter, P.J., "Ophthalmic microsurgical robot and associated virtual environment," *Computers in Biology and Medicine*, 25, 173-182, 1995.
- Brenan, C.J.H. and Hunter, I.W., "Confocal image properties of a confocal scanning laser visible light FT-Raman microscope," *Applied Spectroscopy*, 49, 971-976, 1995.
- Stein, R.B., Hunter, I.W., Lafontaine, S.R. and Jones, L.A., "Analysis of short latency reflexes in human elbow flexor muscles," *Journal of Neurophysiology*, 73, 1900-1911, 1995.
- Doukoglou, T.D. and Hunter, I.W., "A spherical-coordinate scanning confocal laser microscope," *Optical Engineering*, 34, 2103-2108, 1995.
- Brenan, C.J.H. and Hunter, I.W., "Design and characterization of a visible light FT-Raman spectrometer," *Applied Spectroscopy*, 49, 1087-1093, 1995.
- Brenan, C.J.H. and Hunter, I.W., "Volumetric raman microscopy through a turbid medium," *Journal of Raman Spectroscopy*, 27, 561-570, 1996.

Selected Publications of Ian W. Hunter

- Madden, J.D. and Hunter, I.W., "3D micro-fabrication by localized electrochemical deposition," *Journal of Microelectromechanical Systems*, 5, 24-32, 1996.
- Korenberg, M.J. and Hunter, I.W., "The identification of nonlinear biological systems: Volterra kernel approaches," *Annals of Biomedical Engineering*, 24, 250-268, 1996.
- Charette, P.G. and Hunter, I.W., "Robust phase unwrapping method for phase images with high noise content," *Applied Optics*, 35, 3506-3513, 1996.
- Charette, P.G., Hunter, I.W. and Hunter, P.J., "Large deformation mechanical testing of biological membranes using speckle interferometry intranmission, part I: Experimental apparatus" *Applied Optics*, 36, 2238-2245, 1997.
- Charette, P.G., Hunter, P.J. and Hunter, I.W. "Large deformation mechanical testing of biological membranes using speckle interferometry in transmission, part II: Finite element modeling," *Applied Optics*, 36, 2246-2251, 1997.
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- Madden, J.D., Cush, R.A., Kanigan, T.S. and Hunter, I.W., "Fast contracting polypyrrole actuators," *Synthetic Metals*, 113, 185-192, 2000.
- Korenberg, M.J., David, R., Hunter, I.W. and Solomon, J.E., "Parallel Cascade Identification and Its Application to Protein Family Prediction," *Journal of Biotechnology*, 91, 35-47, 2001.
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- Tangorra, J.L., Jones, L.A., Hunter, I.W., "System Identification of the Vestibulo-ocular Reflex during Head-free Tracking," *Journal of Vestibular Research*, 14, 419-441, 2004.

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