ANNUAL REPORT

September 2006 - August 2007

NUCLEAR ENGINEERING AND RADIOLOGICAL SCIENCES

University of Michigan

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September 1, 2006 – August 31, 2007

NUCLEAR ENGINEERING AND RADIOLOGICAL SCIENCES

University of Michigan

MichiganEngineering

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Contents

Summary of Activities

This is the twelfth Annual Report of the Department of Nuclear Engineering and Radiological Sciences (NERS) at the University of Michigan. The report was assembled for the purpose of providing a record of teaching, research and service activities of the faculty, staff and students of the department.

The department taught a total of 35 (including six special topics) courses during AY 2006-2007. Independent study and projects courses (NERS 499, 599 and 799) had enrollments totaling 35. In addition to the NERS courses, NERS faculty taught two sections of the first-year course ENG 101, *Introduction to Computers and Programming*, averaging 188 students per section. The enrollments for NERS 211, *Introduction to Nuclear Engineering and Radiological Sciences*, offered as an elective for engineering students outside the department, had 178 total students last year for the Fall and Winter sections.

The Fall 2006 term enrollments totaled 76 (NERS) and 22 (Eng Physics) undergraduate students and 77 graduate students. During AY 2006-2007, the department awarded 17 BSE-NERS and 8 BSE-Eng Physics degrees, 24 MS/MSE, 10 PhD degrees, and one Nuclear Engineer Professional Degree.

This past year the undergraduate and graduate students were again successful in winning numerous awards. Eleven undergraduates were recipients of the National Academy for Nuclear Training (NANT) scholarships, one was a recipient of a Department of Homeland Security scholarship, seven received American Nuclear Society (ANS) awards, and twenty-one were recipients of U.S. Department of Energy (DoE) scholarships. Graduate students won nine fellowships from DoE, two from the Department of Homeland Security (DHS), one from NANT, six fellowships from other federal agencies and professional societies, and six scholarships from ANS. In addition, five graduate students won college or department fellowships. This outstanding record of student accomplishments in attracting fellowships and scholarships will continue: 89 awards have already been made to undergraduate and graduate students for academic year 2006-2007.

Our faculty are also being recognized for their achievements: Rod Ewing was awarded the Lomonosov Gold Medal from the Russian Academy of Sciences and also Honorary Doctor from University Pierre et Marie Curie; James Holloway was appointed Associate Dean for Undergraduate Education by the U-M College of Engineering, and was awarded an Arthur F. Thurnau Professorship by the University of Michigan; Glenn Knoll received the Radiation Instrumentation Outstanding Achievement Award from the IEEE/Nuclear and Plasma Sciences Society; Karl Krushelnick was awarded the Charles V. Boys Medal and Prize from the UK Institute of Physics ; John Lee received the NERS Award for Outstanding Teacher; and Gary Was was awarded the U-M College of Engineering Department Faculty Award for

Outstanding Achievement. In addition, the University of Michigan awarded Gary the first endowed professorship to a NERS faculty member, the Walter J. Weber, Jr. Professor of Sustainable Energy, Environmental, and Earth Systems Engineering.; and he was appointed Director of the Michigan Memorial Phoenix Energy Institute (MMPEI).

The faculty supervised a total of 72 research projects with expenditures of $6.6M. The NERS research projects included three DoE NEER grants and eight DoE NERI and I-NERI grants. The NERS faculty published 109 articles in archival journals in calendar year 2006.

The ANS student chapter earned an honorable mention in the 2007 Samuel Glasstone Award competition from the American Nuclear Society. The award is presented to a student ANS chapter for "accomplishing the most notable achievements in public service and the advancements of nuclear engineering." The department salutes the student ANS chapter for their outstanding achievement in winning prestigious awards three years in a row for their dedication and service as a professional society.

Faculty Honors, Awards, & Appointments

Rodney C. Ewing

- Russian Academy of Sciences
  Lomonosov Gold Medal
- University Pierre et Marie Curie
  Honorary Doctor

James Paul Holloway

- U-M College of Engineering
  Associate Dean for Undergraduate Education
- University of Michigan
  Arthur F. Thurnau Professorship

Glenn F. Knoll

- IEEE/Nuclear and Plasma Sciences Society
  Radiation Instrumentation Outstanding Achievement Award

Karl Krushelnick

- UK Institute of Physics
  Charles V. Boys Medal and Prize

John C. Lee

- Nuclear Engineering and Radiological Sciences
  Award for Outstanding Teacher (Selected by NERS students)

Gary S. Was

- University of Michigan
  Director of the Michigan Memorial Phoenix Energy Institute (MMPEI)
  and
  Walter J. Weber, Jr. Professor of Sustainable Energy, Environmental, and Earth Systems Engineering
  (First endowed professorship awarded to a NERS faculty member.)
- U-M College of Engineering
  Department Faculty Award for Outstanding Achievement

Student Organizations

ALPHA NU SIGMA SOCIETY

The objective of the Alpha Nu Sigma Society is "to recognize high scholarship, integrity, and potential achievement in applied nuclear science and nuclear engineering among outstanding students by means of membership in the Society."

Additionally, the Michigan Alpha Chapter provides tutoring for students both in and outside the department taking NERS courses. This tutoring is offered for students five days a week in one-on-one tutoring sessions. Since 1993, the Chapter has recognized a faculty member for contributions to undergraduate and graduate education. Professor John C. Lee was selected by the students as the 2006-07 recipient of the NERS Award for Outstanding Teacher.

Alpha Nu Sigma established a tutoring schedule to help students with classes. Any student within the department or taking a departmental course is eligible to use the tutoring services. At least one tutor is available five days a week to help answer questions. This service has the ability to evolve according to students' needs.

Alpha Nu Sigma's laptop borrowing program continues to be popular. Last year, the laptops were checked out by numerous students for use on NERS projects and presentations. These laptops are available on a first-come, first-serve basis for undergraduate and graduate students alike.

AMERICAN NUCLEAR SOCIETY

The 2006-07 academic year has been successful for the University of Michigan Student Section of the American Nuclear Society (U-M ANS). With fifty-six members and high attendance at all events, U-M ANS has been a vibrant and active student society at the University of Michigan. Increasing enrollment in NERS has not only supplied a larger recruiting base for U-M ANS, but also a growing demand for its services. U-M ANS continues to provide intellectual, professional, and social opportunities for NERS students, the University, and community at large.

The goals of U-M ANS for the 2006-07 academic year have been to foster professional development and to increase student participation at ANS national conferences. Ten regular meetings were held throughout the academic year featuring guest speakers from the nuclear

industry and presentations from NERS students. With additional aid from the NERS department and the College of Engineering, U-M ANS sponsored five students to attend the ANS Winter Meeting and seven students to attend the ANS Student Conference. U-M ANS also submitted a bid to host the 2008 ANS Student Conference.

U-M ANS participated in many outreach activities to promote nuclear science and technology. Some of these included the U-M Energy Fest, Sally Ride Festival, Detroit Area Pre-College Engineering Program, Shadow Days, and TECH Day. U-M ANS also helped the NERS Department at various campus recruiting events and welcome days.

HEALTH PHYSICS SOCIETY

The University of Michigan Student Branch of the Health Physics Society was among the charter groups of student branches formed in 1992. The Health Physics Society is dedicated to the development, dissemination, and application of both the scientific knowledge of and the practical means for radiation protection, with an emphasis on protection of people and the environment from unnecessary exposure to radiation. The student branch has been involved in a number of professional activities, parties, seminars, and public relations activities, including tours, teacher training workshops and visits to high schools for the dissemination of basic information about radiation and radiation health effects.

Curriculum

PROGRAM CHANGES

A major curricular change was made to the undergraduate program this year: the notion of separate nuclear engineering and radiological science tracks was dropped, and the curriculum was changed to require all students to take both NERS 441, *Nuclear Reactor Theory I*, and NERS 484, *Radiological Health Engineering Fundamentals*. Students can still take NERS 442, *Nuclear Reactor Theory II*, or NERS 554, *Radiation Shielding*, as their major design experience. Along with these changes, NERS 311 & 312, *Elements of Nuclear Engineering and Radiological Sciences I & II*, were reduced to 3 credit hours by recognizing some overlap, both between NERS 311 & 312, and with modern physics taught in NERS 250, *Fundamentals of Nuclear Engineering and Radiological Sciences*. In addition, radiation transport was previously in the syllabus for NERS 312, but had never been taught in the course. The program changes are in effect for students who declare the program starting in Fall 2007.

COURSES OFFERED*

COURSE NO.	COURSE TITLE	TERM	CREDIT HRS
NERS 211	Intro to Nuclear Engineering & Radiological Sciences	I, II	4
NERS 250	Fundamentals of Nuclear Engineering & Radiological Sciences	II	4
NERS 311	Elements of Nuclear Engineering & Radiological Sci I	I	4
NERS 312	Elements of Nuclear Engineering & Radiological Sci II	II	4
NERS 315	Nuclear Instrumentation Laboratory	II	4
NERS 421	Nuclear Engineering Materials	I	3
NERS 425	Applications of Radiation	II	4
NERS 441	Nuclear Reactor Theory I	I	4
NERS 442	Nuclear Power Reactors	II	4
NERS 462	Reactor Safety Analysis	I	3
NERS 471	Introduction to Plasmas	I	3
NERS 472	Fusion Reactor Technology	II	2
NERS 481/BioE 481	Engineering Principles of Radiation Imaging	II	2
NERS 484/BioE 484	Radiological Health Engineering Fundamentals	I	4
NERS 490	Special Topics in Nuclear Engineering & Radiological Sciences	All	TBA
NERS 499	Research in Nuclear Engineering & Radiological Sciences	All	1-3
NERS 511	Quantum Mechanics in Neutron-Nuclear Reactions	II	3
NERS 512	Interaction of Radiation and Matter	II	3
NERS 515	Nuclear Measurements Laboratory	I	4
NERS 518	Advanced Radiation Measurements and Imaging	I	2 Alt Yrs
NERS 521	Radiation Effects in Nuclear Materials	I	3
NERS 522	Nuclear Fuels	II	3 Alt Yrs
NERS 531	Nuclear Waste Management	II	3 Alt Yrs
NERS 543	Nuclear Reactor Theory II	I	3
NERS 551	Nuclear Reactor Kinetics	II	3
NERS 554	Radiation Shielding	II	4

*Roman numeral indicates term(s) the course will be offered, and number in parentheses indicates credit hours. Fall term, I; Winter term, II; Spring/Summer terms,III A/B

COURSE NO.	COURSE TITLE	TERM	CREDIT HRS
NERS 561	Nuclear Core Design and Analysis I	II	3
NERS 562	Nuclear Core Design and Analysis II	IIIA	3
NERS 571	Intermediate Plasma Physics I	I	3
NERS 572/ AppPhy 672	Intermediate Plasma Physics II	II	3
NERS 575/EECS 519	Plasma Generation and Diagnostic Laboratory	II	4
NERS 576	Charged Particle Accelerators and Beams	I	3 Alt Yrs
NERS 577	Plasma Spectroscopy	I	3 Alt Yrs
NERS 578/EECS 517	Physical Processes in Plasmas	II	3 even Yrs
NERS 579/EHS 692	Physics of Diagnostic Radiology	II, IIIA	3
NERS 580/BioE 580	Computation Projects in Radiation Imaging	II	1
NERS 582/BioE 582	Medical Radiological Health Engineering	II	3
NERS 583/EHS 683	Applied Radiation Dose Assessment	II	4
NERS 585	Transportation of Radioactive Waste	I	2 Alt Yrs
NERS 586	Applied Radiological Measurements	II	4
NERS 587	Internal Radiation Dose Assessment	II	3
NERS 588	Radiological Health Engineering Practicum	All	1-12
NERS 590	Special Topics in Nuclear Engineering & Radiological Sciences II	All	TBA
NERS 599	Master's Project	I, II, IIIA-B	1-3
NERS 621	Nuclear Waste Forms	I	3 Alt Yrs
NERS 622/ MSE 622/Mfg 622	Ion Beam Modification and Analysis of Materials	II	3 Alt Yrs
NERS 644	Transport Theory	I	3
NERS 671	Theory of Plasma Confinement in Fusion Systems I	I	3 Alt Yrs
NERS 672	Theory of Plasma Confinement in Fusion Systems II	II	3 Alt Yrs
NERS 673	Electrons and Coherent Radiation	II	3
NERS 674/ AppPhy 674	High Intensity Laser-Plasma Interactions	I	3
NERS 799	Special Projects	All	1-6
NERS 990	Dissertation/Pre-candidate	I, II , III IIIA-B	2-8 1-4
NERS 995	Dissertation/Candidate	I, II, II, IIIA-B	8 4

COURSE ENROLLMENTS

COURSE	TITLE	Fall '06	W '07	Sp/Su '07
NERS 211	Introduction to Nuclear Engr and Radiological Sci	70	108	
NERS 250	Fundamentals of Nuclear Engr and Radiological Sci		39	
NERS 311	Elements of Nuclear Engr and Radiological Sci I	32		
NERS 312	Elements of Nuclear Engr and Radiological Sci II		31	
NERS 315	Nuclear Instrumentation Laboratory		30	
NERS 421	Nuclear Engr Materials	19		
NERS 425	Applications of Radiation		21	
NERS 441	Nuclear Reactor Theory I	20		
NERS 442	Nuclear Power Reactors		14	
NERS 462	Reactor Safety Analysis	15		
NERS 471	Introduction to Plasmas	22		
NERS 481	Engr Principles of Radiation Imaging (BioE 481)		19	
NERS 484	Radiological Health Engr Fundamentals (BioE 484)	11		
NERS 490	Special Topics in Nuclear Engr and Radiological Sci		45	
NERS 499	Research in Nuclear Engr & Radiological Sci	5	6	1
NERS 515	Nuclear Measurements Laboratory	4		
NERS 521	Radiation Effects in Nuclear Materials	8		
NERS 531	Nuclear Waste Management		20	
NERS 543	Nuclear Reactor Theory II	9		
NERS 554	Radiation Shielding		15	
NERS 561	Nuclear Core Design and Analysis I		11	
NERS 571	Intermediate Plasma Physics I	9		
NERS 572	Plasma Physics II		4	
NERS 575	Plasma Generation and Diagnostics Lab (EECS 519)		21	
NERS 580	Computation Proj in Radiation Imaging (BioM 580)		6	
NERS 582	Medical Radiological Health Engr (BioM 582)		6	
NERS 585	Transportation of Radioactive Materials	9		
NERS 590	Special Topics in Nuclear Engr & Radiological Sci II	39	34	
NERS 599	Master's Project	2	3	
NERS 622	Ion Beam Modification and Analysis of Materials (Mfg 622) (MSE 622)		9	
NERS 673	Electronics and Coherent Radiation	8		
NERS 674	High Intensity Laser-Plasma Interactions (Appl Phys 674)		7	
NERS 799	Special Projects	7	11	
NERS 990	Dissertation-Precandidate	12	35	2
NERS 995	Dissertation-Candidate	35	31	3

Student Academics, Honors and Employment

AWARDS AND HONORS
MADE IN 2006 FOR A/Y 2006-2007

Undergraduate Scholarships for A/Y 2006-2007

- First Year Merit Scholarships

  John Bergsma Jr, David Genevich, Archis Joglekar, Ryan Orizondo, Dane Reggia, Charles Sullivan, Andrew Till
- NERS Continuous Scholarship

  Jonathan Fritz, Douglas Fynan, Justin Lamy
- Second Year Undergraduate Merit Scholarship

  Ian Faust, James Laird II, Justin Lamy, Scott Pfeffer, Christopher Tobin
- Kikuchi Scholarship

  Benjamin Betzler, Yvan Boucher
- American Nuclear Society Undergraduate Scholarship Award

  Matthew Franzi, Jonathan Fritz, Douglas Fynan, Justin Lamy, Natallia Pinchuk, Robert Reed, Christopher Tien
- American Nuclear Society Undergraduate Scholarship Award – Michigan Section

  Robert Reed
- U.S. Department of Energy Nuclear Engineering Undergraduate Scholarship

  Scott Ambers, Benjamin Betzler, Yvan Boucher, Thomas Briley, Jennifer Dolan, Ian Faust, Jonathan Fritz, Matthew Franzi, Douglas Fynan, Andrew Haefner, Justin Lamy, Diana Li, Jeffrey Neumann, Kyle Patterson, Scott Pfeffer, Robert Reed, Stephen Rice, Christopher Tien, Stephen Troyer, Patricia Voss, Scott Wagner
- National Academy for Nuclear Training Scholarship

  Scott Ambers, Thomas Briley, Ian Faust, Jonathan Fritz, Douglas Fynan, Andrew Haefner, Kelsey Hanson, Eric Miller, Robert Reed, Christopher Tien, Patricia Voss
- Joseph B. and Florence V. Cejka Scholarship

  Kelsey Hanson

- Ziegler Family Scholarship
  Stephen Rice
- Class of 1931E Scholarship
  Douglas Fynan
- Bernard J. and Ronni S. Lacroute Scholarship
  Patricia Voss
- GE Scholarship
  Christopher Tien
- Earnest F. Hollings Scholarship
  William Kolodzey

Undergraduate Honors and Awards for A/Y 2006-2007

- Outstanding Undergraduate Student Award (Engineering Physics)
  Toby Mitchell
- Outstanding Undergraduate Student Award (Nuclear Engineering and Radiological Sciences)
  Douglas Fynan
- Distinguished Leadership Award
  Thomas Briley

Graduate Fellowships for A/Y 2006-2007

- American Nuclear Society Graduate Awards
  Jason Hayward, Nicholas Jordan, Bryan Toth, Christopher Wahl, Brandon Weatherford, Emily Wolters
- Applied Materials
  Nicholas Jordan
- College of Engineering Dean's/Named Fellowship
  Christopher McGuffey, Brandon Weatherford

- College of Engineering Regent's Fellowship
  Shikha Prasad
- Directed Energy Professional Society
  Brad Hoff
- Health Physics Society
  Zachary Whetstone, Benjamin Hammargren, Nathan Haverland
- IEEE/NPSS Graduate Scholarship Award
  Wilkin Tang, Phongphaeth Pengvanich, Nick Jordan
- NASA Graduate Student Research Program
  Jason Hayward
- National Academy for Nuclear Training Fellowship
  Nuclear Engineering: Bryan Hayden
- Rackham Engineering Award Fellowship
  Andrew Gerlach, Edward Cruz
  Renewals: Tiberius Moran; Alejandro Perez-Bergquist, Elaine West
- Rackham Predoctoral Fellowship
  Phongphaeth Pengvanich
- Rackham Barbour Fellowship
  Yan Cao
- U.S. Department of Energy Civilian Radioactive Waste Management Fellowship
  Nathan Haverland, Kelly (Prater) Wichman
- U.S. Department of Energy Computational Sciences Fellowship
  Allan Wollaber
- U.S. Department of Energy Naval Nuclear Propulsion Fellowship
  Troy Becker, Micah Hackett, Bryan Toth
- U.S. Department of Homeland Security
  Adrienne Lehnert, William Kaye
- U.S. Department of Energy Nuclear Engineering/Health Physics Fellowship
  Emily Wolters
- U.S. Department of Defense National Defense Science and Engineering
  Michaela (Flak) Eddy, Christopher Wahl
- University Research Alliance (AFCI)
  Jason Haas

Graduate Honors and Awards for 2006-2007

- College of Engineering 2007 Distinguished Leadership Award
  Tiberius Moran
- College of Engineering 2007 Distinguished Achievement Award
  Jason Hayward
- TMS 2007 Student Poster Competition – Structural Materials Division winner and Best of Show, TMS Student Representative PRICM-6 Conference in Jeju Island, South Korea.
  Micah Hackett
- Roy G. Post Foundation Scholarship
  Micah Hackett
- 2007 IEEE Nuclear and Plasma Sciences Society Graduate Scholarship Award
  Wilkin Tang, Phongphaeth Pengvanich, Nicholas Jordan

AWARD DECISIONS MADE IN 2007 FOR A/Y 2007-2008

Undergraduate Scholarships for A/Y 2007-2008

- NERS Continuous Scholarship
  Jonathan Fritz, Justin Lamy
- Second Year Undergraduate Merit Scholarship
  Ross Barnowski, Steve Cavnar, Christopher Fischer, David Genevich, Meghan Haigh, Archis Joglekar
- Kikuchi Scholarship
  Matt Orians, Andrew Till
- American Nuclear Society Undergraduate Scholarship Award
  Yvan Boucher, Matthew Franzi, Jonathan Fritz, David Genevich, Archis Joglekar, Matt Orians
- U.S. Department of Energy Nuclear Engineering Undergraduate Scholarship
  Scott Ambers, Benjamin Betzler, Yvan Boucher, Thomas Briley, Jennifer Dolan, Ian Faust, Jonathan Fritz, Matthew Franzi, Andrew Haefner, Justin Lamy, Diana Li, Kathryn Masi, Jeffrey Neumann, Kyle Patterson, Scott Pfeffer, Ian Rittersdorf, Scott Wagner
- U.S. Department of Homeland Security
  Allen Fisher
- National Academy for Nuclear Training Scholarship
  Scott Ambers, Thomas Briley, Ian Faust, Matthew Franzi, Jonathan Fritz, Andrew Haefner, Eric Miller, Ian Rittersdorf
- Class of 1931E Scholarship
  Ross Barnowski

Graduate Fellowships for AY 2007-2008

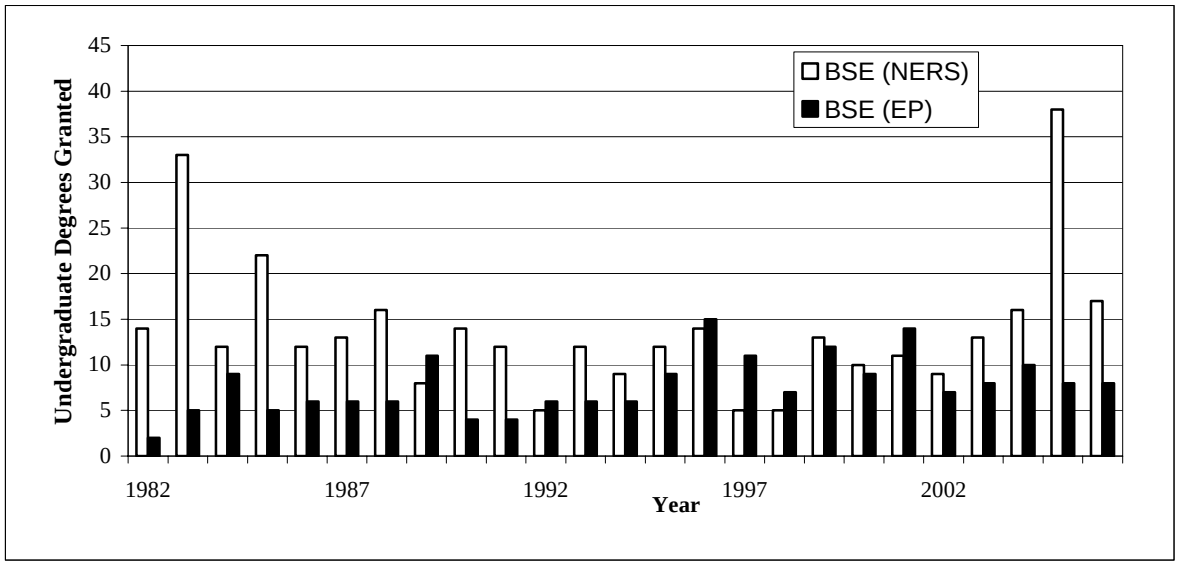
- American Nuclear Society Graduate Awards
  Micah Hackett, Jason Hayward, Brad Hoff, Emily Wolters, Jacob Zier
- American Nuclear Society (Professional Women in)
  Michaela (Flak) Eddy, Shikha Prasad

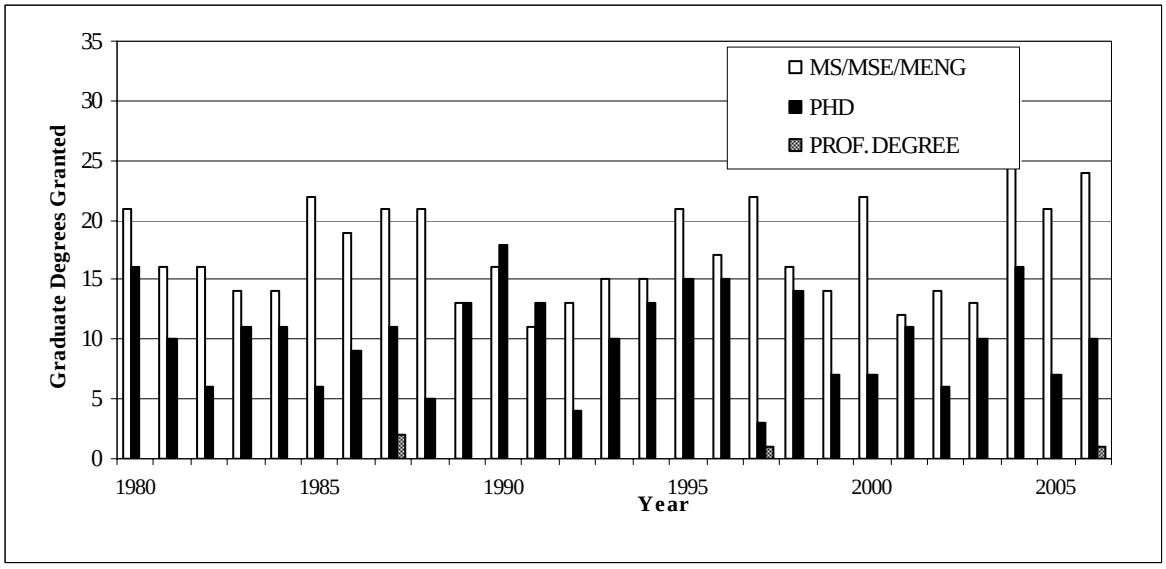
- College of Engineering Dean's/Named Fellowship
  Eric Baker, Paul Cummings
- College of Engineering Regent's Fellowship
  William Morgan
- Directed Energy Professional Society
  Brad Hoff
- Graduate Student Research Program, Marshall Space Flight Center
  Jason Hayward, Brandon Weatherford
- Michigan Memorial Phoenix Energy Institute
  Athi Varuttamaseni
- National Academy for Nuclear Training in Nuclear Engineering Fellowship
  Nuclear Engineering: Ceris Hamilton
  Health Physics: TBD
- National Physical Sciences Consortium
  Jacob Zier
- National Science Foundation
  Seth Johnson
- Rackham Engineering Award Fellowship
  Carlos Di Stefano, Douglas Fynan
- Rackham Engineering Award Fellowship (renewal)
  Tiberius Moran, Elaine West, Alejandro Perez-Bergquist, Ed Cruz
- Stockpile Stewardship Graduate Fellowship
  Matthew Gomez
- U.S. Department of Energy Computational Sciences Fellowship
  Allan Wollaber
- U.S. Department of Energy Naval Nuclear Propulsion Fellowship
  Troy Becker, Micah Hackett, Bryan Toth
- U.S. Department of Energy Nuclear Engineering/Health Physics Fellowship
  Emily Wolters
- U.S. Department of Energy Office of Civilian Radiation Waste Management
  Kelly (Prater) Wichman
- U.S. Department of Defense National Defense Science and Engineering
  Christopher Wahl, Michaela (Flak) Eddy
- U.S. Department of Homeland Security
  Adrienne Lehnert, Zachary Whetstone, William Kaye
- University Research Alliance; Advanced Fuel Cycle Initiative
  Jason Haas

DEGREES AWARDED BY ACADEMIC YEAR

September 2006 through August 2007

Degree	Number
BSE in Nuclear Engineering and Radiological Sciences	17
BSE in Engineering Physics	8
MSE and MS in Nuclear Engineering and Radiological Sciences (including 13 students continuing in doctoral program)	24
PhD in Nuclear Engineering and Radiological Sciences, and in Nuclear Science	10
Professional Degree (Nuclear Engineer)	1





DOCTORAL THESES TITLES

For Degrees Conferred September 2006–August 2007

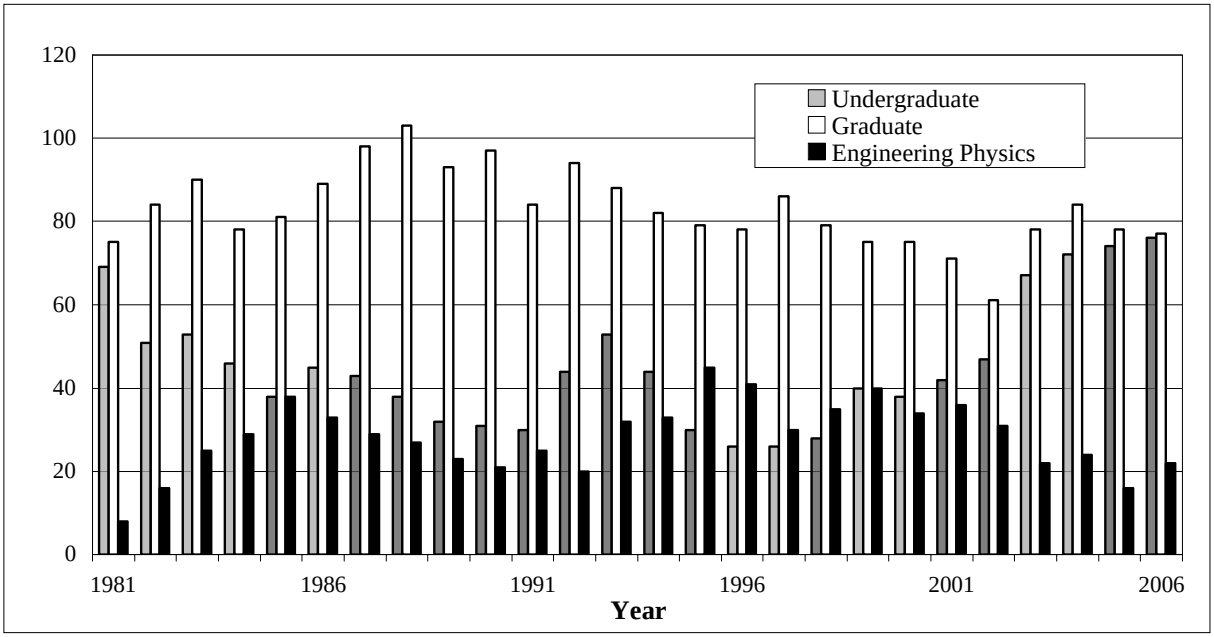
STUDENT	TITLE	ADVISOR
Davis, Jeffrey	Optimizing Fast Reactors Through Direct Adjoining Control Theory	Professor John C. Lee
Ding, Tianhua	Self-Organization Process of Three-Dimensional Nano-Void Superlattice Formation in Electron Irradiated Calcium Flouride	Professor Lumin Wang
Kiff, Scott	Coplanar Anode Implementation in Compressed Xenon Ionization Chambers	Professor Zhong He
Lee, Wonho	A Dual Modality Gamma Camera Using LaC3 (CE) Scintillator	Professor David Wehe
Liang, Liang	Development and Application of a Random Lung Model for Dose Calculations in Radiotherapy	Professor Edward Larsen
Matuszak, (Coselmon) Martha	Controlling Beam Complexity in Intensity Modulated Radiation Therapy	Professor Edward Larsen
McClarren, Ryan	Spherical Harmonics Methods for Thermal Radiation Transport	Professor James P. Holloway
Sorensen, Reuben	Systematic Method for Optimizing Plutonium Transmutation in LWRs	Professor John C. Lee
Sturm, Benjamin	Gamma-Ray Spectroscopy Using Depth-Sensing Coplanar Grid CdZnTe Semiconductor Detectors	Professor Zhong He
Tchou, Philip	Visual Performance in Medical Imaging Using Liquid Crystal Displays	Professor Edward Larsen & Adjunct Professor Mike Flynn

Doctoral Theses in Progress for Academic Year 2006-2007

STUDENT	TITLE	ADVISOR
Alpay, Bulent	Degradation Monitoring Using Probabilistic Inference	Professor James P. Holloway
Davidson, Gregory	A Two-Cell Block Inversion Method for Solving the Time-Dependent S_N Equations	Professor Edward Larsen
Hackett, Micah	Understanding the Mechanism of Radiation-Induced Segregation Reduction through Oversized Solute Addition to 316SS	Professor Gary Was
Hayward, Jason	High-Purity Germanium Double-Sided Strip Detector Gap Characterization	Professor David K. Wehe
Ji, Wei	Neutronic Analysis of Stochastic Distribution of Fuel Particles in the Very-High Temperature Gas-Cooled Reactor	Professor William R. Martin
Wollaber, Allan	A Monte Carlo-Deterministic Method for Global Time-Dependent Photon Transport Calculations	Professor Edward Larsen

FALL ENROLLMENT

Year	Undergraduate	Graduate	Engineering Physics
1980	68	88	0
1981	69	75	8
1982	51	84	16
1983	53	90	25
1984	46	78	29
1985	38	81	38
1986	45	89	33
1987	43	98	29
1988	38	103	27
1989	32	93	23
1990	31	97	21
1991	30	84	25
1992	44	94	20
1993	53	88	32
1994	44	82	33
1995	30	79	45
1996	26	78	41
1997	26	86	30
1998	28	79	35
1999	40	75	40
2000	38	75	34
2001	42	71	36
2002	47	61	31
2003	67	78	22
2004	72	84	24
2005	74	78	16
2006	76	77	22



EMPLOYMENT STATISTICS
AND CONTINUING EDUCATION

Place of First Employment of Graduates
September 2006 – August 2007

Undergraduate Students

EMPLOYER	BSE STUDENTS
DC Cook Nuclear Power Plant	Stephen Troyer
Dominion	Brian Kitchen
Hiresite	Peter Gullekson
ISL, Inc	Christopher Chwasz
Knolls Atomic Power Laboratory	Nicholas Krupansky
Nexant, Inc	Blair Wilcox
Nuclear Regulatory Commission	Patricia Voss
	Oswaldo Font

UNIVERSITY	BSE STUDENTS
University of California – Berkeley	Amy Coffer
University of Michigan	Douglas Fynan
(Nuclear Engineering and Radiological Sciences)	Eric Gillman
	Natallia Pinchuk
	Robert Reed
	Bradley Sommers
	Michael Terjimanian
	Christopher Tien
	Jeffrey Adams
Other Graduate Schools (unknown)	Gregory Kress
	Toby Mitchell
	Pacha Mongkolwongrojn
	Gurlovleen Rathore
	Stephen Rice
	Jennifer Schlicht

UNKNOWN	BSE STUDENTS
	Kelley Belenky
RETURN TO HOME COUNTRY	Nor Syarizan Mat Nor

Graduate Students

EMPLOYER
Defense Nuclear Facilities Safety Board
First Energy Corp. (Perry Power Plant)
General Electric
GE-Hitachi
Knolls Atomic Power Laboratory
Nuclear Regulatory Commission
Pacific Northwest National Laboratory
Westinghouse Electric BWR Core Tech Group
Unknown

MS/MSE STUDENTS
Andrew Gerlach
Benjamin Kevern
Natallia Pinchuk
Adam Dow
Virinder Sandhu
Brian Wagner
Mark Shaver
Bryan Hayden
Benjamin Hammargren
Jiali Wu
Nathan Haverland

EMPLOYER
Brazilian Navy

PROFESSIONAL DEGREE STUDENTS
Miesher Rodrigues

EMPLOYER
Anderson Cancer Center Medical Imaging Physics
Cypress Semiconductor
Brookhaven National Laboratory
Johns Hopkins Applied Physics Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Pacific Northwest National Laboratory
University of California-Irvine
University of Michigan-NERS
William Beaumont Hospital

PhD STUDENTS
Philip Tchou
Tianhua Ding
Wonho Lee
Reuben Sorensen
Benjamin Sturm
Ryan McClarren
Scott Kiff
Liang Liang
Jeffrey Davis
Martha Matuszak

UNIVERSITY
University of Michigan
(Nuclear Engineering and Radiological Sciences)

MS/MSE STUDENTS
Pantip Ampornrat
Matthew Gomez
Manhee Jeong
Wan-Ting "Anny" Liao
Tiberius Moran
Niravun "Por" Pavenayotin
Alejandro Perez-Bergquist
Shikha Prasad
Nicholas Touran

UNIVERSITY (continued)
University of Michigan
(Nuclear Engineering and Radiological Sciences)

MS/MSE STUDENTS
Brandon Weatherford
Elaine West
Zachary Whetstone
Jacob Zier

INTERNSHIPS

Undergraduate

Katherine Masi	Bovard Hills Nursing Home	MI
Najeb Abdul Jabbar	Brookhaven National Laboratory	NY
Scott Amers	DTE Energy – Fermi Plant	MI
Alexander Hunter	DTE Energy – Fermi Plant	MI
James Laird	DTE Energy – Fermi Plant	MI
Eric Miller	DTE Energy – Fermi Plant	MI
Robert Newton	DTE Energy – Fermi Plant	MI
William Walsh	DTE Energy – Fermi Plant	MI
Kristine Madden	Duke Energy Catawaba Nuclear Station	SC
Jeff Admas	Eli Lilly	IN
Curtis Dauw	Exelon	IL
Andrew Caldwell	General Electric	NC
Jonathan Fritz	General Electric	NC
Justin Lamy	General Electric	NC
Scott Pfeffer	General Electric	NC
Thomas Zak	General Electric	NC
Maggie Hwang	General Motors	MI
Scott Wagner	Goldman Sachs	NY
Tomas Briley	Knolls Atomic Power Laboratory	NY
Matthew Franzi	L-3 Communications	CA
Eric Gillman	L-3 Communications	CA
David Sumpter	Las Animas County Road Commission	CO
Allen Fisher	Lawrence Livermore National Laboratory	CA
Christopher Tien	Lawrence Livermore National Laboratory	CA
Ian Faust	Los Alamos National Laboratory	NM
David Sirajuddin	Los Alamos National Laboratory	NM
Benjamin Yee	Micron	ID
Jonathan Barr	Oakland University, REU Experience	MI
Andrew Haefner	Pacific Northwest National Laboratory	WA
Jeffrey Neumann	Pacific Northwest National Laboratory	WA

E. Douglas Cooper	Palisades Nuclear Power Plant	MI
Kyle Patterson	Palisades Nuclear Power Plant	MI
Ian Rittersdorf	Palisades Nuclear Power Plant	MI
Lindsey Baumgarten	Progress Energy	SC
Ross Barkowski	Sargent & Lundy	IL
Amy Coffer	Schlumberger	NJ
Jennifer Dolan	Schlumberger	NJ
Robert Reed	Schlumberger	NJ
Michael Claus	Tacom	MI
C. Johanna Corney	TXU, Comanche Peak Steam Electric Station	TX
Elizabeth Thomas	University of Kentucky, REU Experience	KY
Brian Dick	University of Michigan	MI
	Materials Science and Engr	
Nathan Bennett	University of Michigan	MI
	Nuclear Engr and Radiological Sciences	
Tyler Fowler-Guzzardo	University of Michigan	MI
	Nuclear Engr and Radiological Sciences	
Joshua Miesel	University of Michigan	MI
	Nuclear Engr and Radiological Sciences	
Brett Rogers	University of Michigan	MI
	Nuclear Engr and Radiological Sciences	
Michael McKervey	University of Michigan	MI
	Physics Laboratory	
Diana Li	University of Michigan	MI
	Radiation Oncology	
Blair Willcox	University of Michigan	MI
	School of Natural Resources	
Gurlovleen Rathore	University of Michigan	MI
	Space Physics Sciences Laboratory	
Nicholas Bachman	Westinghouse	PA
Yvan Boucher	Westinghouse	PA
Robert Blackburn	World Magnetics Company	MI

Graduate Internships

Nicholas Touran	Idaho National Laboratory	ID
Elaine West	Knolls Atomic Power Laboratory	NY
William Kaye	Lawrence Berkeley National Laboratory	CA
Zachary Whetstone	Lawrence Livermore National Laboratory	CA
Tiberius Moran	Lawrence Livermore National Laboratory	CA
Kelly Prater	Oak Ridge National Laboratory	TN
Nathan Haverland	Oak Ridge National Laboratory	TN
Gokhan Yesilyurt	Oak Ridge National Laboratory	TN
Wilkin Tang	Sandia National Laboratories	NM

Employment Patterns of Graduates September 2006 – August 2007

	BS	*MS/ MSE*	*PhD*	*Prof*
Federal Government				
Department of Defense				
United States Navy	1			
United States Air Force				
Department of Energy				
Bechtel Bettis				
Brookhaven National Laboratory			1	
Johns Hopkins Applied Physics Lab			1	
Knolls Atomic Power Laboratory	1	1		
Lawrence Livermore National Laboratory			1	
Los Alamos National Laboratory			1	
Pacific Northwest National Laboratory		1	1	
Sandia National Laboratories				
National Nuclear Security Administration				
Defense Nuclear Facilities Safety Board		1		
Nuclear Regulatory Commission	2	1		
Electrical and Nuclear Utilities				
DC Cook Nuclear Power Plant	1			
Duke Power				
First Energy Nuclear Operating Company		1		
GE-Hitachi		1		
Nuclear Reactor Manufacturers				
Dominion	1			
Westinghouse		1		
Architecture-Engineering Firms				
Consulting Firms				
ISL, Inc	1			
Nexant, Inc	1			
Entrepreneurial				
Hiresite	1			
Other Industrial and Medical Organizations				
Anderson Cancer Center Medical Imaging			1	
Cyprus Semiconductor			1	
General Electric Research Center		1		
William Beaumont Hospital			1	
Foreign Governments				
Military				1

	BS	*MS/ MSE*	*PhD*	*Prof*
Academic Institutions: Grad, Post Doc, and Faculty				
University of California – Berkeley (Nuclear Engr)	1			
University of California – Irvine			1	
University of Michigan (Medical School)				
University of Michigan (NERS)	8	13	1	
Unknown Graduate Schools	6			
Employment Outside the Profession				
Returned to Home Country and Unknown	1	3		
TOTALS	25	24	10	1

Employment Patterns of Graduates
37-Year Summary: August 1970 - July 2007

	BS	*MS*	*MEng*	*PhD*	*Prof*
Federal Government					
Department of Commerce				7	
Department of Defense					
Armed Forces	64	22	1	8	
Civilian Employees	3	3		15	
Department of Energy	11	43	3	95	
Department of Transportation				2	
Environmental Protection Agency			2		
NASA		1			
Nuclear Regulatory Commission	7	3	1		1
Waste Management Federal Services		1			
Electrical and Nuclear Utilities	70	37	1	8	
Nuclear Reactor Manufacturers	38	50		21	1
Architecture-Engineering Firms	18	29	1	5	
Consulting Firms	6	5	3	9	
Entrepreneurial	1				
Other Industrial & Medical Organizations	23	41	4	58	
Foreign Governments	1	11		12	4
Academic Institutions					
Faculty and Staff	7	6	2	52	
Graduate School and Postdoctoral Work	340	352	10	51	
Employment Outside the Profession	14	10		2	
Returned to Home Country and Unknown	85	41	7	29	3
Fulbright Award	1				
TOTALS	689	655	35	374	9

NERS Colloquia Fall 2006

DATE	SPEAKER	TITLE
Sept. 15	William R. Martin U-M NERS	Departmental Welcome
Sept. 22	Kurt M. Haas Big Rock Point Restoration Project	Big Rock Point - Lessons Learned During Decommissioning
Sept. 29	King-Lap Wong Princeton Plasma Physics Laboratory	Energetic Alpha Particles in Fusion Plasmas
Oct. 6	Feng Zhang and Dan Xu U-M NERS	3-D Position-Sensitive Room Temperature Semiconductor Gamma-Ray Imaging Spectrometers
Oct. 13	No Colloquium	Fall Break
Oct. 20	Tom Sanford Sandia National Laboratories	Review of Dynamic Hohlraum Research at SNL – A Powerful Radiation Source for ICF
Oct. 27	Chang Kue Park Korea Atomic Energy Research Inst.	Nuclear Research and Development Program in Korea
Nov. 3	Mihaela Rosu U-M Radiation Oncology Dept.	4-D Radiotherapy of Lung Tumors – How Much is Enough?
Nov. 10	Industry Forum and Career Fair	Job Opportunities and Current Activities for NERS Graduates
Nov. 17	Mark Peters Argonne National Laboratory	Research on the Closed Nuclear Fuel Cycle in U.S. National Laboratories
Nov. 24	No Colloquium	Thanksgiving Break
Dec. 1	Robert Grove Knolls Atomic Power Laboratory	New Particle Transport Methods for Reactor Simulations at KAPL
Dec. 8	Rachel Goldman U-M Materials Science & Engin.	Ion-Beam Synthesis of Semiconductor Nano-composites for Energy Conversion Applications

NERS Colloquia Winter 2007

DATE	SPEAKER	TITLE
Jan. 12	John Baglin IBM	Review of Advances in Ion Beam Modification of Materials
Jan. 19	Ken Powell U-M Aerospace Engineering Dept.	Engineering CFD versus Science CFD: Similarities and Differences
Jan. 26	Todd Palmer Oregon State University	A Comparison of Monte Carlo and Deterministic Transport Dose Calculations of the Mammosite™ Breast Cancer System
Feb. 2	Tim Smith U-M Aerospace Engineering Dept.	Electric Propulsion Research at the U-M Plasma-dynamics and Electric Propulsion Laboratory
Feb. 9	Karl Krushelnick U-M NERS	Recent Results in Ultra-High Intensity Laser Plasma Interactions: Towards Table-Top GEV Electron Beams and Efficient Attosecond Pulses
Feb. 16	Yanwen Zhang Pacific Northwest National Lab	Experimental Study of Electronic Stopping Powers in Compounds
Feb. 23	NERS Student Presentations	
Mar. 9	Paul Wilson University of Wisconsin	Innovations in 3-Dimensional Neutronics Analysis for Fusion Systems
Mar. 16	Levi Thompson U-M Chemical Engineering Dept.	Beyond Fossil Fuels: Nanostructured Materials for Hydrogen Production and Conversion
Mar. 23	David Hammer Cornell University	Physics Issues Associated with Plasma Development in Wire-Array Z-Pinches
Mar. 30	Anthony Earley Chairman & CEO, DTE Energy Co.	The Nuclear Renaissance: How Real Is It?
Apr. 6	Patrick McKenty Laboratory for Laser Energetics University of Rochester	The Current Role of the OMEGA/OMEGA EP Laser in the Pursuit of ICF Ignition
Apr. 13	Mark J. Colby General Electric Company	Economic Simplified Boiling Water Reactor (ESBWR) Core Engineering

Research Activities

FISSION SYSTEMS AND RADIATION TRANSPORT

Development of Time-Dependent Pn Solver for ALEGRA

J. P. Holloway, PI
Sandia National Laboratories
$120,827/3 yrs

Under this project we have developed new ways to solve the time-dependent spherical harmonics equations providing high-resolution in both space and time, while requiring only two linear solves per time step. In fully nonlinear radiative transfer applications we have solved the radiation transport problem fully coupled to the material energy balance, avoiding the "operator splitting" normally used in these applications. This work has advanced our understanding of the spherical harmonics equations, and made clear how the properties of linearity, rotational invariance, and hyperbolicity conspire to allow unphysical negative radiation energy density, and how one of these properties must be sacrificed to avoid this defect.

R. McClarren, J. P. Holloway and T. A. Brunner, "A P_1 Benchmark for Time Dependent Thermal Radiative Transfer," *Proceedings of M and C 2007: Joint International Topical Meeting on Mathematics and Computations and Supercomputing in Nuclear Applications,* April 15-19, 2007, Monterey, CA, on CD ROM, The American Nuclear Society (2007).

R. McClarren and J. P. Holloway, "High Resolution Time Integration for the Spherical Harmonics Equations," *Proceedings of M and C 2007: Joint International Topical Meeting on Mathematics and Computations and Supercomputing in Nuclear Applications,* April 15-19, 2007, Monterey, CA, on CD ROM, The American Nuclear Society (2007).

R. McClarren, J. P. Holloway and T. A. Brunner, "An Upwind Spherical Harmonics Method for Thermal X-ray Transfer," *Transactions of the American Nuclear Society*, **95** (2006).

R. McClarren, J. P. Holloway, T. A. Brunner and T. A. Mehlhorn, "A Quasi-Linear Implicit Riemann Solver for the Time-Dependent P_n Equations," *Nuclear Science and Engineering*, **155**, 290-299 (2006). (Invited)

Model Based Transient Control and Component Degradation Monitoring in Generation IV Nuclear Power Plants

J. P. Holloway, PI and J. C. Lee, Co-PI
U.S. Department of Energy/NERI
$1,382,504/42 mos

This project involving the University of Michigan, Westinghouse and Sandia National Laboratories supports the development of advanced nuclear power technology. The project developed advanced methodologies for constructing control systems for fission power systems. The project also developed an advanced model-based approach to monitoring nuclear plant systems for degradations. These two tasks are united by their reliance on sensor networks that map sensor signals to plant state information through the use of plant system models. This plant sensor information is used to connect models of plant state to the actual plant state. Nonlinear state-space control algorithms were developed to provide robust and automatic plant control in a wide variety of plant transient maneuvers, including startup, shutdown, and load follow maneuvers, including large or total load rejections. By providing smooth transient control without reactor trip these control systems can greatly improve both plant safety and economics. The quest for long-life cores in highly integrated and modular reactor designs places great demands on the already difficult maintenance systems of nuclear power stations. Advanced degradation monitoring will allow nuclear plant operators to optimize plant maintenance subject to both safety and economic factors. The unscented Kalman filter has been successfully used for monitoring power plant components with full nonlinear representation of system dynamics.

B. Alpay and J. P. Holloway, "Degradation Monitoring in IRIS Steam Generators," *Proceedings of M and C 2007: Joint International Topical Meeting on Mathematics and Computations and Supercomputing in Nuclear Applications,* April 15-19, 2007, Monterey, CA, on CD ROM, The American Nuclear Society (2007).

J. P. Holloway, "Nonlinear Reactor Control using the Power Derivative in Feedback and Multiple Time-Scale Analysis," *Proceedings of M and C 2007: Joint International Topical Meeting on Mathematics and Computations and Supercomputing in Nuclear Applications,* April 15-19, 2007, Monterey, CA, on CD ROM, The American Nuclear Society (2007).

B. Alpay and J. C. Lee, "Degradation Monitoring through Unscented Kalman Filtering," *Transactions of the American Nuclear Society*, **94**, 579-580 (2006).

S. E. Aumeier, B. Alpay and J. C. Lee, "Probabilistic Techniques for Diagnosis of Multiple Component Degradations," *Nuclear Science and Engineering,* **153**, 101-123 (2006).

Advanced Variance Reduction for Global k-Eigenvalue Simulations in MCNP5

E. W. Larsen, PI and W. R. Martin, Co-PI
U.S. Department of Energy/NEER
$299,982/3 yrs

The goal of this project is to develop and implement new advanced variance reduction strategies for practical, continuous-energy k-eigenvalue and eigenfunction simulations in the Monte Carlo particle transport code MCNP5. This FORTRAN-90 version of MCNP, developed at Los Alamos National Laboratory and recently released by RSICC, contains new features–in particular, a multigroup cross section generator and a dual mesh which overlays the computational mesh–that allow MCNP5 to employ the automatic variance reduction method AVATAR for source-detector problems. The implementation of these features in MCNP5 will greatly facilitate the implementation and testing of more advanced variance reduction techniques that require the same multigroup cross sections and dual mesh.
In this project, we will implement in MCNP5 the Variational Variance Reduction (VVR) method for enhancing the Monte Carlo simulation of k-eigenvalue problems, In this recently-developed technique, a variational functional, which requires estimates of both forward and adjoint k-eigenfunctions, is evaluated to estimate k. This functional is more expensive to evaluate than the standard Monte Carlo functional, which requires only an estimate of the forward k-eigenfunction. However, because the variational functional is more accurate, a significant gain in the figure of merit is achieved.

The VVR method has been developed in preliminary work at the University of Michigan during the past six years and has undergone successful but very limited testing. The extension of this method to continuous-energy Monte Carlo simulations, its implementation in MCNP5, and its testing on difficult, realistic problems, is the essence of this proposed research.

E. W. Larsen and J. Yang, "New Monte Carlo Functional Methods for Estimating *k*-Eigenvalues and Eigenfunctions," submitted to *Transactions American Nuclear Society*.

Radiation Transport Methods Research for Stochastic Media and Semi-Implicit Time Discretizations

E. W. Larsen, PI
U.S. Department of Energy/LANL
$69,000/1 yr

The goal of this work is to research and develop new numerical methods for radiation transport that are more accurate or are obtained more efficiently.

The first area of proposed work is to research and develop a numerical transport method for electron transport through stochastic media, such as the human lung. Atomically mixing

the different materials gives the incorrect solution under most situations. Incorrect solutions adversely affect the probability of cure in radiation cancer therapy treatments. For large, multi-physics simulations, incorrect atomic-mix solutions represent wasted computational effort because the errors cannot be corrected by increasing the resolution in other independent variables. By exploring ways to extend the atomic mix model to improve its accuracy, new methods can be formed that hopefully will improve accuracy without substantially changing the existing infrastructure of transport software.

The second area of work is to investigate explicit and semi-implicit time discretization methods for deterministic thermal radiation transport. The successful implementation of these methods into existing ASC codes should allow the execution of high-fidelity problems that cannot be run with current methods on existing computing platforms. The possible gains with this approach are application of high-order transport to new mesh geometries, dramatically reduced memory requirements, and speed performance at least equal to that of current transport technology.

L. Liang, E. W. Larsen and I. J. Chetty, "An Anatomically-Realistic Lung Model for Monte Carlo-Based Dosimetry," *Med. Phys*ics, **34**, 1013 (2007).

E. W. Larsen and L. Liang, "The Atomic Mix Approximation for Charged Particle Transport," *SIAM J. Appl. Math.*, to appear.

G. Davidson and E. W. Larsen, "An Unconditionally-Stable Time-Dependent Transport Method Without Sweeps," *Trans. Am. Nucl. Soc.*, submitted.

Development of TRU Transmuters for Optimization of the Global Fuel Cycle

J. C. Lee, PI and R. F. Fleming, Co-PI
U.S. Department of Energy/NERI
$611,465/36 months

The project aims to develop advanced fuel cycles for the transmutation of transuranic (TRU) elements in irradiated nuclear fuel from light water reactor (LWR) power plants. The research will focus on developing fast-spectrum nuclear reactors that could efficiently transmute long-lived TRUs, thereby significantly reducing the radioactivity of the irradiated fuel. We have developed an equilibrium fuel cycle methodology to consistently compare the performance of LWR transmuters with that of other transmuters. We have studied ways to implement thorium in reload fuel cycles for both pressurized water rectors (PWRs) and sodium-cooled fast reactors (SFRs) for efficient transmutation of TRUs. Recent effort has focused on the development of general optimization algorithms that can systematically and efficiently optimize a multitude of fuel cycle parameters for PWRs and SFRs, while rigorously satisfying operational constraints including the peak power density. The optimization algorithm has

been implemented and tested for 2-D optimal fuel loading pattern searches for the AP600 and other PWR configurations. A similar fuel cycle optimization algorithm has successfully been implemented also for full 3-D optimization of SFR configurations including heterogeneous core designs and TRU transmutation targets.

R. T. Sorensen, J. C. Davis and J. C. Lee, "Thorium-based Fuels for Enhancing Plutonium Transmutation in Light Water Reactors," *Trans. Am. Nucl. Soc.*, **94**, 87 (2006).

J. C. Davis, R. T. Sorensen, J. C. Lee and R. F. Fleming, "Transmutation Characteristics of Thorium-Based Fuel in a Multiple-Tier Fuel Cycle," *Trans. Am. Nucl. Soc.*, **94**, 89 (2006).

R. T. Sorensen, J. C. Davis and J. C. Lee, "Systematic Method for Optimizing Plutonium Transmutation in LWRs," *Trans. Am. Nucl. Soc.*, **95**, 217 (2006).

R. T. Sorensen and J. C. Lee, "LWR Equilibrium Cycle Search Methodology for Assembly-Level Fuel Cycle Analysis," to appear in *Nuclear Science and Engineering.*

J. C. Davis and J. C. Lee, "Optimizing SFR Transmutation through Direct Adjoining Control Theory," submitted for presentation at the ANS Meeting in November 2007.

Reactor-Accelerator Coupling Experiments (RACE) Project

J. C. Lee, PI
U.S. Department of Energy/Idaho State University
$65,000/15 months

As an integral part of the DOE Advanced Fuel Cycle Initiative, we have been collaborating with the Idaho State University (ISU) to develop an international program to perform accelerator-driven subcritical systems (ADSS) experiments. In the initial phase of the Reactor-Accelerator Coupling Experiments (RACE) project, we have performed reactor physics simulations of an ISU subcritical reactor configuration driven by an electron linear accelerator. The simulation effort focused on 3-D ERANOS kinetics study of the RACE configuration following the injection of a neutron source generated by photo-neutron reactions in a Cu-W target. Recent effort has been directed to developing accurate methods to account for space-time effects in pulsed source experiments in general.

V. V. Kulik and J. C. Lee, "Space-Time Correction for Reactivity Determination in Source-Driven Subcritical Systems," *Nucl. Sci. Eng.,* **153**, 69 (2006).

Y. Cao, T. Zhou, I. Al-Qasir, A. I. Hawari, R. F. Fleming and J. C. Lee, "MCNP5 Simulations of ZrH Scattering Experiments," *Trans. Am. Nucl. Soc.*, **94**, 603 (2006).

Y. Cao and J. C. Lee, "An Improved Modal-Local Methods for ADS Transient Analysis," *Trans. Am. Nucl. Soc.*, **96**, 675 (2007).

An Advanced Neutronic Analysis Toolkit with In-line Monte Carlo Capability for VHTR Analysis

W. R. Martin, PI and J. C. Lee, Co-PI
U.S. Department of Energy/NERI
$600,000/3 yrs

The goal of this project is to develop, implement, and test a lattice physics code for very high temperature reactor (VHTR) neutronic design and analysis. This code is based on a production-quality lattice physics code used in LWR analysis and is augmented by Monte Carlo capability to treat resonance absorption in TRISO particle fuel. The approach takes advantage of the highly developed capabilities available for light water reactor neutronic analysis, in which lattice physics codes generate effective cross sections at the assembly level. These cross sections can be used in nodal codes to allow efficient calculation of global flux/power distributions and keff as a function of fuel depletion and temperature.

This project will incorporate the capability of the nodal Monte Carlo code, MCNP5, directly into the lattice code, CPM-3, to establish "proof-of-principle." Code linking will be accomplished through an interface that will enable the MCNP5 capability to be extensible to other cross-section generation codes as well. This capability will be demonstrated by linking MCNP5 to CASMO-4. The resultant package will inherit the substantial downstream capabilities of CASMO-SIMULATE, including cross-section generation for global nodal analysis and depletion, systematic preparation of cross-section sets for accident analysis, and efficient fuel cycle analyses and assessment of alternative fuel management schemes. The final result will be a validated neutronics methodology for VHTR design and analysis, including cross-section generation, global reactor analysis, depletion, and fuel management.

Collaborating Organizations: Studsvik of America, Idaho National Laboratory, Los Alamos National Laboratory, General Atomics, Oak Ridge National Laboratory, and TransWare Enterprises, Inc.

G. Yesilyurt, W. Ji, S. Prasad, W. R. Martin and J. C. Lee, "Coupled Nuclear-Thermal-Hydraulics Analysis for VHTR," *Trans. Am. Nucl. Soc.*, **96**, 580 (2007).

G. Yesilyurt, W. R. Martin and J. C. Lee, "Preliminary Analysis of VHTR Decay Heat Source," *Trans. Am. Nucl. Soc.*, **95**, 445 (2006).

Global Monte Carlo Simulation with High Order Polynomial Expansions
W. R. Martin, PI and J. P. Holloway, Co-PI
U.S. Department of Energy/NEER
$300,000/3 yrs

This is a research project involving the development of a computational methodology to predict the global neutron scalar flux and thermal power profiles throughout a nuclear reactor. This methodology is based on the utilization of high order polynomials within a Monte Carlo algorithm to accelerate Monte Carlo fission source iterations for loosely coupled reactor systems. Preliminary work has demonstrated the feasibility of using high order polynomials to estimate spatially and angularly varying quantities such as the scalar flux distribution within a lattice or the interface current distribution on a boundary. This work has also led to a second approach based on imbedding this methodology into a response matrix formalism, allowing one in principle to estimate high order response matrices that could be used to estimate global flux and power distributions with improved accuracy and efficiency compared with conventional Monte Carlo methods. These methods should improve the convergence of Monte Carlo fission source iterations for loosely coupled systems.

MATERIALS

Structure, Properties and Relaxation of Shear Bands in Metallic Glasses
M. Atzmon, PI; A. Ganuza, Graduate Student; K. Rajulapati, Research Fellow
National Science Foundation, Division of Materials Research
$426,898/4 yrs

In crystalline solids, the atomic scale structure has been understood for a long time. On the other hand, the structure of some nonequilibrium materials is still the subject of current research. In amorphous materials, the density is variable and is a function of the thermomechanical history. Structural relaxation has a significant effect on the properties. Since mechanical deformation introduces shear bands whose density is lower than that of the matrix, it is important to understand their structure and effect on mechanical and transport properties. In recent work, the anelastic deformation of metallic glasses has been used to characterize defects produced by permanent deformation.

D. Jang and M. Atzmon, "Grain-Boundary Relaxation and its Effect on Plasticity in Nanocrystalline Fe," *Journal of Applied Physics,* **99**, 083504 (2006).

W. H. Jiang and M. Atzmon, "Plastic Flow of an Amorphous/Nanocrystalline $Al_{90}Fe_5Gd_5$ Composite Formed by Rolling," *Intermetallics,* **14**, 962 (2006).

W. H. Jiang and M. Atzmon, "Mechanically-Induced Nanocrystallization and Defects in Amorphous Alloys: a High-Resolution Transmission Electron Microscopy Study,"*Scripta Materialia,* **54**, 333 (2006). (Invited)

M. Atzmon, D. Jang and K. Rajulapati, "Shear Band Behavior and Anelasticity in Metallic Glasses," *Workshop on Fundamental Issues in Metallic Glasses,* October 22-26, 2007 Kunming and Guilin, China. (Invited)

M. Atzmon, D. Jang and K. Rajulapati, "Low-Temperature Anelastic Deformation in an Al-Rich Metallic Glass," *International Symposium on Metastable and Nanomaterials*, to be held in Corfu, Greece, August 2007. (Invited)

M. Atzmon, D. Jang and K. Rajulapati, "Shear-band Behavior in Metallic Glasses," *Workshop on Bulk Metallic Glasses : Science and Technology (BMG2007)*, Indian Institute of Science, January 12-16, 2007. (Invited)

M. Atzmon and W. H. Jiang, "Shear-Band Behavior in a Metallic Glass – the Effect of Free Volume and Strain Rate," *THERMEC 2006, International Conference on Processing and Manufacturing of Advanced Materials*, Vancouver, July 2006. (Invited)

M. Atzmon, "Rate Dependence of Shear-Band Formation in Metallic Glasses," *First International Conference on Mechanics and Mechanical Properties of Non-Crystalline Materials I: Amorphous Metals*, Beijing, April 2006. (Invited)

M. Atzmon and W. H. Jiang, "Strain-Rate Dependence of Shear-Band Behavior and Serrated Flow in a Metallic Glass," *TMS Annual Meeting, Symposium on Bulk Metallic Glasses*, San Antonio, March 2006. (Invited)

Nanoparticle-Environment Interfaces: Interactions in Natural Systems

R. C. Ewing and L. M. Wang, Co-PIs (with U. Beker, Geological Sciences)
N. Pavenayotin, Graduate Student; S. Zhu, Research Fellow
National Science Foundation, Nanoscale Interdisciplinary Research Team (NIRT) Program
$1,499,000/4 years

Recent developments in surface analysis, computer simulations using quantum mechanical and empirical methods, and advanced techniques in electron microscopy now allow the accurate characterization and modeling of interface properties between nanoparticles and their immediate atomic-scale environment. These properties encompass the structural relationships between both phases, the stability of nanomaterials in their respective hosts, the chemistry in and near the interface, electron transfer mechanisms across the interface, and magnetic ordering in the nanoparticle, as well as in the near-interface region of the host matrix. In this research program, we apply the combination of newly-developed experimental and theoretical capabilities to a variety of research topics that collectively focus on the important role of nanoparticle interfaces in natural systems, such as the formation of metal particles on sulfide and oxide surfaces and their incorporation into the bulk, transport of metal-bearing nanoparticles in atmospheric particulates and groundwater colloids, and to biomineralization processes. A number of undergraduate and graduate students from different disciplines, such as mineralogy, geology, nuclear engineering, materials science, and chemical engineering are involved in the proposed projects.

S. Zhu, K. Sun, L. M. Wang, R. C. Ewing and R. Fromknecht, "TEM Characterization of Au Nano-Particles in TiO_2 Single Crystals by Ion Implantation," *Nuclear Instruments and Methods in Physics Research B*, **242**, 152-156 (2006).

D. Shi, J. Lian, W. Wang, G. K. Liu, P. He, Z. Y. Dong, L. M. Wang and R. C. Ewing, "Luminescent Carbon Nanotubes by Surface Functionalization," *Advanced Materials*, **18**, 189-193 (2006).

J. Lian, L. Yang, X. Y. Chen, G. K. Liu, L. M. Wang, R. C. Ewing and D. Shi, "Deposition of Ultrathin Rare-Earth Doped Y_2O_3 Phosphor Films on Alumina Nanoparticles," *Nanotechnology*, **17**, 1351-1354 (2006).

M. Reich, S. Utsunomiya, S. E. Kesler, L. M. Wang, R. C. Ewing and U. Becker, "Thermal Behavior of Metal Nanoparticles in Geologic Materials, *Geology*, **34**, 1033-1036 (2006).

X. T. Zu, S. Zhu, L. M. Wang and R. C. Ewing, "Enhancement of Paramaganetic Defects in Yttria Stabilized Zirconia Implanted by Cs Ion Irradiation," *Journal of Alloys and Compounds*, **428**, 25-28 (2007).

S. Zhu, S. X. Wang, L. M. Wang, R. C. Ewing and X. T. Zu, "Behavior of Implanted Strontium in Yttria-Stabilized Zirconia, *Applied Physics Letters*, **90**, 171915 (2007).

Particle-Induced Amorphization of Complex Ceramics

R. C. Ewing, PI and L. M. Wang, Co-PI
H. Xiao, Visiting Research Investigator; W. Li, Grad. Student (MSE);
and J. Lian, Assistant Research Scientist (GeoSciences)
U.S. Department of Energy, Office of Basic Energy Sciences
$853,201/3.5 yrs

The crystalline-to-amorphous (c-a) phase transition is of fundamental importance. Particle irradiations provide a highly controlled means of investigating this phase transformation and the structure of the amorphous state. The interaction of heavy-particles (alpha-recoil nuclei, fission fragments and implanted ions) with ceramics is complex because these materials have a wide range of structure types, complex compositions, and because chemical bonding is variable (not only from structure-type to structure-type, but also within a single structure). Radiation damage and annealing can produce diverse results, but most commonly, single crystals become aperiodic (the metamict state) or break down into a polycrystalline aggregate (sometimes not the same as the original phase). In this research program, the transitions from the periodic to aperiodic state of various nonmetallic materials (both natural and synthetic) are studied by detailed x-ray diffraction analysis, *in-situ* transmission electron microscopy, high resolution transmission electron microscopy, x-ray photoelectron spectroscopy, extended x-ray absorption fine structure spectroscopy/x-ray absorption near edge spectroscopy and other spectroscopic techniques. A theoretical model is also being developed to predict the relative

susceptibility of ceramic materials to radiation-induced amorphization based on the experimental results.

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Stress Corrosion Cracking of Neutron Irradiated Cast Stainless Steels in High Temperature Water

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U.S. Department of Energy/UT-Batelle, LLC
$293,502/2 yrs

The U.S. contribution to ITER(International Tokamak Experimental Reactor) program includes about 20% of the first wall and shield, consisting of 93 modules each weighing about 3.5T and 375 FW panels. There is a potential for significant cost savings by utilizing casting technology rather than welding/HIPing wrought plate material and employing extensive machining to fabricate the shield module. It is the responsibility of the US-program to demonstrate that the utilization of cast material will not impair the mechanical performance and corrosion behavior of the shield module.

The objective of this project is to investigate the stress corrosion cracking susceptibility of cast stainless steel in both unirradiated and neutron-irradiated condition in order to determine whether cast stainless steel can function in its intended role in ITER. The program includes

the development of the facility for testing neutron-irradiated stainless steels in controlled water chemistry at temperatures below 300°C. Experiments performed in a controlled water environment will be conducted to determine the baseline stress corrosion cracking behavior of the unirradiated cast alloy and the behavior of neutron-irradiated cast alloy.

Accelerator-Based Study of Irradiation Creep of Pyrolytic Carbon Used in TRISO Fuel Particles for Very High Temperature Reactors (VHTR)

L. M. Wang, PI and G. S. Was, Co-PI; R. S. Zhou, Post-doctoral Scholar and
A. Davis, Graduate Student
U.S. Department of Energy, Nuclear Energy Research Initiative (NERI)
$616,851/3 yrs

Pyrolytic carbon (PyC) is one of the structural materials in the TRISO fuel particles which will be used in the next generation of gas-cooled very-high-temperature reactors. When the TRISO particles are under irradiation, creep of the pyrocarbon layers can cause radial cracking leading to catastrophic particle failure. Therefore, a fundamental understanding of the creep behavior of PyC during irradiation is required to predict the overall fuel performance.

The primary objective of this project is to characterize the creep behavior of PyC through a systematic program of accelerator-based proton irradiation and *in-situ* measurements under stress at various temperatures between 400°C and 1,200°C. Test data will be analyzed to determine creep coefficients, which will then be correlated to existing coefficients measured under neutron irradiation. In addition, initial experiments on the transport of select fission products (e.g., Ag and Sr) in PyC under irradiation and stress will be conducted by implanting ions into the sample surface. The PyC microstructure will be studied with advanced analytical transmission electron microscopy (TEM).

Self-Organized 3-D Array of Nanostructures Under Irradiation

L. M. Wang, PI
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U.S. Department of Energy, Office of Basic Energy Sciences
$580,335/3.5 yrs

The main goal of this research project is to obtain better scientific understanding of a spectacular phenomenon induced by radiation effects, i.e. the formation of 3-D ordered arrays of nanoclusters for the advancement of nanoscience and technology. The phenomenon was first observed over 30 years ago as void lattice in irradiated pure metals, but the nanocluster in the array can also be interstitial plates (dislocation loops), gas bubbles or metal colloids (in multiple component nonmetals). These arrays are considered as nanostructures not only

because the clusters in the array are nanometer in diameter, but also because the "lattice parameters" of the array are also in the nanoscale. *In situ* and high resolution TEM are used to reveal the process of the nanostructure formation during ion beam irradiation. State of the art facilities that link modern TEMs with ion accelerators at Argonne National Laboratory and in Japan are used for the study.

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Consortium on Cladding and Structural Materials for Advanced Nuclear Energy Systems

G. S. Was, PI and L. Wang, Co PI; with U. Wisconsin, U. C. Berkley, U. C. Santa Barbara, Penn State Univ. and Alabama A&M
U.S. Department of Energy, Nuclear Energy Research Initiative (NERI) and Electric Power Research Institute
$3,500,000/3 yrs

The goal of this consortium is to address key materials issues in the most promising advanced reactor concepts that are yet to be resolved, or that are beyond the existing experience (dose/burnup) base, in order to 1) provide for a sound fundamental and engineering basis for operation in the intended application, 2) bring together key university, national laboratory and industry capability and support in order to provide the most comprehensive approach possible, and 3) create a long term, evolutionary program that seeks to address these and future nuclear materials issues in a progressive manner. This consortium will serve as a nucleation site, about which materials research activities will be catalyzed and grown among the leading individuals and institutions from academia, the national laboratories and industry. It represents an unprecedented opportunity to combine expertise and facilities in an effort to attack the challenge of materials behavior under irradiation on a scale that is not feasible for a single individual or institution.

The objectives of the initial three-year phase of the consortium are to:

- Develop an understanding of the high dose radiation stability of candidate sodium fast reactor (SFR) cladding and duct alloys under a range of temperatures and doses expected in the SFR, using a closely integrated program combining targeted charged particle and neutron irradiations, *in-situ* irradiation and computer simulation of defect microstructure
- Determine the stability of oxide dispersion strengthened (ODS) steel and ultrafine, precipitation strengthened (HT-UPS) austenitic steel
- Characterize and understand the mechanisms of irradiation creep in SiC in TRISO fuel, ferritic-martensitic (F-M) alloys and ODS and UT-UPS steels
- Develop barrier layers for protection of F-M alloys from fuel-clad chemical interaction, and of alloy 617 from attack by coolant impurities in the VHTR intermediate heat exchanger

- Develop modeling tools to explain the behavior of F-M steels under irradiation, and predictive tools to extend the reach of our understanding beyond the experimental database

The objectives will be accomplished in a research program consisting of three major thrusts: 1) high dose radiation stability of advanced fast reactor fuel cladding alloys, 2) irradiation creep at high temperature and 3) innovative cladding concepts embodying functionally-graded barrier materials. While the initial three-year program will emphasize ion irradiation and irradiated microstructures, we expect that, if successful, the second three-year program will increasingly emphasize reactor irradiations and will include mechanical property determination through national user facilities.

Industry partners (EPRI and GE) will utilize the core program as leverage to guide or support additional activities that are of special interest to them, and that fall within the scope of the core program. National laboratory partners (ANL, INL, LANL, ORNL and PNNL) will provide additional capability and direction to various aspects of the core program that are of interest to them. Our technical society partner, ASME, will introduce the data generated by the consortium into the ASME Codes & Standards (C&S) process.

Beyond scientific achievements, this consortium will provide substantial additional outcomes that are expected to provide long term benefits to the advanced rector program, including the education of around eight graduate students and several post-docs, inclusion of minority students into the radiation effects and reactor materials fields through the participation of Alabama A&M University (a HBCU institution), creation of new working relationships between universities, laboratories and industry in an unprecedented manner and to an unprecedented degree, and establishment of a pathway to begin to incorporate data generated by the research thrusts into the ASME codes and standards that will be crucial for success of the advanced reactor programs.

Acquisition of a Research Grade Ion Implanter for Research and Education in Ion Beam Modification of Materials

G. S. Was, PI and L. M. Wang, Co-PI (with K. Najafi of EECE and R. Goldman of MSE)
National Science Foundation
$864,288/2 yrs

A new and highly versatile ion implanter will provide greatly expanded capabilities to the University's research programs, attract new research projects and foster the training of graduate and undergraduate students in ion-solid interactions. The 400 kV ion implanter made by National Electrostatics Corporation consists of an ion source and lens system, a gas supply system, a 90° analyzing magnet, a mass defining slit, beam position monitor, accelerator tube, and electrostatic quadrupole triplet lens, a beamline with a Faraday cup, neutral beam trap and raster-scanner, and a target station capable of 6 inch (150 mm) wafer handling, a four-position faraday cup arrangement for dose measurement and target

temperature control from LN_2 temperature to 800°C, and an ion source (Danfysik model 921A) for the production of high current and high brightness ion beams. Its versatility is due to its ability to ionize materials that have a low vapor pressure by using an oven to heat the charge materials to several hundred degrees, giving it the capability of making ions from a large fraction of the periodic chart. The implanter will be utilized immediately in research programs encompassing a wide range of scientific disciplines and focusing on nanoparticle formation in metals and ceramics, semiconductor nanostructures and heterostructures, atomic and molecular structure modification, and biomedical device materials. Examples of some of the novel uses of this facility are the formation of 3-D arrays of nanostructures to enhance physical and mechanical properties of materials, semiconductor nanopatterning by seeding the formation of nanometer-sized arrays of semiconductor structures, synthesis of bipolar quantum dot thermoelectric devices, femtosecond laser-assisted molecular beam epitaxy, refractive index patterning and the improvement of photoactive devices via ion implantation, and improved adherence of polymer coatings used in next-generation embolization coils for treating neurovascular defects, such as aneurysms and brain tumors. It will also play the lead role in providing surface modification capability to users of the NSF National Nanotechnology Infrastructure Network (NNIN) at the Michigan node. Overall, this implanter will provided a critical resource to 14 active research programs encompassing the work of 28 faculty in 9 departments at Michigan and representing over $22M of active or pending research programs, and will provide a unique resource to surrounding and partner schools. A significant role of the implanter will be to promote the teaching, training and education of graduate, undergraduate students and post-docs in surface modification and materials at the nanoscale, through research projects and formal classes, and to provide special programs for undergraduate students and K-12 outreach.

Alloys for 1000°C Service in the Next Generation Nuclear Plant

G. S. Was, PI (with J. W. Jones and T. Pollock)
D. Kumar and J. Kim, Graduate Students
U.S. Department of Energy, Nuclear Energy Research Initiative (NERI) ($873,912/3 yrs)
Idaho National Laboratory
$181,000/3 yrs

The objective of the proposed research is to define strategies for the improvement of alloys for structural components, such as the intermediate heat exchanger and primary-to-secondary piping, for service at 1000°C in the He environment of the NGNP. Specifically, we will investigate the oxidation/carburization behavior and microstructure stability and how these processes affect creep. While generating this data, the project will also develop a fundamental understanding of how impurities in the He environment affect these degradation processes and how this understanding can be used to develop more useful life prediction methodologies. Our initial studies will focus on the mechanisms controlling the high

temperature degradation of nickel-base alloy 617. Understanding the degradation mechanisms will allow us to predict long-term behavior (to extrapolate lab results to long-term service performance) and to identify an effective approach to modify existing alloys for improved performance. To achieve the latter, we will also investigate two material modification strategies; alloy modifications that provide additional solid solution strengthening and reduce interdiffusion (and therefore creep), and grain boundary engineering to reduce creep. The alloy selection and materials requirements will be based on the Next Generation Nuclear Plant Materials Selection and Qualification Program Plan (INEEL/EXT-03-01128) and the research plan will be closely integrated with, and designed to complement ongoing and planned studies on alloy 617 at INEEL and ORNL. The research will also provide a platform for educating students in the area of nuclear reactor materials and related issues.

BWRVIP Highly Irradiated Stainless Steel Crack Growth

G. S. Was, PI
S. Teysseyre, Assistant Research Scientist
General Electric
$50,000/2 yrs

This program focuses on post-test fracture surface examination of CGR samples in a scanning electron microscope (SEM) in a hot cell, in support of a larger program being conducted by General Electric for the Electric Power Research Institute. The microscope we will be using is a Philips Quanta-HiVac SEM. This instrument is ideal for hot cell applications since the vacuum and column system can be separated from the computer control. Therefore, the instrument can be moved into the hot cell when needed, while the computer control is located outside. Further, this instrument has a large specimen chamber and sample mounting system, both easing SEM use within a hot cell. The Quanta SEM uses operating voltages between 1 and 30 kV, allowing for analysis on a wide range of materials and excitation of the x-rays from all elements of interest. Energy dispersive x-ray spectrometry and a back-scatter detector will provide compositional analysis of irradiated specimens.

Each sample fracture surface will be examined to verify the straightness of the crack front and also to verify that the crack mode was indeed intergranular. Fracture surfaces will also be used to calibrate the DCPD results. The fracture mode during crack growth will be characterized in terms of the degree of intergranularity and to characterize secondary cracking. Both halves of the CT sample will be examined.

Candidate Materials Evaluation for the Supercritical Water-Cooled Reactor
G. S. Was, PI
R. Zhou, Post-doctoral scholar; E. West, Graduate Student
U.S. Department of Energy, Nuclear Energy Research Initiative (NERI)
$486,250/3 yrs

The supercritical-water-cooled reactor (SCWR) system is being evaluated as a Generation IV concept because it and builds on currently proven light water technology to provide for high thermal efficiency and plant simplification. Development, testing, and selection of suitable materials for cladding and internal components are central to the development of a SCWR. Supercritical water presents unique challenges to the long-term performance of engineering materials. Corrosion and stress corrosion cracking (SCC) in particular have been identified as critical problems because the temperature and the oxidative nature of supercritical water may accelerate the corrosion kinetics and induce stress corrosion cracking. In addition, the presence of radiation can influence corrosion and SCC both by altering the material microstructure and by accelerating corrosion and SCC due to the generation of oxygen and other free radicals via radiolysis. The existing database on the corrosion and stress corrosion cracking of materials in supercritical water is very sparse. Data on the behavior of irradiated alloys is non-existent.

The objective of the proposed research is to investigate degradation of materials in the supercritical water environment. First, representative alloys from the important classes of candidate materials will be studied for their corrosion and stress-corrosion cracking resistance in supercritical water. These will include ferritic-martensitic steels, austenitic stainless steels, and Ni-base alloys. Corrosion and SCC tests will be conducted at various temperatures and exposure times, as well as in various water chemistries. Second, emerging plasma surface modification and grain boundary engineering technologies will be applied to modify the near surface chemistry, microstructure, and stress-state of the alloys prior to corrosion testing. Third, the effect of irradiation on corrosion and stress-corrosion cracking of alloys in the as-received and modified/engineered conditions will be examined by irradiating samples using high-energy protons and then exposing them to supercritical water. All these tests will be performed in close coordination with, and as a complement to, the Generation IV testing programs on radiolysis corrosion/SCC of neutron irradiated materials in supercritical water. The research program will be performed by the University of Wisconsin and the University of Michigan. Both these institutions have a proven infrastructure for successfully implementing all aspects of the proposed research. The research will have a strong educational component with several graduate and undergraduate students participating.

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G. Gupta, Z. Jiao, A. N. Ham, J. T. Busby and G. S. Was, "Microstructural Evolution of Proton Irradiated T91," *J. Nucl. Mater.,* **351**, 1-3, 162-173 (2006).

Constant Extension Rate Testing of Alloy 690 in Supercritical Water

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$25,000/1 yr

Stress corrosion cracking susceptibility of Alloy 690 has been assessed by crack growth rate tests at temperatures just below and above the critical limit of water in an effort to obtain accelerated test data and to assess the likelihood of SCC occurring in primary water conditions. Results have produced IGSCC in alloy 690 and slow but stable crack growth rates (recent unpublished data by Jacko and Andresen). Constant extension rate experiments on a

different heat of alloy 690 in 400°C pure SCW containing less than 10 ppb O_2 produced IGSCC, indicating a susceptibility to crack initiation under these conditions [Was, 12th Env. Deg.]. A set of CERT experiments are proposed to 1) determine the SCW conditions under which alloy 690 is susceptible to IGSCC in SCW, 2) whether the cracking depends on water density, 3) whether it is the same as that in subcritical water, and possibly 4) whether hydrogen additions can affect cracking.

High Temperature Materials for the Gas-Cooled Fast Reactor

G. S. Was, PI; G. Gupta, Graduate Student
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$50,000/1 yr

Both France and the United States have a shared interest in the development of advanced reactor systems that employ inert gas as a coolant. Currently, insufficient physical property data exist to qualify candidate materials for gas-cooled fast reactor (GFR) designs. The overall goal of the GFR materials qualification program is to establish candidate metallic and ceramic materials for GFR designs and to evaluate the mechanical properties, dimensional stability, and corrosion resistance.

As part of the GFR evaluation of metallic components, a study is underway to determine if grain boundary engineering techniques can improve the high temperature creep strength of candidate metals by optimizing grain boundary structural orientations. As part of this study, the focus of our work is in the following areas: 1) grain boundary engineering of T91 and HT-9, 2) tests to understand the thermal stability of treatments developed to optimize the grain boundary structure of T91, 3) creep testing of alloy T91 in both the as-received and optimized conditions, 4) characterization of the microstructure in the as-received, aged, crept and optimized alloy T91, and 5) grain boundary engineering of nickel-base alloy 617.

Localized Deformation as a Primary Cause of Irradiation Assisted Stress Corrosion Cracking

G. S. Was, PI (with J. T. Busby, ORNL – collaborator)
G. Jiao, Postdoctoral Scholar
U.S. Department of Energy, Nuclear Engineering Education Research Program (NEER)
$300,000/3 yrs

The purpose of this project is to establish that localized deformation in irradiated LWR core internals is a primary factor in irradiation assisted stress corrosion cracking (IASCC). This mode of degradation is a continuing problem in existing LWRs and is expected to be a more serious problem in advanced LWRs and water-cooled Generation IV concepts such as the supercritical water reactor. Progress in understanding the mechanism driving IASCC has been

slow due to the difficulty in unfolding the various contributions to the irradiated microstructure that may contribute to IG cracking. However, data from both unirradiated and irradiated austenitic alloys point toward slip localization in the form of intense, dislocation channels as a common factor in the cause of IG cracking in these alloys. The plan of work seeks to establish the role of localized deformation using a series of carefully chosen alloys and a systematic set of experiments designed to quantify the degree of slip localization as a function of alloy stacking fault energy (SFE) and dislocation channeling following irradiation. Experiments in BWR normal water chemistry will provide the link between slip localization and IASCC susceptibility. A primary outcome of the project is to provide guidance for the development of mitigation measures for IASCC.

Z. Jiao and G. S. Was, "Localized Deformation and IASCC Initiation in Austenitic Stainless Steels," *J. Nucl. Mater*. (In press)

Z. Jiao and G. S. Was, "The Role of Localized Deformation on IASCC of Proton-Irradiated Austenitic Stainless Steel," *13th International Conference on Degradation of Materials in Nuclear Power Systems – Water Reactors*, T. R. Allen, J. Busby and P. J. King, eds., Canadian Nuclear Society Society. (In press)

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A Mechanistic Basis for Irradiation Assisted Stress Corrosion Cracking

G. S. Was, PI
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Electric Power Research Institute (EPRI)
$60,000/2 yrs

Irradiation assisted stress corrosion cracking (IASCC) refers to intergranular stress corrosion cracking that is accelerated under the action of irradiation in light water reactor core components. It is referred to as "assisted" because irradiation enhances, or accelerates the IGSCC process over the unirradiated state. IASCC has been a problem in the nuclear industry for the last 30 years and continues to occur due to a lack of understanding of its underlying mechanism. It is the single most important problem in core component cracking in boiling water reactors (BWR) [1] and is of growing importance in pressurized water reactors (PWR). Understanding the mechanism of IASCC is required in order to provide guidance for the development of mitigation strategies.

The IASCC problem has taken on new urgency with the proposal of more advanced water reactor concepts under the Generation IV program [2], such as the supercritical water reactor (SCWR). The SCWR represents a more demanding environment than LWRs in temperature,

irradiation dose and the corrosiveness of the media itself. As such, there is an even more pressing need to develop a solution to the IASCC problem. However, in order to do so, the underlying mechanism must first be understood. This proposal aims to establish such an understanding, which will lead directly to mitigation strategies for current and future reactors. The objective is to determine whether deformation mode is a primary factor in the mechanism of irradiation assisted intergranular stress corrosion cracking of austenitic alloys in light water reactor core components.

Z. Jiao, J. T. Busby and G. S. Was, "Deformation Microstructure of Proton-Irradiated Stainless Steels," *J. Nucl. Mater.*, **361**, No. 2-3, 218-227 (2007).

G. S. Was, Z. Jiao and J. T. Busby, "Contribution of Localized Deformation to IGSCC and IASCC," *European Conference on Fracture – 16*, Alexandroupolis, Greece, July 2006.

Radiation-Induced Segregation and Phase Stability in Candidate Alloys for the Advanced Burner Reactor

G. S. Was
J. Peniston, Graduate student
U.S. Department of Energy, Nuclear Energy Research Initiative (NERI)
$750,000/3 yrs

The primary objective of this project is to investigate the effect of irradiation on the segregation and phase stability in candidate alloys proposed for application as structural materials for transmutation in the advanced burner reactor. The project will focus on two ferritic-martensitic alloys, and will also include an experimental ODS alloy and an advanced austenitic alloy in a coordinated experimental and modeling effort to investigate the complex electronic–magnetic–elastic interactions between Cr and radiation induced defects controlling radiation induced segregation in F-M alloys. This project will provide a mechanistic understanding of segregation and phase stability that can be used to develop predictive irradiation performance models. It will also provide data against which forthcoming in-reactor irradiations can be interpreted and understood, as well as guidance and direction for those experiments.

This proposal is centered on the two F-M alloys; T91 and HT-9 as both are viable candidates for the ABTR and form the basis for more advanced alloys for the ABR, and will focus on Cr RIS and phase stability in these alloys under irradiation, as these are potentially limiting processes for their application. However, the full, irradiated microstructure needs to be considered as the radiation effects processes are interrelated. Also included in the workscope is a ferritic ODS alloy because of its superior irradiated microstructure stability and strength. In addition, an advanced austenitic candidate alloy, D9, is included because it is the leading austenitic alloy, and yet it potentially can suffer from RIS (of Si) and the formation of

deleterious phases (silicides) that could affect performance. Experiments will be conduced by proton and heavy ion irradiation over the dose range 3-100 dpa and the temperature range 350-550°C with the inclusion of He at the highest doses. Analysis of RIS, phase microstructure, dislocation microstructure and hardening will be conducted on all conditions to provide a systematic set of data.

The modeling tasks will involve ab-initio electronic structure calculations to investigate the configuration-dependent binding and migration energies of Cr with vacancy and interstitial defects, including small clusters. These values will enable development of atomistic-based kinetic Monte Carlo models similar to those employed previously to evaluate He diffusion in Fe and specifically designed to investigate the Cr diffusivity by interstitial and vacancy mechanisms. The RIS tendencies of Cr in F-M alloys will be predicted as a function of temperature and dose, based on migration mechanisms and energies obtained from ab initio calculations. The outcomes of this modeling task will be mechanistic interpretation of the complex Cr RIS behavior, and key diffusional parameters for both continuum level rate theory models and the development predictive RIS models of Cr and Si in F-M alloys.

The combined experimental-modeling program is designed to provide a set of data on the behavior of RIS, phase microstructure, dislocation microstructure and hardening as a function of dose and temperature in the range 350-550°C and 3-100 dpa. This data will be used to benchmark RIS and dislocation microstructure models developed from ab initio electronic structure calculations and extended to kinetic Monte Carlo and continuum rate theory (MIK) models.

Stress Corrosion Cracking and Corrosion of Candidate Alloys for the Supercritical Water Reactor Concept

G. S. Was, PI
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U.S. Department of Energy, International Nuclear Energy Research Initiative (INERI)
$1,033,207/3 yrs

Supercritical water presents unique challenges to the long-term operation of engineering materials. The generation of oxygen and hydrogen gas by radiolysis and the high solubility of these gases in supercritical water may result in higher corrosion and stress corrosion cracking rates than experienced with other reactor designs. In addition, radiation may accelerate or assist the stress corrosion cracking in the reactor region, and stress corrosion cracking and accelerated corrosion may occur in the preheat and cool-down sections of the circuit. The existing data base on the corrosion and stress corrosion cracking of austenitic stainless steel and nickel based alloys in supercritical water is very sparse. Data on the behavior of irradiated alloys is non-existent. Therefore, the focus of this work will be stress-corrosion-cracking behavior of candidate fuel cladding and structural materials in the unirradiated and irradiated conditions. Two high-temperature autoclave systems have been built to test the SCC and

corrosion behavior of unirradiated and proton-irradiated materials. Proton irradiation is used as a surrogate for neutron irradiated material in order to get a first look at the response of candidate alloys to irradiation, and also to cover alloys for which there are currently no neutron irradiated samples for testing. A third high-temperature autoclave coupled to a loading system, and capable of straining up to four tensile samples in constant extension rate mode or one compact tension sample in crack growth rate mode is being built and operated at the University of Michigan (U-M). This system is being constructed for conducting experiments on neutron-irradiated materials. The resulting data will be used to further narrow the list of promising materials and develop appropriate stress-corrosion-cracking correlations. The capability to conduct both crack growth rate and constant extension rate tensile experiments on neutron-irradiated samples will constitute the first facility capable of assessing SCC of neutron irradiated alloys in supercritical water.

The work plan for this three year (FY05-FY07) program consists of four principal tasks; 1) the completion of a facility to conduct crack growth rate and constant extension rate tensile tests on highly radioactive, neutron irradiated samples in supercritical water, 2) constant extension rate tests and crack growth rate tests of candidate alloys in supercritical water, 3) proton irradiation and constant extension rate tests of proton-irradiated samples in supercritical water and 4) constant extension rate tests and crack growth rate tests of candidate neutron-irradiated alloys in supercritical water.

S. Teysseyre and G. S. Was, "Stress Corrosion Cracking of Neutron Irradiated Steel in Supercritical Water," *13th International Conference on Degradation of Materials in Nuclear Power Systems – Water Reactors*, T. R. Allen, J. Busby and P. J. King, eds., Canadian Nuclear Society Society. (In press)

S. Teysseyre, Z. Jiao, E. West and G. S. Was, "Effect of Irradiation on Stress Corrosion Cracking In Supercritical Water," *J. Nucl. Mater.*, **371,** 107-117 (2007).

S. Teysseyre, Q. Peng, C. Becker and G. S. Was, "Facility for Stress Corrosion Cracking of Irradiated Specimens in Supercritical Water," *J. Nucl. Mater.* (In press)

PLASMAS AND FUSION

Optimization of an ECR Plasma as a Source for Electric Propulsion Systems
J. Foster, PI
NASA GSRP
$29,000/yr

Understanding the Physical Mechanisms of Electron Emission in an Orificed Electron Cyclotron Resonance Plasma Cathode
J. Foster, PI
Rackham Research Grant
$36,705/1 yr

J. E. Foster, E. Gillman, B. Sommers and B. Weatherford, "Magnetically Enhanced Inductive Plasma Source for Electric Propulsion Applications," *Proceedings of the 43rd Joint Propulsion Conference, AIAA Paper 2007-5294*.

Y. Hidaka, J. E. Foster, W. D. Getty, R. M. Gilgenbach and Y. Y. Lau, "Performance and Analysis of an ECR Plasma Cathode," accepted for publication, *Journal of Vacuum Science and Technology*, May 2007.

J. E. Foster, B. Weatherford and B. Sommers, "Electron and Ion Source ECR Plasma for Electric Propulsion Applications, *Proceedings of the 2007 IEEE Pulsed Power and Plasma Science Conference*, Albuquerque, June 17-22, 2007.

J. E. Foster, G. J. Williams, and M. J. Patterson, "Characterization of an Ion Thruster Neutralizer," accepted for publication, *Journal of Propulsion and Power*, February 1, 2007.

M. J. Patterson, J. Foster, H. D. McEwen, E. Pencil and J. VanNoord, "NEXT Multi-Thruster Array Test-Engineering Demonstration," *AIAA Paper 2006-5180, Proceedings of the 42nd Joint Propulsion Conference*, Sacramento, CA, July 2006.

J. Foster, E. Pencil, H. McEwen, M. J. Patterson, E. Diaz and J. Van Noord, "Neutralizer Plasma Coupling in a NEXT Multi-thruster Array," *AIAA Paper 2006-5184, 42nd Joint Propulsion Conference and Exhibit*, Sacramento, CA, July 2006.

J. Foster, E. Pencil, M. J. Patterson, H. McEwen, E. Diaz and J. Van Noord, "Plasma Characteristics Measured in the Plume of a NEXT Multi-Thruster Array," *AIAA Paper 2006-5181, 42nd Joint Propulsion Conference and Exhibit*, Sacramento, CA, July 2006.

Experimental and Theoretical Studies of Wire Z-Pinches

R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
U.S. Department of Energy/Sandia National Laboratories
$300,000/yr

The purpose of this work is to perform detailed diagnostics on expanding plasma ionization dynamics of a new z-pinch plasma experiment built at the University of Michigan.

W. Tang, T. S. Srickler, Y. Y. Lau, R. M. Gilgenbach, J. Zier, M. R. Gomez, E. Yu, C. Garasi, M. E. Cuneo and T. A. Mehlhorn, "Linear and Nonlinear Evolution of Azimuthal Clumping Instabilities in a Z-pinch Wire Array," *Phys. Plasmas*, **14**, 012706 (2007).

T. Strickler, "Azimuthal Wire Motion and Ablation Dynamics in Z-Pinches," *Doctoral Dissertation*, University of Michigan, Ann Arbor (2006).

DURIP Equipment Grant: Versatile Ultrawideband Generator and Antenna System

R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
U.S. Department of Defense/Air Force Office of Scientific Research
$205,000/1 yr

This is supplementary funding for equipment purchase of an ultrawideband generator and antenna for biological applications.

Industrial Affiliates Program (L-3 Communications)

R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
L-3 Communication Electron Devices
$10,000/yr

This gift from L-3 Communications facilitates communication with researchers in the U-M Intense Energy Beam Interaction Laboratory.

Industrial Affiliates Program (Northrop Grumman)
R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
Northrop Grumman Corporation
$10,000/2 yrs

This gift from the Northrop Grumman Corporation facilitates communication with researchers in the U-M Intense Energy Beam Interaction Laboratory.

Nanophysics of Electron Emission and Breakdown for High Power Microwaves
R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
U.S. Department of Defense/Air Force/Univ. CA-Davis
$350,000/5 yrs

This project concerns several issues in microwave generation from vacuum electron microwave devices.

Y. Y. Lau, J. P. Verboncoeur and H. C. Kim, "Scaling Laws for Dielectric Window Breakdown in Vacuum and Collisional Regimes," *Appl. Phys. Lett.*, **89**, 261501 (2006).

K. Jensen, Y. Y. Lau and N. Jordan, "Emission Nonuniformity Due to Profilimetry Variation in Thermionic Cathodes," *Appl. Phys. Lett.*, **88**, 164105 (2006).

L. K. Ang, W. S. Koh, Y. Y. Lau and T. J. T. Kwan, "Space-Charge-Limited Flow in the Quantum Regime," *Phys. Plasmas*, **13**, 056701 (2006). (Invited)

Phase Locking of Commercial Magnetrons
R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
U.S. Office of Naval Research/University of New Mexico
$370,000/3 yrs

This project studies mode locking of high power microwave devices, in collaboration with the University of New Mexico.

Relativistic Magnetron Priming Experiments and Theory
R. M. Gilgenbach, PI and Y. Y. Lau, Co-PI
U.S. Department of Defense/Air Force Office of Scientific Research
$1,856,000/5 yrs

This research provides novel methods of priming relativistic magnetron for generating 100's MW microwave pulses.

W. M. White, R. M. Gilgenbach, M. C. Jones, V. B. Neculaes, Y. Y. Lau, P. Pengvanich, N. Jordan, B. W. Hoff, R. Edgar, T. A. Spencer and D. Price, "Radio Frequency Priming of a Long-Pulse Relativistic Magnetron," *IEEE Trans. Plasma Sci.*, **34**, 627 (2006).

Y. Y. Lau, J. W. Luginsland, K. L. Cartwright and M. D. Haworth, "Role of Ions in a Crossed-field Diode," *Phys. Rev. Lett.*, **98**, 015002 (2007).

Ultra-Wideband RF Enhanced Electroporation for Chemotherapy

R. M. Gilgenbach, PI; Y. Y. Lau and M. Uhler (Medical School), Co-PIs
U.S. Department of Defense/Air Force Office of Scientific Research
$900,000 for 6 years

This is an innovative new research project that explores the fundamental interactions of non-ionizing RF radiation with biological cells. The goal is to combine ultra-wideband radiation with chemotherapy treatment of tumor cells. A factor of 1,000 improvement in chemotherapy drug effectiveness has been demonstrated by the application of high electric fields to cells.

D. W. Jordan, M. D. Uhler, R. M. Gilgenbach and Y. Y. Lau, "Enhancement of Cancer Chemotherapy *in vitro* by Intense Ultrawideband Electric Field Pulses," *J. Appl. Phys.*, **99**, 094701 (2006).

A. L. Garner, Y. Y. Lau, D. W. Jordan, M. D. Uhler and R. M. Gilgenbach, "Implications of a Simple Mathematical Model to Cancer Cell Population Dynamics," *Cell Prolif.*, **39**, 15 (2006).

Study of Plasma Dynamics in the GDM Plasma Thruster

T. Kammash, PI
NASA – GSRP
$72,000/3 yrs

Plasma confined in the Gasdynamic Mirror (GDM) can be heated to sufficiently high temperatures to serve as a thruster when the plasma is ejected from one of the mirrors to generate thrust. Several conditions must be satisfied in order for this to be achieved, including adequate confinement, generation of the accelerating electrostatic potential and stability for the duration of this confinement. This study is aimed at addressing the various plasma phenomena that impact these conditions.

T. Kammash and R. Tang, "Muon-Boosted Fusion Propulsion System," *43rd Joint Propulsion Conference*, Paper #AIAA-2007-5609, Cincinnati, OH, July 8-11, 2007.

T. Kammash and R. Tang, "Antiproton-Driven Fusion Propulsion System for OTV Applications," *43rd Joint Propulsion Conference,* Paper #AIAA-2007-5610, Cincinnati, OH, July 8-11, 2007.

T. Kammash, R. Tang and A. D. Gallimore, "Field Asymmetry and Thrust Control in the GDM Fusion Propulsion System," *43rd Joint Propulsion Conference*, Paper #AIAA-2007-5612, Cincinnati, OH, July 8-11, 2007.

T. Kammash, R. Tang and B. Cassenti, "A Bi-Model Fusion Propulsion System for He-3 Mining of the Planets," *Trans. American Nuclear Society*, **94**, 4-8 (2006).

T. Kammash, "Antiproton-Driven Gas Core Fission Rocket," *J. British Interplanetary Society*, **59**, 23-26 (2006).

T. Kammash, R. Tang and B. Cassenti, "A Bi-Model Fusion Propulsion System for He-3 Mining of the Planets," *Trans. American Nuclear Society*, **94**, 4-8 (2006).

T. Kammash and R. Tang, "Propulsive Capability of Assymmetric GDM Propulsion System," *42nd Joint Propulsion Conference*, Paper #AIAA-2006-4391, Sacramento, CA, July 9-12, 2006.

T. Kammash and R. Tang, "Antiproton Driven Bi-Model Fusion Propulsion System," *42nd Joint Propulsion Conference*, Paper #AIAA-2006-4394, Sacramento, CA, July 9-12, 2006.

Intergovernmental Personnel Act (IPA) Assignment
at Air Force Research Laboratory
Y. Y. Lau, PI
U.S. Department of Defense, Air Force
$116,787/1.5 years

This is to support the 2006 sabbatical leave and AFRL on-site research on high power microwaves.

Y. Y. Lau, J. W. Luginsland, K. L. Cartwright and M. D. Haworth, "Role of Ions in a Crossed-Field Diode," *Phys. Rev. Lett.*, **98**, 015002 (2007).

RADIATION MEASUREMENTS AND IMAGING

Increased Range Neutron Response High Explosives Detection

M. D. Hammig, PI
U.S. Department of Defense, Air Force (subcontract)
$98,359/9 months

A depth-sensitive Compton camera based on fast inorganic scintillators is being developed as a means to rapidly image high explosives and other organic materials in three dimensions at intermediate to long ranges. When coupled with an intense pulsed neutron source, the fast response and sizable detection areas of BaF_2 scintillators permit the rapid imaging of the environment in both depth and angle. This project, a collaboration between the University of Michigan and a small business concern, includes the development of novel position sensing techniques within the volume of a scintillation material and the further advancement of fast timing techniques.

M. D. Hammig and B. T. Wells, "Development of a Depth and Angular-Sensitive Gamma-Camera for Imaging Neutron-Interrogated Materials," presented at *2006 IEEE Nuclear Science Symposium*, San Diego, CA.

Gamma Ray Array for Passive Detection of Hidden Objects

M. D. Hammig, PI
U.S. Department of Defense, Army (subcontract)
$98,224/6 months

During this project, we are determining the optimal means by which one may use the natural background radiation to see hidden objects in buildings and below ground. To that end, we are building a gamma-ray detector array, based primarily on semiconductor devices composed of silicon, to image deviations in the angular distribution of the incident gamma-rays. One of the goals of this business-university collaboration is to extend both the carrier and spatial sensitivities of position-sensing semiconductor devices.

Advanced Radiation Detector Development in Support of National Security Needs

Z. He, PI
U.S. Department of Energy/NA-22 Office
$1,320,000/4 yrs

The goal of this research project is to develop compact radiation detectors which can be useful in non proliferation applications. The project supports exciting research in room temperature detectors using semiconductors such as CZT.

Constructing 3D CdZnTe Polaris II Isotope Identifier

Z. He, PI
U.S. Department of Energy/Battelle Pacific Northwest Laboratories
$724,728/3 yrs

This project develops the first array system using 3-dimensional position-sensitive CdZnTe gamma-ray spectrometers for isotope identification. This system will employ 18 1.5×1.5×1 cm^3 modular detectors, having a total detection volume of 40.5 cm^3. The expected energy resolution is about 1% FWHM or better at 662 keV gamma-ray energy and angular resolution less than 20 degrees within a 4π solid angle. The applications are for nuclear non-proliferation and homeland security.

F. Zhang, Z. He and C. E. Seifert, "A Prototype Three-Dimensional Position Sensitive CdZnTe Detector Array," accepted for publication in *IEEE Transactions on Nuclear Science*, 2007.

Detection of Shielded Uranium and Plutonium

Z. He, PI
Department of Defense, Defense Threat Reduction Agency (DTRA)
$4,500,000/4 yrs

This project is to develop unprecedented array systems using 3-dimensional position-sensitive CdZnTe and HgI_2 gamma-ray imaging spectrometers, which will have total detection volume of more than 100 cm^3 per system. These systems will be tested against real special nuclear materials at the end of the project.

F. Zhang and Z. He, "New Readout Electronics for 3-D Position Sensitive CdZnTe/HgI2 Detector Arrays," *IEEE Tran. on Nucl. Sci.*, **53,** 5, 3021-3027, October 2006.

D. Xu and Z. He, "Filtered Back-Projection in 4-pi Compton Imaging with a Single 3D Position Sensitive CdZnTe Detector," *IEEE Tran. on Nucl. Sci.*, **53**, 5, 2787-2795, October 2006.

D. Xu and Z. He, "Gamma-Ray Energy-Imaging Integrated Spectral Deconvolution," *Nuclear Instruments and Methods in Physics Research A*, **574,** 98-109 (2007).

Development of Pixellated Mercuric Iodide Gamma-Ray Detectors
Zhong He, PI
Constellation Technology Corporation
$149,718/2 yrs

This project develops thick (1cm) pixellated prototype HgI_2 gamma-ray spectrometers with energy resolution of about 1% FWHM at 662 keV.

Development of TlBr Gamma-Ray Spectrometers
Zhong He, PI
Sub-contract from Radiation Monitoring Devices
Prime sponsors: DNDO of Department of Homeland Security and DTRA, Department of Defense
$626,162/2 yrs

Evaluation of Microelectronic Readout for 3D Position-Sensitive CZT/HgI2 Detector Arrays
Zhong He, PI
Dept. of Homeland Security, Domestic Nuclear Detection Office/Brookhaven National Laboratory subcontract
$50,144/4 mos

Test of a 2x2x2 Array of 1.5 cm Thick CdZnTe Detectors and Study of their Internal Backgrounds in High-Altitude Balloon and Space Environment
Zhong He, PI
NASA
$97,343/2 yrs

This project is developing a 2×2 array system using 2×2×1.5 cm^3 CdZnTe 3-dimensional position-sensitive detectors for astrophysics applications.

Voxelated CZT Detectors with Readout and Algorithm Development for Intelligent Personal Radiation Locator (IPRL) Project
Zhong He, PI
Department of Homeland Security/Lawrence Livermore National Laboratory
$247,458/13 mos

For publications of Professor Zhong He's group, see website at:
http://czt-lab.engin.umich.edu

Integration of Electron Tracking into Compton Imaging for the Advanced Compton Telescope

D. K. Wehe, PI
National Aeronautics and Space Administration (NASA)
$24,000/1 yr

This project seeks to understand the significance of the Compton recoil electron direction in enhancing the images produced by electronically collimated gamma ray imagers. As position sensing capabilities continue to improve with finer pitch electrodes, it may be possible by looking at bystander signals to not only determine sub-pitch lateral resolution, but also to infer some information as to the electron's initial direction.

Mobile Robotics and Sensing – University Research Program in Robotics

D. H. Wehe, PI
U.S. Department of Energy
$852,500/yr

The University of Michigan extends the capabilities of current mobile robots to provide increased autonomy of remote operations, so that sensors and other technologies can be quickly and safely delivered to interior and outdoor environments of large expanses. The University of Michigan also develops advanced radiation sensing technologies for use in DOE environments. Current projects include the development of hybrid gamma ray imagers, development of unique digital pulse processing techniques, active interrogation for surveillance and monitoring, and micro-mechanical radiation detectors.

Radionuclides: Radiation Detection and Quantification

D. H. Wehe, PI (with W. L. Rogers)
NIH/U-M Nuclear Medicine (subcontract)
$214,933/3 yrs

This project involves the development of electronically collimated gamma ray imagers for nuclear medicine applications, including SPECT, and combined PET+SPECT for small animal imaging. NERS students work with researchers in nuclear medicine to develop the prototype imaging systems and the algorithms for interpreting the data.

RADIATION SAFETY, ENVIRONMENTAL SCIENCES, AND MEDICAL PHYSICS (REM)

Applied Environmental Radiation Measurements Laboratory

K. J. Kearfott, PI
U-M Elizabeth Caroline Crosby Research Award
$64,000

A new facility has been established which focuses on the measurement of small amounts of radiation in the environment and in laboratory samples. Unique, practical capabilities to solve actual industrial, medical, nuclear power, and national laboratory radiation safety challenges are to be developed through applied research. A variety of specific projects, relating to nuclear facility decommissioning, nuclear power plant emissions verification, geological research, radiotracer experiments, responses to radiological terrorists events, and the clean-up of contaminated environments are possible. Capabilities include alpha spectroscopy, portable and laboratory gamma and X-ray spectroscopy with HPGe and NaI, integrative and temporal radon and radon progeny measurement, and thermoluminescent dosimetry.

Detection of Concealed Conventional Bulk Explosives

K. J. Kearfott, PI
nPoint, LLC
$305,000/yr

Several different neutron-based methods for detecting explosives are possible, all based upon detection of the excess nitrogen found in explosives. This project has as its goals the investigation of several new approaches, as well as the combination of existing approaches for improved sensitivity and specificity. The grant focuses upon the development of an experimental facility for studying these approaches.

M. T. Studenski, N. P. Haverland and K. J. Kearfott, "Simulation, Design, and Construction of a ^{137}Cs Irradiation Facility," *Health Physics Journal, Operational Radiation Safety,* submitted May 2006.

M. T. Studenski and K. J. Kearfott, "Design and Simulation of a Neutron Facility," *Health Physics Journal, Operational Radiation Safety*, submitted June 2006.

Explosives Detection Using Neutrons

K. J. Kearfott, PI
U.S. Department of Defense/Army (TACOM)
$99,999/yr

Simulations are to be performed to fully characterize the interrogation of objects and the environment for the detection of explosives. The simulations should lead to an understanding of the best approach for the detection of explosives. The problems of land mines, improvised explosive devices, car bombs, and large amounts of explosives held in shipping containers are to be addressed separately.

NERS 585 Laboratory Development

K. J. Kearfott, PI
U-M NERS and College of Engineering
$150,000

A new laboratory is being developed for applied radiation measurements, featuring practical laboratory exercises of relevance to radiation safety, environmental sciences, and medical physics. The laboratory will also feature a combination of physical measurements with computational simulations.

Radiation Dosimeter Development

K. J. Kearfott, PI
PreSense, LLC
$285,000/yr

Illicit nuclear materials for atomic or nuclear weapons or for use in radiological dispersive devises (dirty bombs) have become of great national interest since September 11. This research project has as its goals the investigation of optically stimulated and thermally stimulated materials for use to detect such materials through the integration and read-out of signals in unique ways. New materials with specific temporal properties are also being investigated.

Radioactive Materials Risk Transportation

K. J. Kearfott, PI
Sandia National Laboratories
$31,000/yr

This work involves the analytical and experimental study of the radiation exposures that result from the compromise in the lead liner of a high level waste (nuclear fuel) shipping cask. Analytical models based upon point spread functions are to be developed for incorporation into the risk analysis code RADTRAN. Verification of this equation is to be accomplished using MCNP as well as a down-scaled experimental model.

Optimization of High-Dose Conformal Therapy. Project 2 Treatment Individualization Amid Geometric Uncertainty

R. K. Ten Haken, Project Leader (10% effort); B. A. Fraass, Program P.I.
National Cancer Institute
(approximately $250,000. direct cost annually)

The overall goal of Project 2 is to study means to plan, implement, verify, and if necessary, adapt optimized treatments for individual patients, enhancing patient models and applying new knowledge gained from patient-specific measurements as treatment progresses.

N. Tyagi, W. R. Martin , J. Du, A. F. Bielajew and I. J. Chetty, "A Proposed Alternative to Phase-Space Recycling Using the Adaptive Kernel Density Estimator Method," *Medical Physics*, **33,** 553-560 (2006).

I. J. Chetty, M. Rosu, M. L. Kessler, B. A. Fraass, R. K. Ten Haken, F.-M. Kong and D. L. McShan, "Reporting and Analyzing Statistical Uncertainties in Monte Carlo–Based Treatment Planning," *International Journal of Radiation Oncology, Biology Physics*, **65**, 1249-1259 (2006).

D. W. Litzenberg, S. W. Hadley, N. Tyagi, J. M. Balter, R. K. Ten Haken and I. J. Chetty, "Synchronized Dynamic Dose Accumulation," *Medical Physics,* **34**, 91-102 (2007).

M. Rosu, J. M. Balter, I. J. Chetty, M. L. Kessler, D. L. McShan, P. Balter and R. K. Ten Haken, "How Extensive of a 4D Dataset is Needed to Estimate Cumulative Dose Distribution Plan Evaluation Metrics in Conformal Lung Therapy?" *Medical Physics,* **34**, 233-245 (2007).

N. Tyagi, J. M. Moran, D. W. Litzenberg, A. F. Bielajew, B. A. Fraass and I. J. Chetty, "Experimental Verification of a Monte Carlo-Based MLC Simulation Model for IMRT Dose Calculation," *Medical Physics,* **34**, 651-663, 2007.

M. Rosu, I. J. Chetty, D. S. Tatro and R. K. Ten Haken, "The Impact of Breathing Motion versus Heterogeneity Effects in Lung Cancer Treatment Planning," *Medical Physics,* **34**, 1462-1473 (2007).

Better Correlation of Outcome with MC Dose Calculation
R. K. Ten Haken, PI (5% effort)
National Cancer Institute (I. J. Chetty, PI) /University of Nebraska
$13,000 direct cost annually

The purpose of this investigation is to see if clinical outcomes correlate better with dose calculations performed by the Monte Carlo method. The Monte Carlo method is acknowledged to be the most accurate dose calculation method. However, it is not yet resolved that using this method, which involves significant computational overhead, would improve radiotherapy delivery significantly.

Fiscal Year 2007 Research Expenditures

(July 1, 2006 – June 30, 2007)

Total Research Expenditures Attributed to an External Sponsor and Other Sponsored Activity

Project Director	Sponsor	Project Title	Project Grant	Expenditures
Atzmon	NSF	Structural Relaxation and Properties of Planar Defects in Amorphous and Nanocrystalline Metals	F008643	15,452
Atzmon	NSF	Structure, Properties and Relaxation of Shear Bands in Metallic Glasses	F015539	90,648
Ewing	DoE	Particle-Induced Amorphization of Complex Ceramics	C036028	(6,597)
Ewing	NSF	Radiation Effects in Mineral Collaborative Research Program	F004226	16
Gilgenbach /Lau	DoE / Subcontract	Ionization Dynamics of Wire Z-Pinches	F009898	336,150
Gilgenbach /Lau	DoD/AF	Nanophysics of Electron Emission and Breakdown for High Power Microwaves	F010707	42,203
Gilgenbach /Lau	DoD/AF	Relativisic Magnetron Priming Experiements and Theory	F012088	236,861
Gilgenbach /Lau	DoD/AF	Cut-Cathode High-Power Microwave (HPM) Magnetron Experiments & Theories	F012908	(970)
Gilgenbach /Lau	DoD/AF	UWB Microwave Antenna Research for Biological Applications	F013633	94,988
Gilgenbach	DoD/AF	Versatile Ultrawideband Generator with Novel Antenna	F015511	201,330
Gilgenbach	Navy/ Subcontract	Phase Locking of High Energy Commercial Off-the-Shelf (COTS) Magnetrons	F016010	70,703

Gilgenbach	DoE/ Subcontract	User Experiments on Wire Ablation Physics	F017192	30,063
Gilgenbach	Applied Materials, Inc.	Applied Materials Gift Fund	G001636	12,326
Gilgenbach	L-3 Communi-cations	Support for University Research in Vacuum Electronics	N006404	188
Gilgenbach	L-3 Communi-cations	Support for University Research in Vacuum Electronics	N007747	3,819
Hammig	DoD/AF-Subcontract	Depth and Angular Imaging via a Compton Camera Using Fast Inorganic Scintillators	F015209	25,881
Hammig	DoD/Army-Subcontract	An Array of Hybrid Si-Scintillator Direction-Sensitive Detectors for Imaging the Gamma-Ray Background	F015978	40,070
Hammig	DoD/DTRA	Silicon-Based Examination of Gamma-Ray and Neutron Interactions with Solid-State Materials	F016785	54,961
Hammig	Dept of Homeland Security	Silicon-Based 3D Position-Sensitive Scatter Detector with Integrated Amplification	F017068	9,624
He	DoD/DTRA	Evaluation and Testing of 3D Pixellated Mecuric Iodide Gamma-Ray Detectors	F013948	947
He	DoE	Development of Advanced 3-D CdZnTe (Cadmium Zinc Telluride) Detector Arrays	F014259	243,082
He	NASA /SubK	Test of 2x2x2 Array of 1.5cm Thick CdZnTe Detectors and Study of Their Internal Backgrounds in High-Altitude Balloon and Space Environments	F014439	67,194
He	DoE/ Subcontract	Constructing 3D CdNzTe Polaris II Isotope Identifier	F015043	230,378
He	DoD/SubK	Detection of Shielded Uranium and Plutonium	F015358	788,786

He	DoE	Development of High Resolution 3-Dimensional Position-Sensitive CdZn Te Gamma-Ray Spectrometers	F016320	67,565
He	Constellation Tech Corp	Evaluation and Testing of 3D Fully-Pixellated Mecuric Iodide Gamma-Ray Spectrometers	F016600	62,496
He	Homeland Security Subcontract	Evaluation of Microelectronic Readout for 3D Position-sensitive CZT/HgI2 Detector Arrays	F016954	49,457
He	Homeland Security Subcontract	Voxelated CZT Detectors with Readout and Algorithm Development for Intelligent Personal Radiation Locator (IPRL) Project	F017128	80,016
Holloway/ Lee	DoE/NERI	Model-Based Transient Control and Component Degradation Monitoring in Generation IV Nuclear Power Plants	F007323	1,109
Holloway	DoE/ Subcontract	Development of Time-Dependent Pn Solver for Alegra	F009881	26,759
Holloway	DoE/ Subcontract	Exploring Layered Materials with Neutron and Photon Spectroscopy to Determine Depth and Water Content in Subsurface Layers of Planets	F015797	22,781
Kammash	NASA/ Subcontract	Effect of Ambipolar Potential on Propulsive Performance of the GOM Plasma Thruster (Phase 1 and 2)	F013022	83,808
Kammash	NASA	Study of Plasma Dynamics in the Gasdynamic Mirror Plasma Thruster	F013312	23,573
Kearfott	DoE/ Subcontract	Radioactive Materials Transportation Risk Analysis	F011682	1,872
Kearfott	DoD/Army Subcontract	Explosives Detection Using Neutrons	F013093	(287)
Kearfott	DoE/ Subcontract	Nuclear Science for National Security Fellowship for John A. Harvey	F017295	20,027
Kearfott	NPoint, LLC	Detection of Concealed Conventional Bulk Explosives	N006629	(71,960)

Kearfott	NPoint, LLC	Radiation Dosimeter Development	N006630	(212,369)
Knoll	Elsevier Science B. V.	Editorial Services, Nuclear Instruments and Methods in Physics Research	N007321	11,628
Larsen	DoE/ Subcontract	Radiation Transport Methods Research for Stochastic Media and Semi-Implicit Time Descretizations	F015992	60,775
Larsen/ Martin	DoE/NEER	Advanced Variance Reduction for Global k-Eigenvalue Simulations in MCNP5	F011419	91,175
Lau	DoD/AF	Intergovernmental Personnel Act (IPA)	F014573	50,419
Lee	DoE/ Subcontract	Proposal for the Establishment of the Neutron Science Lab	F011912	426,831
Lee/ Fleming	DoE/NERI	Development of TRU Transmuters for Optimization of the Global Fuel Cycle	F012345	206,519
Lee	DoE/ Subcontract	U-M Participation in the AFCI RACE Project	F013911	(218)
Martin	DoE	Support Nuclear Engineering Education and Research at U of M	F006895	(4,858)
Martin/ Holloway	DoE/NEER	Global Monte Carlo Simulation with High Order Polynomial Expansions	F011333	142,678
Martin/Lee	DoE/NERI	An Advanced Neutronic Analysis Toolkit with Inline Monte Carlo Capability for NGNP Analysis	F015010	170,586
Martin	Institute of Nuclear Power Operations	Advanced Fellowships in Nuclear Engineering	C341676	(6,529)
Martin	NANT	Graduate Fellowships in Nuclear Engineering	N007577	20,000

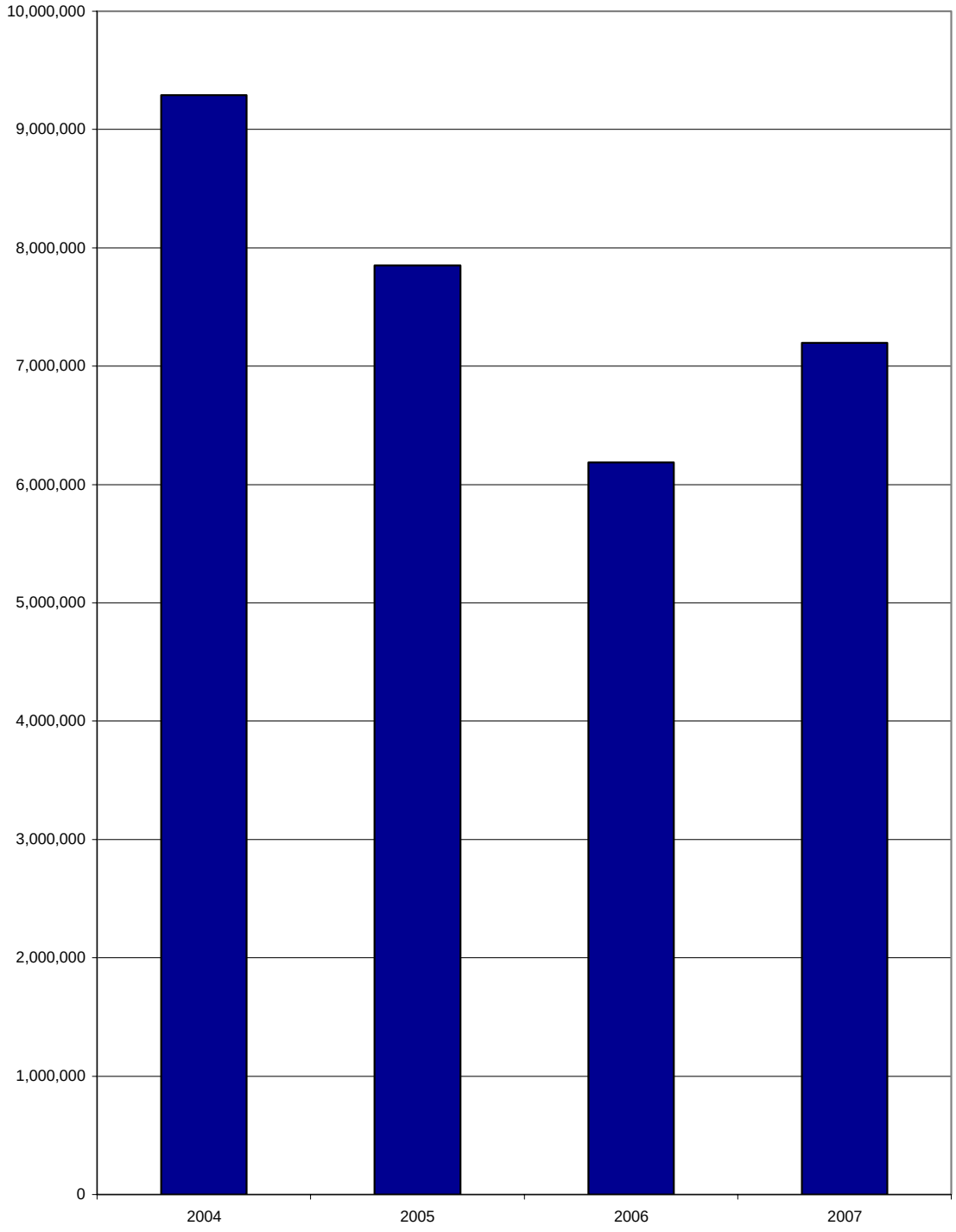
Wang	DoE	Self-Organized 3-D Array of Nanostructures Under Irradiation	F007316	133,691
Wang/ Ewing	DoE	Particle-Induced Amorphization of Complex Ceramics	F012220	110,833
Wang/ Ewing	NSF	Nanoparticle-Environmental Interfaces	F012244	43,006
Wang/Was	DoE/I-NERI	Accelerator Based Study on Irradiation Creep in Pyrolytic Carbon Used in TRISO Fuel Particles for VHTR	F015452	164,914
Was	DoE/ Subcontract	Developing and Evaluating Candidate Materials for Generation IV Supercritical Water Reactors	F008346	(18)
Was	DoE/I-NERI Subcontract	Advanced Corrosion-Resistant Zirconium (ZR) Alloys for High Burn-up and Generation IV Applications	F008451	(2,022)
Was	DoE/ Subcontract	Radiation Effects in Candidate Materials for Spallation Neutron Environments	F008517	(8,790)
Was	DoE/I-NERI Subcontract	Stress Corrosion Cracking of Candidate Alloys for the Supercritical Water Reactor Concept	F011832	221,296
Was	DoE	Strategies for Alloy Development for 1000°C Service in the NGNP	F012633	83,612
Was	DoE/NERI Subcontract	Candidate Materials Evaluation for the Supercritical Water-Cooled Reactor	F012819	112,660
Was	DoE/NEER	Localized Deformation as a Primary Cause of Irradiation-Assisted Stress Corrosion Cracking	F013324	146,711
Was/Wang	NSF	Acquisition of a Research Grad Ion Implanter for Research and Education in Ion Beam Modification of Materials	F013349	583,059
Was	DoE/NERI Subcontract	Alloys for High Temperature Service in the Next Generation Nuclear Plant: 850-900A C	F014792	52,405

Was	DoE/ Subcontract	High Temperature Metallic Materials for GFR	F014870	41,288
Was	DoE	Accelerator Based Study on Irradiation Creep in Pyrolytic Carbon Used in TRISO Fuel Particles for VHTR	F015795	64,029
Was	DoE	Accelerator Based Study on Irradiation Creep in Pyrolytic Carbon Used in TRISO Fuel Particles for VHTR	F015828	46,487
Was	EPRI	Use of Proton Irradiation to Understand IASCC in LWR Cores	N001979	(12)
Was	EPRI	Constant Extension Rate Testing of Alloy 690 in Supercritical Water	N007933	26,935
Was	EPRI	A Mechanistic Basis for Irradiation-Assisted Stress Corrosion Cracking	N007942	47,961
Wehe	DoE	Applied Research in Support of the Robotics Technology Development Program	C023431	(19,052)
Wehe	DoE	Mobile Robotics and Sensing-Univ Research Prog in Robotics	F010788	835,636
Wehe	NASA	Integration of Electron Tracking into Compton Imaging for the Advanced Compton Telescope	F013569	26,942
Wehe	Homeland Security	Support for the DNDO Workshop on Radiation Detection Materials	F015476	20,000
			Sub Total:	**6,643,527**

* Amounts in parentheses were accounting adjustments.

Total Research Expenditures Attributed to an External Sponsor							6,643,527
Total Research Expenditures Not Attributed to an External Sponsor							552,174
Sub Total							7,195,701
GSRA RIP3 Outstate Differential							150,037
GRAND TOTAL							$7,345,738

RESEARCH EXPENDITURES HISTORY



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(January 1, 2006 – December 31, 2006)

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*R. G. McClarren, J. P. Holloway, T. A. Brunner and T. A. Mehlhorn, "A Quasi-Linear Implicit Riemann Solver for the Time-Dependent P_n Equations," *Nuclear Science and Engineering*, **155**, 290-299 (2006). (Invited)

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PLASMAS AND FUSION

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L. K. Ang, W. S. Koh, Y. Y. Lau, and T. J. T. Kwan, "Space-Charge-Limited Flow in the Quantum Regime," *Physics of Plasmas,* **13**, 056701 (2006). (Invited)

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K. Jensen, Y. Y. Lau and *N. Jordan, "Emission Nonuniformity Due to Profilimetry Variation in Thermionic Cathodes," *Applied Physics Letters*, **88**, 164105 (2006).

D. W. Jordan, M. D. Uhler, R. M. Gilgenbach and Y. Y. Lau, "Enhancement of Cancer Chemotherapy *in vitro* by Intense Ultrawideband Electric Field Pulses," *Journal of Applied Physics*, **99**, 094701, May (2006).

T. Kammash, "Antiproton-Driven Gas Core Fission Rocket," *Journal of the British Interplanetary Society*, **59**, 23-26 (2006).

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S. P. D. Mangles, A. G. R. Thomas, M. C. Kaluza, O. Lundh, F. Lindau, A. Persson, F. S. Tsung, Z. Najmudin, W. B. Mori, C. G. Wahlstrom and K. Krushelnick, "Laser-Wakefield Acceleration of Monoenergetic Electron Beams in the First Plasma-Wave Period," *Physical Review Letters,* **96**, 215001 (2006).

S. P. D. Mangles, A. G. R. Thomas, O. Lundh, F. Lindau, M. C. Kaluza, A. Persson, C-G. Wahlstrom, Z. Najmudin and K. Krushelnick, "Effect of Laser Contrast Ratio on Electron Beam Stability in Laser Wakefield Acceleration Experiments," *Plasma Physics and Controlled Fusion*, **48**, B83-B90 (2006).

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C. D. Murphy, R. Trines, R. Bingham, J. Collier, S. P. D. Mangles, Z. Najmudin, A. E. Dangor, K. Krushelnick, J. G. Gallacher, D. A. Jaroszynski, R. Viskup and P. A. Norreys, "Photon Acceleration by Laser Wakefields," *Physics of Plasmas,* **13**, 033108 (2006).

P. M. Nilson, S. P. D. Mangles, L. Willingale, M. C. Kaluza, A. G. R. Thomas, Z. Najmudin, R. G. Evans, A. E. Dangor, K. Krushelnick, M. Tatarakis, R. J. Clarke, K. L. Lancaster, C. Hernandez-Gomez, S. Karsch and J. Schreiber, "Optical Probing of High-Intensity Laser Interactions with Underdense Plasmas Using the VULCAN Petawatt Laser Facility," *Journal de Physique IV,* **133**, 543 (2006).

P. M. Nilson, L. Willingale, M. C. Kaluza, M. S. Wei, C. Kamberidis, Z. Najmudin, W. Rozmus, R. G. Evans, M. G. Haines, A. E. Dangor, R. Heathcote, S. Bandyopadhyay and K. Krushelnick, "Magnetic Reconnection and Plasma Dynamics in Multiple-Beam Produced Plasmas," *Physical Review Letters,* **97**, 255001 (2006).

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T. Kammash, *R. Tang and B. Cassenti, "Antiproton Driven Bi-Modal Fusion Propulsion System," *42nd Joint Propulsion Conference,* AIAA-2006-4394, Sacramento, CA, July 9-12, 2006.

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Journal Articles

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*B. W. Sturm and Z. He, "Analysis of Coplanar Grid CdZnTe Detector Properties," *15th International Workshop on Room-Temperature Semiconductor X and Gamma-Ray Detectors*, San Diego, California, October 29-November 4, 2006.

D. K. Wehe, *H. Yang and M. H. Jones, "U-238 Detection by Delayed Photofission Products," *IEEE Transactions on Nuclear Science*, **53**, 3, 1430-1434 (2006).

*D. Xu, Z. He and Feng Zhang, "Study of Detection Efficiency of 3D Position-Sensitive Pixellated CdZnTe Detectors," *15th International Workshop on Room-Temperature Semiconductor X and Gamma-Ray Detectors*, San Diego, California, October 29-November 4, 2006.

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I. J. Chetty, M. Rosu, M. L. Kessler, B. A. Fraass, R. K. Ten Haken, F.-M. Kong and D. L. McShan, "Reporting and Analyzing Statistical Uncertainties in Monte Carlo–Based Treatment Planning," *International Journal of Radiation Oncology, Biology Physics*, **65**, 1249-1259 (2006).

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K. A. Cunningham and K. J. Kearfott, "The Variations of Radon Gas with Environmental Variables," *Undergraduate Research Opportunities Program (UROP) 2006 Symposium,* April (2006).

J. W. Eberhard, P. Staudinger, A. Schmitz, J. McCoy, M. Rumsey, C. E. Landberg, B. Claus, P. L. Carson, M. M. Goodsitt, H.-P. Chan, M. A. Roubidoux, J. A. Thomas and A. Osland, "Rapid Acquisition Tomosynthesis System for 3D Mammography," *Proceedings of ICIS '06, Society for Imaging Science and Technology,* 401-403, Rochester, NY, May 7, 2006.

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D. Hodson and K. J. Kearfott, "Drift in Laboratory HPGe Gamma Ray Spectroscopy Systems," *Undergraduate Research Opportunities Program (UROP) 2006 Symposium,* April (2006).

C. R. Lawson-Thornton and K. J. Kearfott, "Uranium Mining and Native Americans," *Undergraduate Research Opportunities Program (UROP) 2006 Symposium*, April (2006).

*H. A. Wittaniemi and K. J. Kearfott, "The Effects of Radon Gas on Thermoluminescent Detectors," *Undergraduate Research Opportunities Program (UROP) 2006 Symposium Proceedings*, April (2006).

T. Zak and K. J. Kearfott, "Detection of Explosives Using Neutrons," *Undergraduate Research Opportunities Program (UROP) 2006 Symposium,* April (2006).

*Y. Zhu and K. J. Kearfott, "A Wedge Filter for Radiation Spectroscopic Measurements," *Undergraduate Research Opportunities Program (UROP) 2006 Symposium,* April (2006).

Service

(January 1, 2006 – December 31, 2006)

Service to the College of Engineering

Member, CoE Undergraduate Admissions Committee	Atzmon
Member, Engineering Faculty Library Advisory Committee	Bielajew
Member, CUOS Director Search Committee	Gilgenbach
Course Coordinator, Engineering 101 – Administrative and academic support	Holloway
Member, Undergraduate Recruiting Scholarship Committee	Holloway
Member, International Programs Committee	Holloway
Member, Committee for NANT – NE and HP Scholarship Program Application Preparation	Holloway
Speaker, Tech Day	Holloway
Member, Advisory Board to CRLT North on budgetary and program issues	Holloway
Member, Committee to work on CoE Midterm course evaluation system	Hollaway
Speaker, CRLT seminar on Faculty Research on Student Retention in Engineering	Holloway
Member, Selection Committee ASEE Student Section Outstanding Student Instructor Award	Holloway
Member, U-M Flint, U-M Ann Arbor Partnership	Holloway
Advisor, Alpha Nu Sigma Student Chapter	Holloway
Member, Casebook Committee for Mark Brehob (EECS)	Holloway
Member, Environmental Technology Council	Kearfott
Member, Diversity and Outreach Council	Kearfott
Member, Marian Sarah Parker Award Committee	Kearfott
Member, Curriculum Committee	Kearfott
Member, U-M Engineering College Honors & Awards Committee	Larsen
Member, Scholastic Standing Committee	Lau
Member, Nominating Committee	Wehe
Member, Curriculum Committee	Wehe
Member, McIvor Award Committee	Wehe

Service to the University

Member, SACUA Library Committee	Bielajew
Panel member, GEM Fellowship Panel, sponsored by Office of the Associate Dean for Graduate Education and Rackham Graduate School	Foster
Member, Applied Physics Executive Committee	Gilgenbach
Member, Provost's Steering Committee on Multidisciplinary and Team Teaching	Holloway
Organizer, Rackham Graduate School workshop on How to Get Started in Research	Holloway

Advocate, AGEP (Alliances for Graduate Education in the Professoriate)	Holloway
Member Senate Advisory Committee on University Affairs (SACUA) Grievance Procedures Task Force	Kearfott
Member, Rackham College Divisional Review Board in Physical Sciences and Engineering	Kearfott
Member, U-M Radiation Policy Committee	Kearfott
Member, U-M Radioactive Drug Research Committee (RDRC) Subcommittee on Human Use of Radioisotopes (SHUR), Dosimetrist	Kearfott
Member, Rackham Distinguished Dissertation Award Committee	Lau
Member, Executive Committee, CUOS	Krushelnick
Member, Faculty Search Committee, CUOS	Krushelnick
Member, FOCUS council	Krushelnick
Member, North Campus Planning Committee	Martin
Member, Rackham Appeals Panel	Martin
Member, Rules Committee for Senate Advisory Committee on University Affairs (SACUA)	Wang
Director, Electron Microbeam Analysis Laboratory (EMAL)	Wang
Member, UMTRI Faculty Search Committee – OVPR	Was

Service to the Nation

Member, National Council on Radiation Protection (NCRP) Scientific Committee 6-3, "Uncertainties in the Dosimetry of Internal Radiation Doses"	Kearfott
Member, two Review Panels for Sandia National Laboratories: Hostile Environments; Radiation Effects Sciences (RES)	Larsen
Member, Review Panel for Los Alamos National Laboratory: CCS Division Review Committee	Larsen
Member, Review Panel for Department of Energy Computational Sciences Fellowship	Larsen
Instructor, Big-10 INIE Summer School, Argonne National Laboratory	Lee
Co-Chair, ASCI Prototype Hostile Environment Simulation Review Panel, Sandia National Laboratories	Martin
Member, ASCI Predictive Science Panel (DoE)	Martin
Member of DoE's Interagency Forensics Panel for Nonproliferation and Arms Control	Wehe

Service to the Profession

President, International Mechanochemical Union (a member society in the International Union of Pure and Applied Chemistry)	Atzmon
Member, Chemistry and Physics of Materials Committee, TMS	Atzmon
Member, Steering Committee, International Symposium on Metastable, Mechanically Alloyed and Nanocrystalline Materials	Atzmon

Session organizer, IEEE International Conference on Plasma Science	Foster
Member, AIAA Joint Propulsion Conference Best Paper Selection Committee	Foster
Chair, IEEE Plasma Science and Applications Technical Committee	Gilgenbach
Member, APS Nominating Committee, APS Division of Plasma Physics	Gilgenbach
Member, Division I Technical Review Committee, Lawrence Livermore National Laboratory	He
Member, Program Committee, IEEE Nuclear Science Symposium and Medical Imaging Conference, San Diego, CA	He
Member, Program Committee, SPIE International Symposium on Optical Science, Engineering, and Instrumentation. Program on Hard X-Ray and Gamma-Ray Detector Physics, Optics, and Applications	He
Member, DOE NA-22 Office program review, NIST, Boulder, CO	He
Member, DOE NA-22 Office program review, AlSb project at Berkeley National Laboratory	He
Vice President and Division Program Chair (Nuclear & Radiological Engineering Division) for 2006 ASEE National Meeting	Holloway
Division President, ASEE, Nuclear & Radiological Engineering, 2006 American Society of Engineering Education (ASEE) meeting	Holloway
Member, American Nuclear Society Scholarship Policy and Coordination Committee	Holloway
Member, American Nuclear Society Graduate Scholarship Selection Committee	Holloway
Member, Executive Committee, Michigan Local Section of American Nuclear Society	Kearfott
Member, Planning Committee American Nuclear Society	Kearfott
Faculty Advisor to the Student Health Physics Society	Kearfott
Member, Management committee, Astra Gemini upgrade project (Rutherford Appleton Lab, UK)	Krushelnick
Member, High Laser Facility Access Panel, Central Laser Facility (RAL, UK)	Krushelnick
Member, Technical Review Committee for the Mathematics & Computation Division of the American Nuclear Society	Larsen
Member, APS-DPP Program Committee	Lau
Panel Reviewer, NSF	Lau
Visiting Professor, summer course on "Nuclear Reactor Kinetics," Korea Advanced Institute of Science and Technology	Lee
Member, Executive Committee, Michigan Section of the American Nuclear Society	Martin
Chair, Mathematics and Computation Division, ANS	Martin
Co-Chair, "Corrosion in Supercritical System" Symposium for "Corrosion 2007" (2005-2006)	Teysseyre
Organizer and Session Chair, Dana Symposium, American Geophysical Union (AGU) General Assembly Meeting	Wang
Session Chair, 11th International Workshop on Inert Matrix Fuel, Park City, Utah	Wang

Session Chair, Symposium on Structural and Refractory Materials for Fusion and Fission Technologies, Materials Research Society 2006 Fall Meeting	Wang
Member, TMS Nuclear Materials Committee and TMS Corrosion and Environmental Effects Committee	Was
Member, MRS, Special Programs Committee	Was
Member, AFCI/GenIV Materials Working Group, LANL	Was
Member, Organizing Committee, International Conference on Environmental Degradation of Materials in Light Water Reactors	Was
Board of Directors, Engineering Research Council, American Society for Engineering Education	Was
Member, Executive Committee, Accelerator Applications Division, American Nuclear Society	Was
Member, Materials Review Committee for the Materials Program Plan for the NGNP, INEL	Was
Participant, Natural Sciences and Engineering Research Council of Canada site visit (Canada's NSF)	Was
Organizer, TMS Symposium on Microstructural Processes in Irradiated Materials	Was
Chair, Eleventh Radiation Measurements and Applications Conference	Wehe
Member, IEEE Radiation Instrumentation Steering Committee	Wehe
Chair of the IEEE Awards Committee.	Wehe

Editorial Services

Associate Editor, *Physics of Plasmas*	Gilgenbach
Associate Editor, *Transport Theory and Statistical Physics*	Holloway
Associate Editor, *Health Physics Journal*	Kearfott
Member, Editorial Board and International Advisory Board, *Plasma Physics and Controlled Fusion*	Krushelnick
Member, Editorial Board, *Transport Theory and Statistical Physics*	Larsen
Associate Editor, *Journal of Computational Physics*	Martin
Advisory Editor, *Nuclear Science and Engineering*	Martin
Member, Editorial Board, *Transport Theory and Statistical Physics*	Martin
Member, Editorial Board, *Journal of Nuclear Materials*	Was
Member, Editorial Board, *Metallurgical Transactions A.*	Was
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Editor, *Nuclear Energy and Technology*	Wehe

Personnel

(September 1, 2006 to August 31, 2007)

FACULTY

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Also Professor, Materials Science and Engineering
PhD (Applied Physics) California Institute of Technology, 1985
Thermodynamics of materials, diffusion of solids, amorphous metal alloys, ion beam modification of materials

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Professor
PhD (Theoretical Physics) Stanford University, 1982
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PhD (Radiation Measurements) University of Michigan, 2004
Development of miniature sensors that use mechanical rather than electrical signals to detect ionizing radiation

Zhong He
Associate Professor
PhD (Physics) University of Southampton, United Kingdom, 1993
Room-temperature semiconductor and scintillation detectors for x-ray imaging and spectroscopy

James Paul Holloway
Professor
PhD (Engineering Physics) University of Virginia, 1989
Kinetic theory (plasmas, radiation), inverse problems

Kimberlee J. Kearfott, CHP
Professor
Also Professor, Biomedical Engineering
ScD (Nuclear Engineering) Massachusetts Institute of Technology, 1980
Radiation detectors, dosimetry, radiation protection policy, dose assessments, digital mammography, image reconstruction and analysis for nuclear medicine images

Karl M. Krushelnick
Professor
Associate Director, Center for Ultrafast Optical Science
PhD (Physics) Princeton University, 1994
Plasma physics, ultra-high intensity laser system development, inertial confinement fusion, compact laser-based particle accelerators and applications

Edward W. Larsen
Professor
PhD (Mathematics) Rensselaer Polytechnic Institute, 1971
Analytic and numerical methods for nuclear reactor theory, neutron transport, non-linear radiative transfer, electron and photon transport

Yue-Ying Lau
Professor
Also Professor, Applied Physics Program
PhD (Electrical Engineering) Massachusetts Institute of Technology, 1973
Plasma physics, physics of charged particle beams, radiation sources, vacuum microelectronics

John C. Lee
Professor
PhD (Nuclear Engineering) University of California, Berkeley, 1969
Nuclear reactor physics, reactor safety analysis, dynamics and control of nuclear power plants, nuclear fuel cycle

William R. Martin
Professor and Chair
PhD (Nuclear Engineering) University of Michigan, 1976
Computational methods development for the solution of the Boltzman transport equation, including utilization of advanced computer architectures

Sebastien Teysseyre
Assistant Research Scientist
PhD Ecole Nationale Superieure des Mines de Saint Etienne, France, 2001
Expertise in corrosion stress corrosion cracking and irradiation assisted stress corrosion cracking. In high temperature, aqueous environments including supercritical water

Lumin Wang
Professor
PhD (Materials Science) University of Wisconsin-Madison, 1988
Ion beam modification of materials, transmission electron microscopy, monocrystalline materials, and nuclear materials

Gary S. Was
Professor
Also Professor, Materials Science and Engineering
Director, Michigan Ion Beam Laboratory (MIBL)
Director, Michigan Memorial Phoenix Energy Institute (MMPEI)
ScD (Nuclear Materials Engineering) Massachusetts Institute of Technology, 1980
Radiation effects on materials, ion beam modification of materials, hydrogen embrittlement, stress corrosion cracking, nuclear fuels

David K. Wehe
Professor
PhD (Nuclear Engineering) University of Michigan, 1984
Gamma ray imaging, neutron physics, radiation spectroscopy, artificial intelligence and robotics applications, power plant reliability

Feng Zhang
Assistant Research Scientist
PhD (Nuclear Engineering and Radiological Sciences) University of Michigan, 2004
Room-temperature semiconductor detectors, ASIC readout systems and reconstruction of radiation interactions, 4th-generation 3-D position sensitive CdZnTe detector array system.

EMERITUS FACULTY

A. Ziya Akcasu
Professor Emeritus
Also Professor Emeritus, Macromolecular Science and Engineering
PhD (Nuclear Engineering) University of Michigan, 1963
Dynamics of polymer solutions and blends, stochastic differential equations, reactor physics, kinetics

Terry Kammash
Stephen S. Attwood Professor Emeritus of Engineering
Professor Emeritus
PhD (Nuclear Engineering) University of Michigan, 1958
Fusion reactor physics and engineering, plasma physics, physics of intense charged particle beams, space applications of fusion energy

William Kerr
Professor Emeritus
PhD (Electrical Engineering) University of Michigan, 1954
Reactor safety analysis, probabilistic risk analysis, radiation protection, reactor shielding, energy production

John S. King
Professor Emeritus
(*deceased August 30, 2007)*
PhD (Physics) University of Michigan, 1953
Neutron spectroscopy, neutron physics

Glenn F. Knoll, PE
Professor Emeritus
PhD (Nuclear Engineering) University of Michigan, 1963
Radiation measurements, neutron cross sections, nuclear measurements, radiation imaging

Dietrich H. Vincent
Professor Emeritus
Dr. Rer. Natl. (Physics) Universität Göttingen, Germany, 1956
Gases in metals, ion beam analysis, radiation effects on materials

ADJUNCT FACULTY

Jeremy Busby
Adjunct Assistant Professor
PhD (Nuclear Engineering and Radiological Sciences)
University of Michigan, 2000
Radiation effects on materials, stress corrosion cracking, electron microscopy

Frederick W. Buckman
Adjunct Professor
PhD (Nuclear Engineering) Massachusetts Institute of Technology, 1970
Chairman and CEO of Trans-Elect
Formerly CEO of PacifiCorp and Consumers Power Company,
Nuclear plant design and nuclear reactor safety

Michael J. Flynn
Adjunct Professor
PhD (Nuclear Engineering) University of Michigan, 1975
Senior Staff Scientist, Henry Ford Health System
Medical imaging, image analysis, bioengineering, radiation detection

Mitchell M. Goodsitt
Adjunct Professor
PhD (Nuclear Physics) University of Wisconsin, Madison, 1982
Professor of Radiological Sciences, Radiology, University of Michigan
Professor of Radiological Health, University of Michigan

Randall K. Ten Haken
Adjunct Professor
PhD (Nuclear Physics) University of Wisconsin, 1978
Professor, Radiation Oncology, University of Michigan
Assoc. Professor, Environmental and Industrial Health, University of Michigan

Ruth Weiner
Adjunct Professor
PhD (Chemistry) Johns Hopkins University, 1962
Sandia National Laboratories
Member, Advisory Committee on Nuclear Waste

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Kwang-Il Ahn
Visiting Rackham Scholar
Korea Atomic Energy Research Institute, Korea

Lay-Kee Ang
Visiting Rackham Scholar
Nangyang Technological University, Singapore

Kun-Dar Li
Visiting Research Scientist
Hsing-Kuo University of Management, Taiwan

Tiecheng Lu
Visiting Research Scientist
Sichuan University, Sichuan Province, People's Republic of China

Rongsheng Zhou
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Shanghai Jiao Tong University, People's Republic of China

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Malik Gibbons Hansen, Research Project Engineer
Russell Miller, Engineering Technician
Fabian Naab, Research Lab Specialist Associate
Mark Perreault, Senior Electronics Technician, Plasma Experimental Bay
Victor Rotberg, Senior Research Specialist – retired 5/31/06, now Lab Assistant (temp)
Ovidiu Toader, Research Area Specialist Lead, Michigan Ion Beam Laboratory

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Amber French, Secretary (temp)
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Pat Moore, Office and Editorial Assistant
Shannon Thomas, Accountant Associate

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