

## **CURRICULUM VITAE**

Pierre D. Mourad, PhD

Principal Physicist

Applied Physics Laboratory

Associate Professor

Department of Neurological Surgery

Adjunct Associate Professor

Departments of Bioengineering and Pediatric Dentistry

University of Washington

Co-Founder

EchoGuide Medical, Inc; Parasonica, Inc; PhysioSonics, Inc; PredictDent, Inc; Ultreo, Inc.

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### **• RESEARCH AREAS AND SKILLS**

*active area:* biomedical physics, especially acoustics and, emergently, diagnostic electromagnetic radiation, focused primarily on applications to the diagnosis and treatment of diseases and disorders of the central and peripheral nervous systems.

*skills:* experimental (*in vitro*, *ex vivo*, *in vivo*, and human based studies) supporting medical applications of physics (primarily ultrasound); biological effects due to therapeutic ultrasound; translational research as a field of study and its concrete practice.

### **• EDUCATION**

*Ph.D. Applied Mathematics, University of Washington, June 1987, with emphasis on fluid dynamics and the atmospheric boundary layer; analytical and numerical methods.*

*M.S. Applied Mathematics, University of Washington, June 1982, with emphasis on analytical and numerical methods; fluid dynamics; quantum mechanics.*

*B.A. Mathematics major, physics, music and philosophy minors, (cum laude,  $\phi\beta\kappa$ ) Rutgers University, May 1980.*

• **ACADEMIC EMPLOYMENT HISTORY**

Research Affiliate, Center on Human Development and Disability (from Summer 2009)  
Associate Professor (Adjunct), Department of Bioengineering (from Winter 2009)  
Associate Professor (Adjunct), Department of Pediatric Dentistry (from August 2008)  
Associate Professor, Department of Neurological Surgery (from August 2008)  
Research Associate Professor (Adjunct), Department of Pediatric Dentistry (from April 2007)  
Principal Physicist (rank equivalent to Full Professor), Applied Physics Laboratory  
(from November 2004)  
Member, Seattle Cancer Consortium, neuro-oncology affinity group (from August 2004)  
Research Associate Professor, Department of Neurological Surgery (from January 2004)  
Member, University of Washington Engineered Biomaterials [UWEB] (from May 2000)  
Senior Scientist (rank equivalent to Associate Professor), Applied Physics Laboratory  
(January 1995 – October 2004)  
Scientist (rank equivalent to Assistant Professor), Applied Physics Laboratory (March 1988 --  
December 1994)  
Post-Doctoral Research Associate for Dr. Robert A. Brown, Atmospheric Sciences Department,  
University of Washington (June through December, 1987). Wave-wave interactions in  
mixing and surface layers. Large eddy/inversion dynamics.  
Research Assistant for Dr. Robert A. Brown, Atmospheric Sciences Department, University of  
Washington (Summer, 1982 to Spring, 1987). Applied Mathematics dissertation, with C.  
Bretherton, W. Criminale, J. Kevorkian and J. Riley: wave-wave interactions in unstable  
shear flows; novel mathematical methods using Chebyshev spectral expansions.  
Research Assistant for Dr. Terry Matilsky, Physics Department, Rutgers University. (Spring and  
Summer, 1980). Produced evidence for structure in the Oort cloud, the birthplace of comets.

• **ENTREPRENEURIAL EMPLOYMENT HISTORY**

*Co-Founder:* EchoGuide Medical Inc, which uses ultrasound mounted within a disposable wire  
to guide catheter placement. Useful for treatment of various brain disorders, with other  
applications (central line placement) under consideration. Built and tested first prototypes *in  
vitro* and *in vivo*, submitted two provisional patents, hired the CEO, constructed business  
plan, STTR under construction, discussions underway with Medtronics for investment. From  
March 2012.

*Co-Founder:* of Parasonica, which uses ultrasound to disable or kill parasites with ultrasound  
(think bed bugs, lice, termites and also think of agricultural sterilization. Collected  
preliminary data, now developing business plan. From Summer 2011.

*Board of Advisors:* to *Dental Resource Systems*. This company uses a variety of therapeutic  
modalities, including ultrasound to treat migraine, dental pain, among other head-centric  
pain etiologies. From Fall 2011.

*Consultant:* to Intellectual Ventures, on the use of ultrasound within a novel device for third  
world food-processing applications. Fall 2010.

*Member, Advisory Committee,* for The University Funds (<http://theuniversityfunds.com>), a start-  
up venture capital firm specializing in movement of very early stage technology from within  
target universities through a proprietary incubation process into middle-stage acquisition.  
From Fall 2009 to Summer 2010.

*Consultant:* to Aardvark, Inc, for a novel medical diagnostic device. Advising on fundamental  
physics of their novel model device; speaking on their behalf to venture capitalists.  
From Winter of 2008 to Fall 2010.

*Co-Founder and Consulting Scientist:* of PredictDent, a company dedicated to developing a device that can predict the likelihood that children will get cavities, based on technology co-invented by Pierre D. Mourad and Joel Berg (DDS, Chair of Pediatric Dentistry, UW). Preliminary feasibility research completed; patent submitted.

From Summer 2008 to Summer 2010.

*Co-Founder and consulting scientist:* of Ultreo Inc, a company based on a new toothbrush that combines sonic and ultrasound-based processes, based on technology invented and co-developed by Pierre D. Mourad. Company got a product to market that was well received clinically and commercially. Sadly, went bankrupt after raising \$27M and grossing \$10M, due to bad general economic climate and poor marketing decisions. A new company – Intellident Inc out of Florida has purchased the technology and intends to bring it back to market with a new design that I will create. From Winter 2003 to Winter 2009.

*Co-Founder and consulting scientist:* of PhysioSonics Inc (formerly Allez PhysiOnix Ltd.) a company specializing in novel diagnostic ultrasound-based technology applied to monitoring cerebral vasospasm, emboli, noninvasive monitoring of intracranial pressure as well as the differential diagnosis of pain, based on technology (co-) invented and developed by Pierre D. Mourad. We have raised approximately \$20M through a combination of research grants (\$4M) and investments (angel; Medtronic; Johnson and Johnson). We have submitted our automated transcranial Doppler (aTCD) device to the FDA for 510K approval Spring 2012. Next we will pursue PMA trials in support of an algorithm for predicting intracranial perfusion pressure that the aTCD device would incorporate. From Fall 2000.

*Consultant:* for Spencer Technologies, on their scientific efforts to optimize ultrasound-assisted thrombolysis. From Summer 2003 through Summer 2006.

*Consultant:* for Dominion Engineering, Incorporated, on the use of ultrasound to clean the heat exchange systems of nuclear reactors. Summer 2000.

*Consultant:* for Optiva Corporation, on the acoustics and fluid mechanics of extant and planned electric toothbrushes at Optiva, Fall 1997 to Spring 2001.

*Consultant and expert witness:* for Optiva Corporation, on the acoustics and fluid mechanics of extant electric toothbrushes relative to Optiva's patent on electric toothbrushes, from Fall 1995 to Fall 1997.

*Consultant:* for children's science books (by Becker & Meyer, a publishing company), from Spring 1995 to Fall 1996.

#### • **ACTIVE AREAS OF RESEARCH AND DEVELOPMENT – general description**

*Medical applications of physics* (general studies of medical applications of physics, primarily ultrasound and recently, near-IR and terahertz radiation, including: experiment and modeling of general medical ultrasound; ultrasound imaging of tissue stiffness and of blood flow distributions, and of (painful) sensation distributions, to improve the diagnosis and hence treatment of conditions of the central and peripheral nervous system; modulation of brain function with ultrasound; ultrasound for dental therapy; near-infrared imaging system for dental diagnostics; terahertz imaging systems for assaying the status of skin burns, from Spring 1995)

#### • **PREVIOUS AREAS OF RESEARCH AND DEVELOPMENT – general description**

*planetary boundary layer dynamics and turbulence structure* (using concepts from the general field of fluid dynamics and techniques such as computational fluid dynamics, mathematical modeling, and analysis of remotely sensed data, from 1993 - 2000)

*sonoluminescence* (experiment and theory for single and multi-bubble systems, with applications to sonochemistry, 1993--1996)

*bio-physical systems* (mathematical modeling of the photoresponse of phytoplankton subjected to variable irradiance levels itself arising from environmental forcing, 1993--1995)

*physical oceanography* (mathematical modeling of the properties of Langmuir Circulations when wind and waves are not aligned, 1993--1995)

*acoustic holography* (wavefront reconstruction and imaging theories, 1991--1993)

*acoustic scattering theory and experiment* (basic and applied research on the acoustic properties of arctic sea ice and oceanic sediments, 1988--1993)

#### • ON-GOING RESEARCH

**Mourad PD** as PI, with Marzban C (APL), Chesnut R (Neurosurgery), Vladimir Schwartz (St. Petersburg, Russia) and PhysioSonics, Inc. Use of ultrasound to non-invasively measure intracranial pressure and cerebral perfusion pressure; automation of transcranial Doppler. *Hypothesis #1:* transcranial Doppler imaging and arterial blood pressure data can combine into predictive algorithms for critical neurological medical variables that currently require a neurosurgical procedure to implement. *Hypothesis #2:* palpation or vibration of brain with ultrasound correlates with intracranial pressure. *Hypothesis #3: automatic TCD (aTCD) can improve monitoring of vasospasm.* *Status:* Pre-clinical studies recently completed at Harborview Medical Center in Seattle, University of Pennsylvania, Columbia University, The Barrow Neurological Institute, and Wilford Hall Air Force Hospital; complementary in vitro and animal studies on-going at the University of Washington with funding in hand or anticipated; various papers and patents completed as well as under construction. Human studies of the aTCD starting Summer 2012. Technologies licensed to PhysioSonics, Inc.

**Mourad PD** as PI, with Friedly J, Gellhorn A (Rehab Medicine), Jarvik GA (Radiology), Loeser J (Neurosurgery), Chudler E, Gofeld M, Richebee P, Terman G (Anesthesiology). Use of ultrasound to differentially diagnose sources of pain. *Hypothesis:* use intense focused ultrasound under image guidance to map the distribution of sensations in a patient in pain to localize painful tissue pathology, to assay the extent of central sensitization as well as associated peripheral nerves to facilitate induction of regional anesthesia. *Status:* prototype built and calibrated; animal studies on-going and associated papers and patents in print or under review; human sensory trials finished and associated paper in print; new grants submitted or recently funded; human trials localizing amputee pain under way; in pursuit of forming a new company (TAP, Inc – for ‘transcutaneous acoustic palpation’) based on this technology. Technology currently licensed to PhysioSonics, Inc.

Winebrenner DP (APL) as PI, with Chen A (APL) and **Mourad PD**. Application of terahertz radiation for grading & diagnosis of burns. *Hypothesis:* create images of burns with terahertz radiation to determine the extent of desiccated versus well-vascularized tissue in skin burns. *Status:* Feasibility studies using a rat model of burns completed, papers and a provisional patent under construction, submitted or accepted. New proposals under construction. As Dr. Hassan (recent PhD in EE and Nanotechnology here at UW) leads this effort with greater independence I'll back away from my already supporting role in project.

**Mourad PD** as PI, Murphy S, Moore A and Morrison R (Neurological Surgery), Beauchamp N (Chair of Radiology), Kucewicz J (APL), Stone J and Salzar R (UVA). Imaging endogenous and exogenous brain-tissue displacement patterns for the case of traumatic brain injury. *Hypothesis:* hemorrhage, edema, diffuse axonal injury each have different ranges of shear and bulk modulus compared to normal brain tissue, quantities that our analysis of ultrasound backscatter from that tissue can translate into images of damaged tissue. Such differences can form the basis of brain imaging with a field-deployable ultrasound device. *Status:* early-stage animal based research; have acquired sufficient human data to write up.

**Mourad PD** as PI, with Silbergeld DL, Horner P and Levitt M (Neurosurgery), King BR (Psychiatry at UW and Children's Hospital), Banks WA (Veterans Administration), Pun S (Bioengineering). Opening the blood-brain barrier (BBB) with ultrasound for therapeutic purposes. *Status:* writing up final paper for this project that shows the ability of ultrasound to enhance the flux of blood-bourn *drugs* in addition to dyes into the brain. Exploring use of

catheters to create targeted BBB disruption. Submitted proposal in the context of a larger, program project to NIH to use of US-based BBB disruption for treating autism, where we will try to enhance the transient therapeutic effects of enhanced flux of autism-specific drugs (e.g., oxytocin) with cognitive behavioral therapy during the window of maximum drug efficacy. Animal-care protocol under review to use this approach to activate neuronal stem cells in the subventricular zone, in order to increase the likelihood of these cells to move into the brain for therapeutic effect.

**Mourad PD** as PI and Browd SR (Neurosurgery). Ultrasound-guided disposable catheter for external ventricular drainage. First prototype constructed and tested *in vitro* and *in vivo*; pathway to miniaturization, design improvement and testing from animals through humans in place. Provisional patents submitted. Two bioengineering students assigned to this project. Coulter grant funded, provisional patent submitted, company [EchoGuide Medical Inc founded created], business plan construction on-going, as are discussions with Medtronic.

**Mourad PD** as PI and Ellenbogen RG (Chair of Neurosurgery) Ultrasound-mediated cleaner for catheter and catheter-like implants. First prototype constructed, preliminary data collection started, funding sought.

Tyler WJ (Virginia Tech University) and **Mourad PD**. Neuromodulation of brain function targeted by automatic transcranial Doppler. Animal-based research under way that seeks to optimize means of targeting low-frequency ultrasound to small volumes of brain tissue. Intellectual Property co-generated by Drs. Tyler and Mourad that we will move to NeuroTrek (Dr. Tyler's company) for incorporation of their neuromodulator ultrasound protocols into hardware provided by PhysioSonics (Dr. Mourad's company) and scientific guidance from Drs. Tyler and Mourad.

**Mourad PD** and Shaw S (UW Business School). Networked creativity in the context of medical devices. (#1) Relating extant research on the conflicting roles of networks and isolated leadership to the demise of Ultreo, Inc. (#2) Developing case studies testing the hypothesis that interdisciplinary innovation is lead by knowledgeable outliers working at the interface of each discipline, rather than representative practitioners within each discipline. Paper under construction.

**Mourad PD**. Accelerating desalination via ultrasound-activated reverse osmosis membranes. With Jaffer Ali, graduate student in Civil Engineering at UW. Preliminary data collected supporting the central hypothesis of this work. Record of Invention disclosed to UW Technology Transfer. Seeking funding and collaborators in Saudi Arabia.

#### • CURRENT ACADEMIC DUTIES

*Teacher:* for the Department of Bioengineering. See 'Teaching experience' below.

*Faculty Senator:* for the Department of Neurological Surgery (2003-2004; 2010-2013).

*Faculty Advisor:* Ryan Morton, MD and Mike Levitt, MD, residents within Neurosurgery and for Revathi Murthy, a Master's student in Bioengineering.

*Faculty Advisor:* for the Science and Engineering Business Association (uwseba.com), an on-campus group whose intent is to foster entrepreneurial activity among undergraduate and graduate students in science.

*Reviewing:* neurosurgery resident applicants.

*Referee* for any of these at any given time: *Journal of Neurosurgery, Medical Physics, Neurosurgery, Journal of the Acoustical Society of America, Ultrasonics, Ultrasound in Medicine and Biology, various IEEE journals, UW Research Faculty Fellowships Committee, NASA, NIH and NSF.*

*Mentor and guest lecturer:* see "Teaching Duties" below.

*Research:* summarized below.

• **PAST ACADEMIC DUTIES**

*Member:* Institute for Translational Medical Science. Along with many others, I contributed in a minor way to the proposal that led to NIH funding for this institute as well as helped to create 'targeted symposia' whose goal is to foster collaboration internal and external to the School of Medicine.

*Member of:* Technical Committee for biological effects of ultrasound in the Acoustical Society of America (ASA), known as "Bioresponse to Sound and Vibration", from Fall 1999.

*Serving on:* φβκ Review Committee at the University of Washington, from 1996 to 2002; Mary Gates Foundation Evaluation Committee, from Fall 2002 - 2006.

*Conceived, organized and chaired:* special sessions on Therapeutic Ultrasound at the ASA conference in Vancouver, British Columbia, Canada (December 2005)

*Conceived, organized and chaired:* special sessions on Therapeutic Ultrasound at the Second Annual Symposium on Therapeutic Ultrasound, Applied Physics Laboratory, Seattle, WA (29 July - 1 August 2002).

*Member of:* Scientific Committee for the Second Annual Symposium on Therapeutic Ultrasound, Applied Physics Laboratory, Seattle, WA (29 July - 1 August 2002), from November 2001.

*Conceived, organized and chaired:* special sessions on Therapeutic Ultrasound at the ASA conference in Fort Lauderdale, FL (December 2001)

*Member:* Applied Physics Laboratory Security Committee, Fall 2001.

*Conceived, organized and chaired:* special sessions on Therapeutic Ultrasound at the ICA conference in Rome, Italy (September 2001)

*Member of:* Strategic Council, Applied Physics Laboratory, University of Washington, January – June 2000.

*Conceived, organized and chaired:* special sessions on Therapeutic Ultrasound at the ASA/ICA conference in Seattle, WA (June 1999)

*Founder of:* APL's AIRS (Air/Sea Interaction and Remote Sensing group), a consortium of scientists within APL whose interests are in examining the properties of the marine atmospheric boundary layer using remote sensing and/or understanding the intrinsic physical properties of that layer that affect remote sensing, from April 1997. Chairman until January 1998.

*Served on:* LAKE-ICE Steering Committee, whose purpose is to design an experimental and modeling effort aimed at the study of cold air outbreaks and their precipitation patterns over the Great Lakes, from 15 September 1995.

*Served on:* American Meteorological Society Committee on Boundary Layers and Turbulence (31 January 1995 -- 31 January 1998).

*ONR Marine Boundary Layer Accelerated Research Initiative* workshop, August 1995, Irvine, California. (presentation)

*Attendee, Symposium on Meteorology and Oceanography* for Ship Self-defense and Strike Warfare, sponsored by the Office of Naval Research and the National Academy of Sciences. 12--14 September 1995, at Fallon, Nevada.

*Applied Physics Laboratory Seminar Series:* I organized, maintained, and hosted this weekly seminar series from Fall 1992 through Spring 1994.

*Attendee, Gordon Research Conference* on Predictive Theories in Biological Oceanography and their Evaluation, August 1993, at Colby-Sawyer College, New Hampshire.

*ONR Marine Boundary Layer Accelerated Research Initiative* planning meeting, October 1991, Monterey, California. (presentation)

*ONR Ice Mechanics Accelerated Research Initiative* planning meeting, November 1990, Airley, Virginia. (presentation)

*Section leader:* for the Eighth Symposium on Turbulence and Diffusion, 26—29 April 1988, San Diego, CA. Graduate Student Representative and Graduate Student Senator for the Applied Mathematics Department.

### • TEACHING EXPERIENCE

*Teacher:* for the Department of Bioengineering, for a one-quarter class on 'diagnostic and therapeutic ultrasound with an emphasis on the brain' targeting seniors and early graduate students, with an emphasis on the central and peripheral nervous systems. Annual class, from Winter 2011.

*Teacher:* For the Department of Bioengineering, for a two-quarter sequence entitled "Program for Commercializing Technology" with Buddy Ratner of Bioengineering during the first quarter. Annual class, from Fall 2011-Winter 2012.

*Guest Lecturer:* for the University of Washington's Department of Bioengineering, 2006-2011 (Shahram Vaezy's Ultrasound Class; Albert Folch's Neural Engineering Class [student comments include "Mourad was very good, animated, entertaining and interesting," "Mourad and Chizeck were most interesting," "I really enjoyed Dr Mourad's presentation on pain...").

*Guest Lecturer:* for the University of Washington's School of Business, 2008-2012 (Sonali Shaw's entrepreneurship class).

*Session Leader:* for the University of Washington Undergraduate Research Symposium, May 2004, 2005, 2008, 2009.

*Advisor:* for undergraduate students, many of whom housed with the Department of Bioengineering, with support from various on-campus agencies as noted, whose broad subject is the use of ultrasound for therapeutic purposes, from Fall 1996. (I have about 2-4 undergraduates in my laboratory at any given time, some trying out for a few quarters, many staying for two to three years. Here I've listed the ones that have stayed, along with their fellowships.) Brett Anderson [Mary Gates Foundation; NASA Summer Undergraduate Research Program]; Dan Blizzard [NASA Summer Undergraduate Research Program; Research Fellowship for Advanced Undergraduates]; Chelsea Brossard; Yayun Chen; Nathan Chin [Early Identification Program (EIP)]; Stephanie Chu [APL and Boeing Fellow]; Stephanie Chung [STAR and BRIDGES]; Nathan Coulson; Elizabeth Dahl [NASA Summer Undergraduate Research Program; Mary Gates Foundation]; Trevor Dickey [Rex. J. and Ruth C. Robinson scholarship fund in chemistry, Mary Gates Foundation]; Josephine B. A. Garcia [NASA Summer Undergraduate Research Program]; Lisa Ngyuen [NASA Summer Undergraduate Research Program; Mary Gates Foundation; EIP]; Billy Little [University of Washington Engineered Biomaterials]; Dan Harmon-Gross; Abbi McClintic [NASA Summer Undergraduate Research Program; Applied Physics Laboratory Fellow]; Edin Mehic [Mary Gates Foundation]; Josh Nickerson [STAR and BRIDGES]; Ryan Ollos [NASA Summer Undergraduate Research Program; Mary Gates Foundation; Applied Physics Laboratory Fellow]; Kim Pederson [Mary Gates Foundation]; Steven Quay [UW Neurosurgery Summer Fellowship]; Rachael Sparks [Applied Physics Laboratory Fellow; Mary Gates Foundation; NASA Summer Undergraduate Research Program]; Rowen Tyche [NASA Summer Undergraduate Research Program]; Khasha Toulouei [BRIDGES]; Sara Vaezy [STAR and BRIDGES]; Pavan Vaswani [NASA Summer Undergraduate Research Program; Astronaut Scholarship, from the Washington NASA Space Grant; (Engineering) Dean's Research Award; Research Fellowship for Advanced Undergraduates; The Barry M. Goldwater Scholarship; the UW President's award for best Freshman, Sophomore, Junior and Senior at the University of Washington]; Zinnia Xu [Mary Gates Foundation]; Lorne Walker [NASA Summer Undergraduate Research Program]; George Wang [NASA Summer Undergraduate Research Program]; Alice Ward [Mary Gates Foundation; NASA Summer Undergraduate Research Program]; Kang Ya [APL Hardisty Fellowship]; Anning Yao [Washington Research Foundation Fellow].

*Co-advisor:* for primarily Bioengineering graduate students (Abrab, Cooksey, Curra, Foley, Kwok, Little, Murthy, Noble, Poliachik, Porter), on various topics, often but not always involving diagnostic and/or therapeutic ultrasound, from Fall 1996.

*Co-advisor:* for Neurological Surgery residents (Lazar; Levitt; Mesiwala; Morton; Nemecek) whose broad subject is the use of ultrasound for therapeutic purposes, from Fall 1996.

*Co-advisor:* for a post-doctoral student [Pete Winstead] on the use of Synthetic Aperture Radar (SAR) for imaging atmospheric boundary layer processes, from Fall 1999 to Spring 2000.

*Teaching Assistant:* for introductory calculus, for academic years 1980--1981.

#### • HONORS

*Ernst & Young, Inc:* a nominee for the Ernst & Young Entrepreneur of the Year Pacific Northwest Program, 2008.

*APL Science and Engineering Award*, 2007 "for achievement across a range of medically oriented disciplines of a translational research nature."

*APL Achievement Award*, "for achievement in the development and disclosure of innovative technology," for each of 1997-2004, for being part of the development of various invention disclosures. (see below under Invention Disclosures).

*1998 Editors' Citation for Excellence in Refereeing for JGR-Oceans.* "The purpose of this citation is to express publicly the gratitude of AGU [American Geophysical Union] to those whose reviews have been particularly commendable."

*APL Achievement Award*, "for achievement in the development and disclosure of innovative technology," 28 January 1998, for being part of the development of a version of acoustic surgery (see below under Invention Disclosures).

*APL Achievement Award*, "for achievement in the development and disclosure of innovative technology," 28 October 1993, for co-developing the RITM (see below under Invention Disclosures).

*Directors Award for Distinguished Service*, in recognition for work on the APL Seminar Series, November 1994.

#### • ARTICLES IN PREPARATION

Xu JS, Yao A, Illian PR, **Mourad PD**. Traumatic brain injury can change the stiffness of brain tissue, *in vivo*. For submission to *European Radiology*.

Illian PR, Kliot M, Marzaban C, Morison D, Moore A, Ollos RJ, **Mourad PD**. Toward the prediction of intracranial and cerebral perfusion pressures using Transcranial Doppler and arterial blood pressure measurements. For submission to *Neurosurgery*.

Kucewicz J, Beauchamp N, Illian PR, Moore R, Moore A, **Mourad PD**. Imaging human traumatic brain injury based upon ultrasound detection of endogenous palpation of brain tissue. For submission to *Ultrasound in Medicine and Biology*.

Dickey TC, Ollos RJ, Blizzard D, Gross DH, Kliot M, **Mourad PD**. Predicting intracranial pressure using palpation of brain via focused ultrasound: Initial feasibility study. For submission to *IEEE*.

Sparks RL, Dahl E, Nguyen L, Anderson G, Silbergeld DL, **Mourad PD**. Towards the use of intra-operative HIFU to facilitate enhanced drug delivery into the brain. For submission to *Ultrasound in Medicine and Biology*.



• **ARTICLES SUBMITTED**

- Arbab MH, Winebrenner DP, Dickey TC, Chen A, Klein MB, Mourad PD. Terahertz Spectroscopy for assessment of burn injuries *in vivo*. Submitted to *Proceedings of the National Academy of Sciences*.
- McClintic AM, Dickey TC, Gofeld M, Illian PR, Kliot M, Kucewicz JC, Loeser JD, **Mourad PD**. Ultrasound Applied to Inflamed Tissue Produces Effects Consistent with Its Induction of Temporal Summation. Submitted to *Journal of the Acoustical Society of America*.
- Tych RE, McClintic AM, Garcia JB, Gofeld M, Kliot M, Loeser JD, Pederson KD, Sparks RL, Terman GW, Mourad PD. Intense focused ultrasound stimulation can distinguish between inflamed and normal tissue. Under revision at *Ultrasonics*.
- Noble ML, **Mourad PD**, Ratner BD. On-off ultrasound-mediated controlled release of antibiotics from coated matrices with negligible background leaching. Under revision for *J. Controlled Release*.

• **ARTICLES THAT ARE PUBLISHED**

- Tych RE, Gofeld M, Jarvik JG, Kliot M, Loeser JD, McClintic AM, Ollos RJ, Pederson KD, Sparks RE, Terman GW, **Mourad PD**. Neuropathic tissue responds preferentially to stimulation by intense focused ultrasound. In press at *Ultrasound in Medicine and Biology*.
- McClintic AM, Dickey TC, Gofeld M, Kliot M, Loeser JD, Richebe P, **Mourad PD**. Intense focused ultrasound preferentially stimulates subcutaneous and focal neuropathic tissue: preliminary studies. In press at *Pain Medicine*.
- Xu JS, Chu S, Lee RJ, Paun M, Yao A, Murphy S, **Mourad PD**. Evidence of diaschisis after ischemic stroke through ultrasound-based elastography. In press at *J. Ultrasound in Medicine*.
- Marzban C, Illian PR, Kliot M, Morison D, Moore A, Czosnyka M, **Mourad PD**. A method for estimating zero-flow pressure and intracranial pressure. *Journal of Neurosurgical Anesthesiology*. 19 July 2012 e-pub ahead of print.
- Garcia JB, Gofeld M, Illian PR, Loeser JD, McClintic AM, Ward A, Yao A, **Mourad PD**. Intense focused ultrasound as a useful research tool for the quantification of diurnal inflammatory pain. *Ultrasonics*. 18 April 2012 e-pub ahead of print.
- Dickey TC, Tych RE, Kliot M, Loeser JD, Pederson K, **Mourad PD**. (2012) Intense focused ultrasound can reliably induce sensations in human test subjects in a manner correlated with the density of their mechanoreceptors. *Ultrasound in Medicine and Biology*. 38(1):85-90.
- Arbab MH, Dickey TC, Winebrenner DP, Chen A, Klein MB, **Mourad PD**. (2011) Terahertz reflectometry of burn wounds in rat skin. *Biomedical Optics Express*. V2(8):2339-2347.
- Arbab MH, Dickey TC, Winebrenner DP, Chen A, **Mourad PD**. (2011) Characterization of burn injuries using terahertz time-domain spectroscopy. *Proc. SPIE* 7890, 78900Q, DOI:10.1117/12.876229.
- Roberts F, Hacker BM, Oswald T, **Mourad PD**, McInnes JC. (2010) Evaluation of the use of ultrasound within a power toothbrush to dislodge oral bacteria using an *in vitro* *Streptococcus mutans* biofilm model. *The American Journal of Dentistry*. V23(2):65-69.
- Mourad PD**, Roberts FA, McInnis JC (2007) Synergistic use of ultrasound and sonic motion for removal of dental plaque bacteria. *Compendium of Continuing Education in Dentistry*. V28(7):296-301.
- Miao CH, Brayman AA, Loeb KR, Ye P, Zhou L, **Mourad PD**, Crum LA (2005) Ultrasound Enhances Gene Delivery of Human Factor IX Plasmid. *Human Gene Therapy* July, V16:893-905 (e-available June 05).
- Porter TM, Murthy N, **Mourad PD**, Stayton PS, Hoffman AS, Crum LA (2005) Control of cavitation-induced hemolysis with a surface-active polymer. *Acoustic Research Letters Online*. 6:201-206

- Mourad PD**, Silbergeld DL (2005) Breaking the blood-brain barrier: using high-intensity focused ultrasound to treat malignant brain tumors. *RT-Image*. V18(32):28-32.
- Mourad PD**, Farrell L, Stamps L, Chicione M, and Silbergeld DL. (2005) Why are systemic glioblastoma multiforme rare: systemic and cerebral growth of a mouse glioblastoma. *Surgical Neurology*, V63(6), 511-519.
- Mourad PD**, L. Farrell, P. Santiago, H. L. Fillmore, W. C. Broaddus, and D. L. Silbergeld. (2003) Quantitative Assessment of Glioblastoma Invasion *in vivo*. *Cancer Letters*. Mar 20;192(1):97-107
- Winstead, N. S., Sikora, T. D., Thompson, D. R. and **Mourad PD** (2002) Direct influence of gravity waves on surface-layer stress during a cold-air outbreak, as shown by synthetic aperture radar. *Mon. Wea. Rev.* 130, 2764-2776.
- Mesiwala, A. H. and **Mourad PD** (2002) Monitoring of biologic effects of focused ultrasound beams on the brain. *Radiology*. Jul;224(1):294-6; discussion 296-7.
- Mesiwala, A. H., L. Farrell, H. J. Wenzel, L. A. Crum, D. L. Silbergeld, H. R. Winn, and **Mourad PD**. (2002) High Intensity Focused Ultrasound Selectively Disrupts the Blood-Brain Barrier *in vivo*. *Ultrasound in Medicine and Biology*. 28(1) 389-400.
- Poliachik, S. L., W. L. Chandler, **Mourad PD**, R. J. Ollos and L. A. Crum (2001) Activation, aggregation and adhesion of platelets exposed to high intensity focused ultrasound *Ultrasound in Medicine and Biology* 27(11) 1567-1576.
- Kwok, C. S., **Mourad PD**, L. A. Crum, B. D. Ratner (2001) Self-assembled Molecular Structures as Ultrasonically-responsive Barrier Membranes for Pulsatile Drug Delivery. *J. Biomed. Mat. Res.*57(2) 151-164.
- Winstead, N. S., R. Schaff, and **Mourad PD** (2001) Synthetic Aperture Radar Observations of Surface Signatures of Cold-Season Bands over the Great Lakes. *Weather and Forecasting*. 16 315-328.
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• **PROPOSALS UNDER CONSTRUCTION**

STTR-NIH

*Proof of concept of an ultrasound-guided catheter.*

Cadaveric test of the ability of a stylet emitting ultrasound from its tip to improve neurosurgeon's ability to guide catheters to human ventricles.

\$250K over one year.

Role: With EchoGuide Medical Inc, I will act as Co-PI out of the Department of Neurological Surgery [the company will lead the grant].

TATRC

*Treating vasospasm after blast with ultrasound.*

Animal-based studies of the ability of ultrasound to treat cerebral vasospasm, using an animal model of subarachnoid hemorrhage.

\$600K over two years, for submission Summer 2012.

Role: PI out of the Department of Neurological Surgery.

R01-NIH

*Localizing painful tissue pathology to improve the diagnostic specificity of pain.*

Studies using various animal models of pain to validate and extend my previous research on the use of intense focused ultrasound to localize painful tissue pathology.

~\$3M over five years, for submission Fall 2012.

Role: PI out of the Department of Neurological Surgery.

R42-NIH (Phase II STTR)

*Development of a prototype device to localize sites for regional anesthesia.*

Studies using various animal models of pain to prepare a prototype device for pre-clinical trials on the use of intense focused ultrasound to localize painful tissue pathology and peripheral nerves relevant for generating regional anesthesia.

~\$1.5M over two years, for submission Fall 2012.

Role: Co-PI out of the Applied Physics Laboratory (recall that for STTR grant applications, the PI must be from the company, in this case PhysioSonics, Inc).

**PROPOSALS UNDER REVIEW.**

Psychological Health/Traumatic Brain Injury (PH/TBI) Research Program (DoD)

*Localizing, quantifying and monitoring sources of acute and chronic pain: human studies.*

Human studies quantifying amputee pain after standard amputation or after targeted muscle reinnervation. With Drs. Gofeld and Theodore from the Department of Anesthesiology and Pain Management and Dr. Friedly of the Department of Rehab Medicine.

Role: PI. Total costs - \$2.5M over three years.

Program Project Grant to NIH.

*Towards using ultrasound to treat autism via enhanced drug delivery and neuromodulation.*

Animal-based studies to assay the ability of ultrasound to deliver drugs relevant to autism in a focal, efficacious manner. With William Banks, MD, PhD of the Veterans Administration of Puget Sound, each of us as Co-PIs on a grant with multiple PIs, led by Dr. Bryan King, Chief of Psychiatry at Children's hospital in Seattle. Total grant \$1.5M/year for 5 years in direct costs.

Our portion: \$175K/year for 5 years in direct costs.

R03 to NIH.

Endovascular ultrasound disruption of the blood brain barrier for intra-arterial delivery of drugs. For \$50K in direct funds, for one year's study performed by Neurological Surgery Residents, using both rats and pigs with a commercialized catheter.

Role: PI.

• **FUNDED PROPOSALS**

Coulter Foundation Grant – Summer 2012 – Winter 2013

\$150K to the Department of Neurological Surgery

*Refinement and testing in vivo of an ultrasound-guided catheter.* Laboratory and animal testing. With Sam Browd MD of the Department of Neurological Surgery at UW.

Role: PI.

Coulter Foundation Seed Grant – Winter/Spring 2012

\$50K to the Department of Neurological Surgery

*Development and testing of a disposable, ultrasound-guided catheter.* Laboratory and animal testing. With Sam Browd MD of the Department of Neurological Surgery at UW.

Role: PI.

Grant – Winter 2012-Fall 2013

LSDF, \$150K to the Applied Physics Laboratory

*Definitive human testing of pain localization and quantification based on transcutaneous acoustic palpation (TAP).*

Testing in pre-clinical trials on patients with residual limbs the ability of image-guided intense focused ultrasound (ig-iFU) to localize neuromas, normal peripheral nerves and targeted muscle re-innervation (TMR) sites.

Role: PI.

Grant – Fall 2011-Summer 2014.

TATRC.

*Automated transcranial Doppler for detection of post-TBI vasospasm.*

Test in pre-clinical trials on patients with vasospasm the ability of an automated transcranial Doppler system to detect vasospasm. This device was co-invented by me and developed by my company, PhysioSonics Inc.

\$2.3M to the Applied Physics Laboratory.

Role: PI.

Grant - 15 February 2011-14 February 2014.

CDMRP (Congressionally Directed Medical Research Programs),

Advanced Technology/Therapeutic Development Award.

\$2.6M to the Department of Neurological Surgery

*Towards Development of a Field-Deployable Imaging Device for TBI*

Test and refine *in vivo* an ultrasound imaging system based on detection and mapping of the stiffness of tissue, for the purpose of imaging brain after trauma with the fidelity of CT, but with greater diagnostic power.

Role: PI.

Grant, from 1 January 2009 – 31 December 2011.

Life Sciences Discovery Fund (LSDF) - \$225K (direct costs plus 17% indirect costs), to the Department of Neurological Surgery.

*Transcutaneous Acoustic Palpation (TAP) for localizing painful pathology.*

*In vivo* studies to demonstrate that intense focused ultrasound (iFU) can be used under image guidance to localize pain generators.

Role: Principle Investigator and co-inventor of the technology (along with Jerry Jarvik, MD, MPH of Radiology at the UW and Michel Klot, MD of Neurosurgery at UW.)

Grant # 07270002 30 September 2009 – 30 April 2011.

TATRC - \$250K, to the Department of Neurological Surgery.

*A Non-Invasive Biomarker for Intracranial Pressure*

Animal-based studies targeting the use of intense focused ultrasound (iFU) to palpate brain, thereby determining its stiffness, hence, by correlation, the overpressure causing that stiffness – overpressure caused by intracranial pressure.

Role: PI.

Grant No. 65-1748 1 December 2007 – 30 September 2009

UW (TGIF) - \$50K (only DC), to the Applied Physics Laboratory

*Towards predicting, hence preventing, dental caries ('cavities')*

Laboratory studies using extracted teeth with artificially induced dental lesions to explore the possibility that near-infrared spectroscopy has sufficient sensitivity to detect pre-caries lesions, using a methodology developed by Drs Berg and Mourad.

Principal Investigator: Joel Berg, DDS and Chair of Pediatric Dentistry.

Role: Co-investigator, along with Dr. Chen of the Applied Physics Laboratory

Grant No. A44145 1 December 2008 – 31 December 2009

Washington Research Foundation - \$25K (only DC), to the Applied Physics Laboratory.

*Towards grading burns with THz radiation: initial feasibility studies*

Animal-based studies using terahertz-based radiation, along with near-infrared spectroscopy, to determine the depth, hence grade of skin burn, using methodology developed by Drs. Chen and Winebrenner of the Applied Physics Laboratory

Role: Principle Investigator

Grant, from September 2006-2008

NIH (Phase II STTR) approximately \$1.2M to Ultreo Incorporated.

*Safety and clinical trials of a novel toothbrush.*

Role: wrote the original proposal as a consultant

Grant, from September 2006-2008 (extended to September 2009).

NIH (Phase II STTR) – \$1.1M, to Allez PhysiOnix, the Applied Physics Laboratory & Department of Neurological Surgery.

*Refinement a prototype device for the non-invasive determination of intracranial pressure.*

Human studies whose goal is to advance the development of an approach to the non-invasive determination of intracranial pressure, with an emphasis on incorporating the non-invasive determination of arterial blood pressure.

Role: Principal Investigator on UW portion (recall that UW employees cannot be PIs on STTRs.

Grant, from September 2005-2010

NSBRI –\$1.2M over four years to the Applied Physics Laboratory & Department of Neurological Surgery.

*Testing a non-invasive method for the determination of intracranial pressure.*



Human studies whose goal is to advance the development of an approach to the non-invasive determination of intracranial pressure. With APL, Neurosurgery, Radiology (of UW) as well as Baylor Medical School and the University of Texas at Houston.

Role: Principal Investigator

Contract 1 July 05-31 June 2006

Washington Technology Center and Allez PhysiOnix, Ltd –\$120,000, to the Department of Neurological Surgery, UW (this money has no indirect costs associated with it)

*Automatic acoustic arrays in support of the non-invasive determination of intra-cranial pressure: in silico studies.*

Mathematical research with various parties within Neurosurgery and Applied Physics Laboratory, to develop systems requirements for an acoustic array that can automatically find the middle cerebral artery, in support of the non-invasive determination of intra-cranial pressure, based on technology co-developed by the PI.

Role: Principal Investigator

Contract 1/1/05-6/31/05

Washington Technology Center and Second Act Partners Inc –\$120,000, to the Department of Neurological Surgery, UW (this money has no indirect costs associated with it)

*Towards a truly ultrasonic toothbrush – further in vitro studies.*

*In vitro* research with various parties within the School of Dentistry, Neurosurgery and Applied Physics Laboratory, to further test a new power toothbrush, based on technology co-developed by the PI.

Role: Principal Investigator

Grant 1/1/05-31/12/08

VA Merit Rehabilitation Medicine grant – to Michel Kliot, MD of the Department of Neurological Surgery, VA/UW. \$436,000.

*Ultrasound palpation to safely evaluate painful tissue pathology.*

The goal of this animal-based study is to explore the ability of short, sharp pulses of ultrasound to differentiate between inflamed, abnormal tissue and normal tissue, *in vivo*, with techniques developed by the co-investigator. The animal model consists of modification of the sciatic nerve of the rat via application of a suture/ligature technique, that makes the paw sensitive to external stimulation.

Role: Co-Principal Investigator

Grant No. R43 NS46824-01A1

8/1/04-7/31/05

NIH/NINDS - \$100,000 to Allez PhysiOnix, Ltd, with subcontract to Applied Physics Laboratory and the Department of Neurological Surgery

*Towards the non-invasive determination of intracranial pressure.*

The goal of this STTR proposal is to determine the feasibility of using ultrasound-based interrogation of the brain, plus ancillary physiological data to non-invasively determine the pressure on the brain, i.e., intracranial pressure, in clinical studies, with techniques developed by the co-investigator.

Role: Co-Investigator (recall that UW does not allow UW employees to PI STTR grants.)

Grant No. R41 NS 049719-01

8/1/04-7/31/05

NIH/NINDS - \$100,000 to Allez PhysiOnix, Ltd, with subcontract to Applied Physics Laboratory and the Department of Neurological Surgery

*TAP: transcutaneous acoustic palpation for the differential diagnosis of pain*

The goal of this STTR proposal is to explore the ability of short, sharp pulses of ultrasound to differentiate between inflamed, abnormal tissue and normal tissue, *in vivo*, with techniques developed by the co-investigator.

Role: Co-Investigator (recall that UW does not allow UW employees to PI SBIR or STTR grants.)

Grant No. K25 NS02234-02 9/1/01-8/31/05

NIH/NINDS ~ \$575,000 to the Applied Physics Laboratory, UW

*Blood Brain Barrier Permeabilization Using Ultrasound*

The goal of this training grant is to explore the mechanisms, efficacy, and safety of opening the blood brain barrier using ultrasound to administer therapeutic drugs with techniques developed by the PI.

Role: Principal Investigator

Contract 1/1/04-6/31/04

Washington Technology Center and Second Act Partners Inc –\$120,000, to the Applied Physics Laboratory, UW (this money has no indirect costs associated with it)

*Towards a truly ultrasonic toothbrush – in vitro studies*

*In vitro* research with various parties within the School of Dentistry and Applied Physics Laboratory, to develop a new power toothbrush, based on technology co-developed by the PI.

Role: Principal Investigator

Contract 1/1/04-6/31/04

Allez PhysiOnix, LTD - \$85,000, to the Applied Physics Laboratory, UW

*Non-invasive intracranial pressure – clinical and animal studies*

Work with Dr. Klot of the Department of Neurological Surgery and Dr. Jarvik of the Department of Radiology, to perform laboratory-based and clinical studies of various ways of determining intracranial pressure non-invasively, as co-developed by the PI.

Role: Principal Investigator.

Contract 10/01/03-12/31/03

Washington Technology Center and Second Act Partners Inc - \$48,000, to the Applied Physics Laboratory, UW (this money has no indirect costs associated with it)

*Towards a truly ultrasonic toothbrush – in vitro studies, In vitro* research with various parties within the School of Dentistry and Applied Physics Laboratory, to develop a new power toothbrush, based on technology co-developed by the PI.

Role: Principal Investigator.

Contract 10/1/03-12/31/03

Allez PhysiOnix, LTD - \$33,000, to the Applied Physics Laboratory, UW

*Non-invasive intracranial pressure – a clinical study*

Work with Drs. Klot, Mohr and Mesiwala of the Department of Neurological Surgery to perform laboratory-based and clinical studies of various ways of determining intracranial pressure noninvasively, as co-developed by the PI.

Role: Principal Investigator.

Contract 5/01/03-10/1/03

Allez PhysiOnix, LTD - \$15,000 to the Applied Physics Laboratory, UW

*Non-invasive intracranial pressure – a clinical study*

Work with Klot, Mohr and Mesiwala of the Department of Neurological Surgery to perform laboratory-based and clinical studies of various ways of determining intracranial pressure non-invasively, as co-developed by the PI.

CV for Pierre D. Mourad, PhD

Role: Principal Investigator.

Contract No. B2305R

9/1/00 - 8/31/03

Department of Veterans Affairs, VA Rehabilitation Merit Review Grant ~ \$300,000 to  
Department of Neurological Surgery, UW

*Ultrasound treatment of acute and chronic peripheral nerve injury*

The goal is to test the effects of ultrasound on nerve regeneration after sciatic nerve injury in the rat with ultrasound techniques developed by the co-investigator.

Role: Co-Investigator

Grant No. N00014-96-1-0630

4/1/96 – 8/28/2001

DARPA via ONR ~ \$12,000,000 to Applied Physics Laboratory, UW

*An Acoustic Hemostasis Device for Advanced Trauma Care”*

The goal of this project is to develop a system for acoustic hemostasis for trauma care.

Role: Co-Investigator

Grant No. N00014-98-1-0189                      11/01/97-1/30 2000  
Office of Naval Research ~ \$100,000 to the Applied Physics Laboratory, UW  
*"Imaging Turbulence Using SAR"*

The goal was to remotely sense multiscale atmospheric surface-layer turbulence using synthetic aperture radar (SAR) images of the ocean surface.

Role: Principal Investigator

Grant No. N00014-98-1-0189                      2/2/97-12/31/01  
Office of Naval Research ~ \$90,000 to the Applied Physics Laboratory, UW  
*"Spatial Variation of the Wave, Stress and Wind Field in the Shoaling Zone"*

The goal is to improve models of surface stress in the shoaling zone by adding spatial variation of wind and stress fields based on field measurements

Role: Principal Investigator

Grant No. ATM9707730                      12/8/97-11/30/99  
National Science Foundation ~ \$345,000 to the Applied Physics Laboratory, UW  
*"Analysis of Multiscale Atmospheric Turbulence Structure within the Surface Layer of Lake-Induced Convection"*

The goal was to measure spatial and temporal evolution of microfronts on Lake Michigan and obtain SAR images of lake surface to remotely sense multiscale atmospheric turbulence structure.

Role: Principal Investigator

Contract                      12/8/97-11/30/99  
NASA - \$131,000 to Northwest Research Associates and the Applied Physics Laboratory, UW  
*"Comparison of Patterns in SAR and AVHRR Imagery and Ocean Color"*

The goal was to use satellite-derived synthetic aperture radar (SAR) and AVHRR images of the ocean surface during Bering Sea plankton blooms to study the relationship of plankton activity and remotely-sensible surface conditions.

Role: Principal Investigator

Contract                      2001-2003  
NASA ~ \$460,000 to the U.S. Naval Academy and the Applied Physics Laboratory, UW.  
*"Surface wind speed and fluxes from SAR: validation and application to the tropics"*

The goal was to SAR images of the ocean surface to remotely key aspects of air/sea interaction, with validation using in situ data.

Role: Principal Investigator

Grant                      1998-1999  
ONR - \$180,000 to the Applied Physics Laboratory, UW  
*Fine-Scale Structure of Turbulence in the Marine Planetary Boundary Layer.*  
Analysis of co-located SAR imagery and in-situ turbulence measurements taken during the ONR MBL/ARI in May 1995.

Role: Principal Investigator

Grant                      1996-2001  
ONR - \$200,000 to the Applied Physics Laboratory, UW  
*Shoaling Waves Initiative.*  
Experimental study involving remotely-sensed data and *in situ* measurements of wave shoaling and its interaction with atmospheric turbulence.

Role: Principal Investigator

Grant 1996  
ONR - \$80,000 to the Applied Physics Laboratory, UW  
*Intermittency and Connectivity of Turbulence in the Marine Planetary Boundary Layer.*  
Continuation of the "Multiplicity of Scales" proposal listed below  
Role: Principal Investigator

Grant 1995-1997  
NSF - \$450,000 to the Applied Physics Laboratory, UW  
*Synchronous Picosecond Sonoluminescence.*  
For analysis of the phenomena of sonoluminescence in which squeezing an isolated bubble with sound causes that bubble to emit light.  
Role: Co-Investigator

Grant 1994-1995  
ONR - \$270,000 to the Applied Physics Laboratory, UW  
*Multiplicity of Scales in the Marine Planetary Boundary Layer*  
Partially overlapping combination of work in marine meteorology, physical oceanography, and biological oceanography, all relevant near the air/sea interface, Role: Principal Investigator

Grant 1994-1995  
ONR - \$435,000 to Applied Physics Laboratory, UW  
*Numerical and Experimental Studies of Sonoluminescence.*  
Numerical and experimental treatment of sonoluminescence, with me as PI for the numerical part and Ron Roy as PI of the experimental part.  
Role: Principal Investigator, as described above.

Grant 1993  
ONR - \$200,000 the Applied Physics Laboratory, UW  
*Ocean Acoustic Holography: a Method for Calibrating High Gain Arrays for Oceanic Variability.*  
Studing the creation of acoustic holograms as a way to minimize the effects of oceanic variability on acoustic signal propagation.  
Role: Co-Investigator

Grant 1992-1993  
ONR - \$200,000 the Applied Physics Laboratory, UW  
*The Physics and Biological Effects of Multiscale Large Eddies.*  
Earlier version of "Multiplicity of Scales in the Marine Planetary Boundary Layer."  
Role: Principal Investigator

Grant 1992  
ONR - \$88,000 to the Applied Physics Laboratory, UW  
*Acoustic Holography.*  
Studing the creation of acoustic holograms as a way to minimize the effects of oceanic variability on acoustic signal propagation.  
Role: Co-Investigator

Grant 1991  
ONR - \$50,000 to the Applied Physics Laboratory, UW  
*Measurements of Physical Parameters and the Associated High Frequency Backscatter of First-Year Arctic Sea Ice*  
Analysis of acoustic data gathered in the Arctic on high frequency acoustic properties of arctic sea ice, and validation of associated theory.  
Role: Co-Investigator.

Grant 1990-1993  
NAVOCEANO - \$460,000 to the Applied Physics Laboratory, UW  
*Modeling Low Frequency Acoustic Properties of Oceanic Sediments*  
Modeling of low frequency acoustic backscatter properties of the bottom of the ocean.  
Role: Co-Investigator

Grant 1985-1987  
NSF - \$200,000 to the Department of Atmospheric Sciences, UW  
*Modeling Large Eddies of the Atmospheric Boundary Layer*  
Work toward a Ph.D. in Applied Mathematics.  
Role: Co-Investigator