COMPLEXITY IN HUMAN, NATURAL AND ENGINEERED SYSTEMS

Innovation Group Proposal

Principal Investigators

Virginia A. Folcik, Internal Medicine, OSUMC
Ian Hamilton, Evolution, Ecology and Organismal Biology, Mathematics, BMPS
Mark Moritz, Anthropology, SBS
Keith Warren, Social Work, CSW
David Woods,* Integrated Systems Engineering, ENG (corresponding faculty member)

Collaborating Faculty

Social and Behavioral Sciences (SBS)
Julie Field, Anthropology (field.59@osu.edu)
Richard Yerkes, Anthropology (yerkes.1@osu.edu)
Bruce Weinberg, Economics (weinberg.27@osu.edu)
Darla Munroe, Geography (munroe.9@osu.edu)
Ningchuan Xiao, Geography (xiao.37@osu.edu)
Craig Volden, Political Science (volden.2@osu.edu)
Marianna Klochko, Sociology (klochko.1@osu.edu)

College of Engineering (ENG)
Blaine Lilly, Integrated Systems Engineering, Mechanical Engineering (lilly.2@osu.edu)
Kevin Passino, Electrical and Computer Engineering (passino.1@osu.edu)

College of Biological, Mathematical, and Physical Sciences (BMPS)
Ciriyam Jayaprakash, Physics (jayaprakash.1@osu.edu)
Yuan Lou, Mathematics (lou.8@osu.edu)

College of Food, Agricultural, and Environmental Sciences (FAES)
Elena Irwin, Agricultural, Environmental and Development Economics (irwin.78@osu.edu)

Austin E. Knowlton School of Architecture (KSA)
Hazel Morrow-Jones, City and Regional Planning (morrow-jones.1@osu.edu)

College of Humanities (COH)
Morgan Liu, Department of Near Eastern Languages & Cultures (liu.737@osu.edu)

College of Medicine (OSUMC)
Nicanor Moldovan, Internal Medicine (nicanor.moldovan@osumc.edu)
ABSTRACT

We are committed to forging a collaboration between empirical and theoretical complex systems researchers at The Ohio State University. Complex systems are composed of multiple agents interacting over time. A complex system may be social, biological or consciously designed. Complex systems range from anthills to ecosystems, from individuals to small groups to cities and metropolitan regions, and from distributed robotics to air traffic control networks. All of these systems face formidable challenges of control, coordination and resilience. All meet those challenges through decentralized networks of nonlinear interactions between individual agents. The analysis of such complex systems requires an interplay between reductionism and synthesis. The analyst first gathers information about the parts and interactions that compose the system. This information is used to build a computational model, producing hypotheses about the dynamics and output of the system. These hypotheses can then be tested using interactions-based statistical models, network analysis, geographic information systems, time series analysis, experimental and ethnographic methodologies. Our group is transdisciplinary in two senses. First, because complexity science draws on multiple disciplines, our members represent multiple academic fields. We bring very different perspectives to the study of complex systems, and have already begun to learn from each other. Second, our group includes both theorists and empirical researchers. This combination allows a pragmatic focus on the application of complexity science to policy and intervention. Complexity will be the science of the 21st century. We believe that OSU should be the leader in this emerging and important field.
DESCRIPTION OF FOCUS

The collapse of the financial markets, the cascading effects of climate change, failures in the national power grid, and the escalating complexity in our health care system have one thing in common; they all are cascading events that have occurred in complex systems. Complex systems are human, natural and engineered systems consisting of multiple interacting components, often over multiple scales in space and time, which change and adapt over time. These systems exhibit high levels of uncertainty, lack master plans and are susceptible to catastrophic, cascading failures. Understanding how to anticipate and avoid such breakdowns and how to manage continually changing complex systems requires taking an approach that differs from an exclusively reductive focus on the behavior of isolated components and the linear models that are dominant in the social and natural sciences. Rather, such complex systems – which also include bird flocks, societies of social insects and other animals, cancer, immune systems, central nervous systems, computer systems, ecosystems, global climate change, electric power systems, irrigation systems – are characterized by nonlinear interactions and emergent properties, meaning that the dynamic interaction between agents results in the appearance of often surprising and dramatic phenomena at higher levels of organization, and, therefore, must be analyzed as a whole. The study of complexity addresses a fundamental question shared across academic disciplines: when is the whole more than the sum of its parts? The study of complex systems also brings together diverse fields and connects different ways of thinking about fundamental theoretical and practical problems. Finally, complex systems are part of our day-to-day lives, and a science of complex systems is necessary for managing important problems of national, state and local interest, as described in our initial examples.

Scientists across disciplines are turning to non-linear models to better understand and predict a wide range of different systems that display dynamics that cannot be deduced from the sum of their parts. Scientific collaboration in interdisciplinary and transdisciplinary research centers and institutes has been critical in the study of complex systems. Early steps toward the development of complex systems theory began at the Santa Fe Institute; now many research universities have established an interdisciplinary center devoted to the study of complex systems (e.g., Arizona State University, University of Chicago, University of Michigan, UCLA). Given the efforts of these peer institutions, it is surprising that the Ohio State University does not have such a center yet, especially since complexity science represents the new paradigm across disciplines and there is much interest in complex systems among faculty and graduate students from a wide range of different departments and colleges across campus.

Complex systems are ubiquitous and diverse, and investigation of complex systems similarly involves a diversity of disciplines and approaches. However, there are commonalities in the research questions and approaches used to study complex systems across disciplines. Key issues that underlie the common research core of complex systems, and that are of interest to all members of the complex systems innovation group, include:

- Modeling (nonlinear interconnected systems, continuous/discrete mixed dynamics, multi-level/multi-scale modeling, model validation)
- Computational modeling and analysis (large scale simulations, agent-based models and simulations, Monte Carlo simulations, statistical analysis)
- Characteristic behaviors in complex systems (robust emergent dynamics, coordinated motion, division of labor, task allocation, competition/cooperation, cooperative choice/allocation/care/defense)
• Evolution and design (computational evolutionary analysis, evolutionary game theory, principles of robust engineering design)
• Mathematical analysis of complex systems (nonlinear and statistical methods, robustness, stability, convergence, adaptation)
• Application of complex systems knowledge (use of complex systems principles to build more adaptable and resilient engineered and social systems)

We think that a group devoted to complex systems fits extremely well with the goal of the innovation initiative of the university. An innovation group at OSU would bring together researchers on complex systems from across campus and beyond, allowing them to find the common threads that link apparently disparate fields and accelerate the development of theoretical and computational tools, such as agent-based, nonlinear and multilevel modeling. These benefits go beyond the theoretical; application of complexity theory and methods has the promise to provide solutions to solve real-world problems in social, economic, environmental, and climate systems – at local, national, and global levels.

PLANNED ACTIVITIES

The activities of our group are aimed to facilitate interactions, collaborations, and mentoring among faculty and students from departments and colleges across campus who are interested in complexity in human, natural and engineered systems.

Weekly Seminars. We will organize a seminar series with weekly meetings with presentations from researchers from OSU and other institutions followed by extensive time for questions and discussions.

Modeling Workshops. Every quarter we will organize one-day workshops for faculty and graduate students to develop skills in research of complex systems, in particular training in agent-based modeling software, e.g., Swarm, Repast, NetLogo. We will bring experts to the OSU campus for one-day workshops and provide all the participating faculty and students with software and documentation.

Collaborative Research Groups. During the three years we will further strengthen our common research and policy focus through the development of collaborative and interdisciplinary research programs and grant proposals that share a common theoretical focus but examine complex systems in different settings. All innovation group members will be encouraged to participate in each collaborative group. The names of key members expected to be involved in each group are listed.

• Coupled human and natural systems (Field, Hamilton, Moritz, Munroe, Passino, Yerkes)
• Urban and metropolitan development (Irwin, Jayaprakash, Morrow-Jones, Munroe, Warren)
• Enhancing the resilience and safety of complex engineered system (Woods, Lilly, Passino)
• Emergent cooperation (Hamilton, Klochko, Liu, Passino, Volden, Warren, Yerkes, Field)
• Biomedical research (Folcik, Moldovan, Woods)

The groups share a common theoretical core, complex systems, they are overlapping and interdisciplinary as is evidenced by faculty participating in multiple groups, and they translate complex systems theory though specific research projects into policies and practical solutions for a wide array of problems and issues.

Undergraduate and Graduate Education. The weekly seminar series will serve as a trans-disciplinary course for graduate students, in which students read papers written and/or assigned by the presenters and meet with them for an hour after the talk. Meetings following
talks will provide students with opportunities to discuss research on complex systems with researchers from OSU and elsewhere and with one another and to discuss future directions in complex systems research. We will also encourage graduate students at OSU to participate as speakers in the seminar series.

We expect that the workshops, collaborative research groups and other research activities of our group will include extensive involvement by graduate students and undergraduate researchers. Ian Hamilton and Yuan Lou are directors of a National Science Foundation funded undergraduate research program in mathematical biology at OSU, Research for Undergraduates in Mathematical Biology and its Applications (RUMBA), which provides two- to three-year team-based undergraduate research fellowships in mathematical biology. We will collaborate with the RUMBA program to develop funded undergraduate research opportunities within our collaborative research groups.

**Integrative Metalanguage Pilot Project.** One of the obstacles encountered by interdisciplinary research groups such as this are the inherent differences in the terminology and language that we use to discuss complex systems. This challenge is all the greater in a group such as ours, which seeks to integrate highly mathematical disciplines such as physics and engineering with less mathematically grounded social sciences such as anthropology and social work. We will bridge that gap by focusing on the construction of a common set of terms, a metalanguage, that can be used to describe analogous processes that contribute to the formation of complex systems (e.g., interaction, replication, exchange, and many others). The metalanguage will be posted in a glossary on our wiki (complex-systems.wikidot.com). The construction of a metalanguage will be critical to the integration of our group, as it will aid communication and foster the cross-pollination of ideas between the disciplines. Further, it will allow group members to consider which ideas are truly fundamental for the study of complex systems. For instance, there is an inherent trade-off between optimization and resilience in complex systems. To optimize a system for one set of circumstances is to make it less resilient when circumstances change, a principle that appears to be unavoidable and applies to biological, social and engineered systems.

The construction of the metalanguage will be facilitated by a crosscutting pilot project that will involve the collaboration of group members from multiple disciplines. This pilot project will focus on the operation of the Medical Intensive Care Unit (MICU) at The Ohio State Medical Center. Several members of our group already have investigated aspects of critical care units, but not yet examined them as complex systems. The MICU is a good example of a complex system, with interactions between humans (doctors, nurses, patients), engineered systems (medical equipment and computers) and biological diseases. It is an extraordinarily difficult environment in which to work, with life and death decisions being made on an ongoing basis. Care has been codified as a set of best practices for critical care that must be accomplished every day for each patient. It takes high levels of coordination among medical personnel to consistently provide these best practices, and many factors can interfere with such coordination—priority of duties for medical personnel, overlap of duties, communication between doctors and nurses, even the architecture of the MICU. There is also the usual trade-off between optimization and resilience. For example, reduction in the overlap of duties may increase efficiency while decreasing the ability to catch errors. We will analyze the problem of provision of best practices through a sequential process of gathering data from MICU workers through face-to-face interviews and observations, utilizing the data to prime an agent-based model, and then testing the model output against empirical measures of MICU functioning. Once
we have a model that adequately reflects unit functioning, we can begin to use it to pre-test possible policy changes, which could then be implemented.

**GOVERNANCE PLAN**

The organized activities of the group will be managed by a team of five principal investigators from different colleges, but we will keep the decision-making process of the group open and democratic, which is in line with the emergent cooperation of some complex systems. For example, in preparing the proposal we used a wiki to collaboratively discuss, develop and write this proposal (complex-systems.wikidot.com). It allowed all collaborating faculty to participate in the decision-making process.

The group will be advised by an advisory board that consists of directors from centers at OSU and outside institutions. The OSU members of the advisory board are: Joseph Fiksel, Co-director of the Center for Resilience; Martin Golubitsky, Director of the Mathematical Biosciences Institute; Richard K. Herrmann, Director of the Mershon Center; Randall J. Olsen, Director, Center for Human Resource Research and the Initiative in Population Research; and Philip J. Smith, Co-director of the Institute for Ergonomics.

The external members of the advisory board are: Marco Jannsen, Associate director of the Center for the Study of Institutional Diversity at the Arizona State University and co-director of Open Agent-Based Modeling Consortium; Dwight Read, Director of the Human Complex Systems Center at UCLA; and Rick L. Riolo, Computer Laboratory Director of the University of Michigan Center for the Study of Complex Systems, and officer and member of the Board of Directors of the Swarm Development Group.

**POTENTIAL TO GROW INTO A CENTER OF INNOVATION**

We anticipate that our innovation group will attract significant external funding to develop into an innovation center within three years. The goals of the center will be to support the development of research and education on complexity in human, natural and engineered systems at OSU. We plan to pursue external funds to support the training of undergraduate students, graduate students, and faculty through workshops, summer institutes, and graduate training programs. We also seek external funding to build a computer laboratory with agent-based and other modeling software and support a lab manager with advanced modeling experience who will assist students and faculty with integrating agent-based modeling in their research projects.

Current members of the innovation group have already been awarded external funding for research and/or education of complex systems: David Woods has funding from the Army Research Labs ($7.9 million) for "Advanced Decision Architectures"; Mark Moritz has funding from the NSF CAREER program ($530,738), for "Pastoral Management of Open Access: The Emergence of a Complex Adaptive System"; Keith Warren, Elena Erwin, Ciriyam Jayaprakash and Darla Munroe have funding from the NSF ($1.4 million) for "Large Lake Ecosystems: Modeling Interactions Among Human, Biological, and Physical Processes"; Ian Hamilton and Yuan Lou have funding from NSF for Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences ($980,012); Keith Warren and Ciriyam Jayaprakash have a pending award from NIH, NIDA under the American Recovery and Reinvestment Act (ARRA) ($272,000, direct costs) for "Maintenance and Correlates of Cooperative Behavior in Therapeutic Communities"; and Virginia A. Folcik has an R21 award pending under the ARRA and the NIH,
NHLBI ($275,000, direct costs) for "Agent-based Modeling to Reveal Mechanisms of Idiopathic Interstitial Lung Disease".

The National Science Foundation, the National Institutes of Health, and James S. McDonnell Foundation offer many opportunities for funding research on complex systems, across programs and directorates, including (but not limited to):

- The James S. McDonnell Foundation funds research on Complex Systems annually
- NSF Virtual Organizations as Sociotechnical Systems program (VOSS)
- NSF Integrative Graduate Education and Research Traineeship Program (IGERT)
- NSF CISE Computing Research Infrastructure (CRI)
- NSF CISE Pathways to Revitalized Undergraduate Computing Education (CPATH)
- NSF Broadening Participation in Computing (BPC)
- NSF Dynamics of Coupled Natural and Human Systems (CNH)
- NIH Predictive Multiscale Models of the Physiome in Health and Disease (R01)
- NIH Exceptional, Unconventional Research Enabling Knowledge Acceleration (R01)
- NIH Using Systems Science Methodologies to Protect and Improve Population Health (R21)
- NIH Biobehavioral Methods to Improve Outcomes Research (R01 and R21)
- NIH Short Courses on Mathematical, Statistical, and Computational Tools for Studying Biological Systems (R25)

With so many opportunities, we anticipate that our innovation group will attract significant external funding for an innovation center within three years. In addition to external funding for institutional and educational development, we are also developing more targeted applications based around our five collaborative research groups. The current emphasis among federal agencies on interdisciplinary and systems oriented work makes this a propitious time to pursue such projects, for example, for the development models of urban and regional dynamics that are of critical interest to the state of Ohio.

Institutional support from the Office of Academic Affairs for our innovation group would position the Ohio State University at the forefront of an emerging field that has great promise for theoretical breakthroughs as well as solutions to real-world problems.

**METRICS FOR EVALUATION**

To evaluate the innovation group's progress, we will develop and use metrics that indicate: (a) productivity (such as number of collaborative projects, theses, publications, and proposals); (b) quality of products (such as student research awards, impact factor of journals where papers are published, number of citations of papers published); (c) sustainability of the group's activities (such as funding, attendance at group sponsored events, number of students enrolled in new courses); (d) education (such as new courses or revised courses, jointly taught courses, course enrollments, theses made possible by the group's activities); and (e) interaction metrics (such as number of cross-college collaborations, jointly supervised students). The group and advisory board will examine progress in these 5 categories each year and suggest changes in the group's activities and investment choices to increase the number of successes. One of the group's tasks will be to apply advances in measuring complex systems to the activities of the group. New metrics of dynamic networks are currently being developed that have shown promise in assessing the degree of cross-influence in collaborative networks and how well innovations develop and spread.
The financial support of the Office of Academic Affairs would allow us to organize activities to facilitate interactions and collaborations among faculty from departments and colleges across campus who are interested in complexity in human, natural and engineered systems. We will use the funds to organize weekly seminars, quarterly workshops, and to conduct an integrative pilot project to develop a common metalanguage.

We have received offers of matching funding from the College of Social and Behavioral Sciences (SBS) ($10,000); the College of Engineering (ENG) ($10,000); the Department of Internal Medicine (OSUMC) ($10,000); the College of Biological, Mathematical and Physical Sciences (BMPS), the Mathematical Biosciences Institute (MBI), the Department of Mathematical and the Department of Statistics ($10,000); while the Mathematical Biosciences Institute has offered space for seminars and workshops. With the matching funding from four of the participating colleges we have a budget of $100,000 for three years.

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We will organize a weekly seminar series with presentations from researchers from OSU and other institutions. The seminar series will also serve as a trans-disciplinary course for graduate students, in which students read papers written and/or assigned by the presenters and meet with them for an hour after the talk. The seminar will allow us to develop grant proposals for building an educational program in complexity sciences, for example, a graduate school minor.

We will organize quarterly one-day workshops for faculty and graduate students to develop skills in research of complex systems, in particular training in a range of agent-based modeling software, e.g., Swarm, Repast, NetLogo. We will bring experts to the OSU campus for one-day workshops and provide all the participating faculty and students with software and documentation. We will use the workshops to develop grant proposals for building a computer laboratory dedicated to the study of complex systems.

We will organize an integrative pilot product that has as its goal the construction of a metalanguage that facilitates communication and fosters the cross-pollination of ideas between the disciplines. The pilot project will involve the collaboration of multiple group members and focus on the operation of the Medical Intensive Care Unit (MICU) at The Ohio State Medical Center. The MICU is an example of a complex system, with interactions between humans (doctors, nurses, patients), engineered systems (medical equipment and computers) and biological diseases.
CURRICULUM VITAE

DR. VIRGINIA ANN FOLCIK NIVAR

Contact Information:
(614) 366-1332 (office)                    (740) 360-2835 (cell)
virginia.nivar@osumc.edu

Education:
1988:  B.S. Biology, *Magna Cum Laude*, Cleveland State University, Cleveland, Ohio.
1993:  Ph. D. Regulatory Biology, *Summa Cum Laude*, Cleveland State University, Cleveland, Ohio.
2005:  B.S. Computer Science and Engineering, *Magna Cum Laude*, Ohio State University, Columbus, Ohio.

Professional Experience:
1/07-Present:  Research Scientist/Principal Investigator, Department of Internal Medicine, Division of Pulmonary, Allergy, Critical Care and Sleep Medicine, the Ohio State University Medical Center.
6/05-8/06:  Research Scientist/Principal Investigator, Department of Surgery, Division of Transplantation, the Ohio State University Medical Center.
2/02-6/05:  Student Programmer, Department of Surgery, Division of Transplantation, the Ohio State University Medical Center.
5/99-12/99:  Research Associate, Nondestructive Testing Laboratory, Department of Industrial Engineering, Cleveland State University.
7/96-8/98:  Postdoctoral Fellow, Department of Neurosciences, Lerner Research Institute of the Cleveland Clinic Foundation.
7/93-7/96:  Postdoctoral Fellow, Department of Cell Biology, Research Institute of the Cleveland Clinic Foundation.
9/89-4/93:  Graduate Student Research Assistant, Department of Cell Biology, Research Institute of the Cleveland Clinic Foundation.
3/88-8/89:  Graduate Student Teaching Assistant, Biology Department, Cleveland State University
9/87-3/88:  Undergraduate Teaching Assistant, Biology Department, Cleveland State University.
1/86-6/87:  Laboratory Technologist (Cooperative Education Position) Microbiology Laboratory, MetroHealth Medical Center, Cleveland Ohio

Grant Awards:
1990:  Applied for and received competitively awarded funds from the Graduate Student Research Expense Support Award Program, the Department of Graduate Studies, Cleveland State University.
1993:  Applied for and received a one year fellowship grant from the American Heart Association, Northeast Ohio Affiliate.
1994:  Applied for and received a three year National Research Service Award from the National Heart, Lung and Blood Institute of the National Institutes of Health.
2006:  Applied for and received a Technology Enhanced Learning & Research, Research on Research Student-Faculty ePartnership Award from the Digital Union of the Ohio State University.
http://digitalunion.osu.edu/r2/summer06/sass/
Publications:


Abstracts:


Virginia A. Folcik and Charles G. Orosz. 2006. An Agent-Based Model Demonstrates that the Immune System Behaves Like a Complex System and a Scale-Free Network. Presented at The Tenth Annual SwarmFest Agent-Based Simulation Meeting, sponsored by the Department of Computer Science and Engineering, the Center for the Study of Biocomplexity and the Swarm Development Group at the University of Notre Dame, Notre Dame, Indiana. http://www.nd.edu/~swarm06

Biographical Sketch
Ian M. Hamilton

Professional Preparation
University of Calgary, Calgary, Alberta, Ecology, B.Sc. (Hon.) 1993
University of Calgary, Ecology, M.S. 1996
Simon Fraser University, Burnaby, British Columbia, Biology, Ph.D. 2001
Concordia University, Montreal, Quebec, Biology, Post-doc 2002-2003
University of Bern, Switzerland, Behavioral Ecology, Post-doc 2003-2006
Ohio State University, Electrical and Computer Engineering / EEOB, Post-doc 2006-2007

Appointments
Assistant Professor, Dept. EEOB (80%), Dept. Mathematics (20%), Ohio State University, November, 2007-present

Selected Publications
Heg, D, E Jutzeler, JS Mitchell and IM Hamilton. Female subordinate cichlids pay to reproduce. In press, PLoS ONE.
Hamilton IM and D Heg. 2007. Female clutch size adjustments within reproductive skew models: effects on reproductive partitioning and group stability. Behav Ecol. 18: 467-476.


Recent funding history


Professional service.
Long-term visitor at the Mathematical Biosciences Institute, Ohio State University

Thesis advisor and postgraduate scholar sponsor.

Postdoctoral sponsor (total = 2): W. Pangle (Michigan State), Roger Schürch (U Bern).
Two-page CV of Principal Investigator Dr. Mark Moritz

Professional Preparation

Leiden University (Netherlands)  Cultural Anthropology  M.A. 1995
University of California at Los Angeles  Anthropology  Ph.D. 2003

Appointments

Assistant Professor, 2006-present
Department of Anthropology, The Ohio State University

Assistant Professor, 2005-2006
Department of Anthropology, Western Oregon University

Lecturer, 2003-2004
University of California, Santa Cruz

Selected grants

National Science Foundation, 2008

National Geographic Society’s Committee for Research and Exploration, 2007
• Title: Managing Open Access: The Political Ecology of Pastoral Mobility (8306-07)($20,000).

Wenner-Gren Foundation for Anthropological Research Grant, 2000
• Dissertation research: The market and the moral economy of Fulani pastoralists in northern Cameroon (Gr. 6661)($18,000).

National Science Foundation Dissertation Improvement Grant, 1999
• Dissertation research: The market and the moral economy of Fulani pastoralists in northern Cameroon (BCS-9910557)($12,000).

Selected publications

Moritz, Mark, Britney Kyle, Kevin C. Nolan, Steve Patrick, Marnie F. Shaffer, and Gayatri Thampy

Moritz, Mark

Moritz, Mark

Moritz, Mark

Moritz, Mark
Synergistic Activities

Two of my innovative teaching activities have been published in the third and fourth editions of *Teaching Strategies in Anthropology* (edited by Rice and McCurdy), including one in which I integrated research using experimental economics in ethnographic settings.

In my *Ethnographic Writing* class at Western Oregon University, I trained my undergraduate students to become anthropological writers. Together we wrote a review of Weeks’ *Unpopular Culture: The Ritual of Complaint in a British Bank* (2003), which has been accepted for publication in the *Anthropology of Work Review*.

In my *Ecology of Pastoral Societies* class at the Ohio State University, I trained my graduate students in publishing in peer-reviewed journals. We wrote a review paper together in which we evaluated Stephen Sandford’s “too many people, too few livestock” thesis (2006). We will submit the paper to *Society and Natural Resources*.

Together with Paul Scholte and Saïdou Kari I have studied pastoral systems in the Logone floodplain and on this basis have designed development activities for the Waza Logone Project (IUCN) (see for example, Scholte et al. 1996 *The involvement of nomadic and transhumance pastoralists in the rehabilitation and management of the Logone floodplain*).

I am member of the scientific committee of Centre d’Appui à la Recherche et au Pastoralisme (CARPA), a Cameroonian NGO that aims to support research and development of pastoral systems in Northern Cameroon. I have a general advisory role and assist with the development of research and development programs.
Brief Curriculum Vitae
Dr. Keith Warren

Professional Preparation

1998-2000    Postdoctoral Fellow, Mental Health Services Research Training Program, School of Social Work, University of Wisconsin-Madison
1998         Doctorate in Social Work, The University of Texas at Austin.
1994         Master of Science in Social Work, The University of Texas at Austin.

Professional Experience

2006—present  Associate Professor, The Ohio State University
2000—2006     Assistant Professor, The Ohio State University

Selected Grants and Contracts

2007    Co-investigator, $110,620 grant from The Ohio Department of Mental Health, “Recovery Emphasis in Ohio Behavioral Health Organizations’ Inpatient Units.” With Theresa Early.
2004    Principal Investigator, $9860 contract from the Families and Schools Together National Training Center for project, “Application of nonlinear dynamics to the evaluation of the Families and Schools Together Program.”
2004    Co-investigator on $1.4 million dollar grant from the National Science Foundation for project, “Large lake ecosystems: Modeling interactions among human, biological, and physical processes.” With Elena Irwin, Ciriyam Jayaprakash, Darla Munroe, Keith Bedford, Jay Martin, David Culver and Jeffrey Reutter.

Selected Publications


**Selected Proceedings and Presentations**


**Synergistic Activities**


Research chair, Ohio Therapeutic Communities Association.

Co-designed and co-taught an EEOB 694 F group study on the interaction of social, biological and physical systems in large lakes. Course was taught at the Stone Lab in the summers of 2004 and 2005.
David D. Woods  
Professor  
The Ohio State University  
Integrated Systems Engineering  
Phone: 614.946-0123  
Columbus, OH 43210  
Fax: 614.292.7852  
E-mail: woods.2@osu.edu  
http://csel.eng.ohio-state.edu  

Education  
1979       Ph.D., Cognitive Psychology, Purdue University (West Lafayette, IN)  
1977       M.S., Experimental Psychology, Purdue University (West Lafayette, IN)  
1974       B.S., Psychology, Canisius College (Buffalo, NY)  

Appointments  
1996 - present  
Professor, The Ohio State University – Integrated Systems Engineering,  
Industrial and Systems Engineering, Anesthesiology, Industrial Design,  
Institute for Sensing Systems, Institute for Ergonomics  
1990 - 1996  
Associate Professor, The Ohio State University – Industrial and Systems  
Engineering, Anesthesiology, Industrial Design (from 1993)  
1988 - 1990  
Assistant Professor, The Ohio State University – Industrial and Systems  
Engineering, Anesthesiology  
1979 – 1988  
Senior Engineer, Westinghouse Research & Development Center,  
Pittsburgh, PA  

Other:  
President, Human Factors and Ergonomic Society, 1998-1999  
Associate Director, Center for Inquiry on Patient Safety, Veterans Health  
Administration, VISN 10, Ohio, 1999 to 2002.  
Founding Board Member, National Patient Safety Foundation, 1996-2002.  

Research Interests: Studies brittleness and resilience of human-automation  
systems – in nuclear power emergencies, in pilot-automation teams, in anomaly  
response in space shuttle mission operations, in critical care medicine, in replanning  
military missions, in professional information analysis, and in disaster response  
systems. Develops measures of collaboration and synchronization when risk critical  
operations and decisions are distributed over multiple groups and roles. Models how  
people adapt following introduction of new technology. H index = 40 with 13 papers  
cited over 100 times (based on Google scholar).  

Selected Recent Publications  
Concepts and Precepts. Ashgate, Aldershot, UK.  
From Individual to Distributed Systems. Theoretical Issues in Ergonomics, in press.  
Integrating Diverse Perspectives in Anomaly Response. Computer Supported  
of Real-Time Imaging on Decision-Making in a Simulated Incident Command Task.


Selected Examples of Impact
- One paper was selected to the top 30 papers in the 50 year history of the journal Human Factors 2009 (Cooke and Salas, in press).
- Google Research Award, 2008.
- Two publications were named to the top 100 papers in the history of the field of Human Factors (Moray, 2005)

Selected Recent Grants
PI in over $16 million in sponsored projects from 1989 to present
- Advanced Decision Architectures, Army Research Laboratory, 2001-2009, $7.9 million
- Cognitive Systems Engineering for Innovation in Information Analysis and Comprehension, Department of Defense, 2004-2009, $1.7 million
- Multi-level, Active Attention Surveillance, National Science Foundation (ITR), 2004-2007, $1.3 million (co-PI)
BIOSKETCHES OF COLLABORATORS

**Julie S. Field** is an assistant professor in the Department of Anthropology. She specializes in GIS-based analyses of archaeological data, and the application of GIS-based technologies to studies of landscape and human-environmental interaction. She also has a long-standing interest in evolutionary theory, in particular the use of evolutionary models to understand and explain cultural change. She is currently conducting research in the archipelagos of Fiji and Hawaii, and is a senior collaborator on an NSF-HSD funded research program focused on the prehistory of Kohala, on the Island of Hawaii. This research integrates excavation data, demographic calculations, and geochemical studies of agricultural soils to model population growth and expansion in prehistory. Her future research projects will include fieldwork in the Western Pacific, with an emphasis on assessing Holocene climatic change and the transition of colonizing populations from coastal foragers to terrestrial farmers. More information is available at: http://anthropology.osu.edu/faculty/pages/jfield2009/index.html

**Virginia A. Folcik** earned a B.S. in Biology in 1986, a Ph.D in Regulatory Biology in 1993 and a B.S. in Computer Science and Engineering in 2005. Her work involves the study of the immune system as a complex system using agent-based modeling and Repast software. The objective is to study the way that the rules for behavior of the cells affect how the immune system interacts with the body to eliminate or cause disease. Humans have one immune system to protect a variety of tissues from pathogens and cancer and to aid in the injury healing process. Because the immune system is complex and not optimized for one type of challenge, the cellular rules for behavior can result in unexpected consequences, such as inflammation that causes many acute and chronic diseases. Some examples are septic shock, allergies and autoimmunity (respectively). Agent-based modeling allows the study of the complex system as a whole, to find the emergent behaviors that are responsible for disease, and indicate targets for intervention. More information is available at: http://digitalunion.osu.edu/r2/summer06/sass/references.html

**Ian M. Hamilton** received his PhD in Biology from Simon Fraser University in Burnaby, British Columbia. He has post-doctoral training from the Department of Biology at Concordia University, Montreal, the Zoology Institute at the University of Bern, Switzerland and the Departments of Electrical and Computer Engineering and Evolution, Ecology and Organismal Biology at The Ohio State University. He is currently an Assistant Professor with a joint appointment in the Department of Evolution, Ecology and Organismal Biology and the Department of Mathematics at The Ohio State University. He has published numerous articles in such journals as American Naturalist, Behavioral Ecology, Behavioral Ecology and Sociobiology, Ecology, Journal of Animal Ecology, Proceedings of the Royal Society of London (Series B). He is the director of a National Science Foundation funded undergraduate research program at The Ohio State University: Research for Undergraduates in Mathematical Biology and its Applications (RUMBA). He uses a combination of mathematical modeling and experimental work, mainly with fish, to study the evolution of social behavior. In particular, his research focuses on the evolution of cooperative behavior, the evolution of variation in mating behavior, the transmission of information in groups and the impact of environmental change on social behavior. More information is available at: http://excelsior.biosci.ohio-state.edu/~eeob/drupal/?q=userpages/85
Elena Irwin is an Associate Professor in the Department of Agricultural, Environmental, and Development Economics at Ohio State University. Her research interests include land use economics and policy, urban spatial systems, and the interactions between human decision making and changes in ecological systems. Her research applies theory and methods from the fields of spatial and regional economics, including spatial econometrics, geographic information systems and system dynamics. She has published her work in a variety of disciplinary and interdisciplinary outlets, including Proceedings of the National Academy of Sciences, Journal of Economic Geography, Annual Review of Resource Economics, Regional Science and Urban Economics, Landscape Ecology and Agriculture, Ecosystems and Environment. She is currently a Co-Investigator with the Baltimore Ecosystem Study, a Long Term Ecological Research (LTER) project sponsored by the National Science Foundation (NSF). In addition to NSF, her research has been funded by NOAA, USDA Forest Service, Economics Research Service and the James S. McDonnell Foundation. She received a B.A. from Washington University in St. Louis in German and History (1988) and a Ph.D. in Agricultural and Resource Economics from the University of Maryland (1998).

Ciriym Jayaprakash is a Professor in the Department of Physics. He received his Ph. D from the University of Illinois and was a postdoctoral fellow at Cornell University and then a Visiting Scientist at IBM Yorktown Heights before joining Ohio State. He has worked in condensed matter physics in the areas of magnetism and superconductivity and in many areas of nonlinear dynamics including probabilistic cellular automata and coupled map lattices and on applications to earthquakes and turbulence. His recent interests lie in the applications of statistical mechanics to (i) immunology (in collaboration with an experimental group at the Mt. Sinai School of Medicine) and (ii) human and ecological systems. His research has been funded by the NSF, NIH, DOE, and AFOSR. He was a Sloan Foundation Fellow and a Presidential Young Investigator and is a Fellow of the American Physical Society.

Marianna Klochko (Ph.D. Cornell, 2004; BA/MA Kharkiv National University, Ukraine, 1996) is an Assistant Professor of Sociology. Her research interests include Economic Sociology, Rational Choice, Social Networks, Criminology, Game Theory and Collective Action. Her research examines the relationship between individual time preferences and other social phenomena such as drug addiction, corruption, gang membership and prisoners’ rehabilitation. She has also co-written “Endogenous Time Preferences in Social Networks” with Peter C. Ordeshook (Edward Elgar Publishing, 2005). The book addresses an under-studied issue from Rational Choice theory – the common assumption that individual time preferences are exogenous and fixed. The empirical evidence is then presented to suggest that this is not the case, exploring a computer simulation model that allows for the evolutionary change of time preferences. Her next project is devoted to the examination of connections between health choices of young adolescents and their time discounting.

Blaine Lilly is an Associate Professor holding a joint appointment in the departments of Integrated Systems Engineering and Mechanical Engineering. He also holds an adjunct appointment in the Department of Industrial, Interior, and Visual Communication Design. He has taught courses in mechanical design, manufacturing, and product design at Ohio State, and in 2006 was awarded the OSU Alumni Award for Distinguished Teaching. His research interests
are in the general area of innovative product design, particularly how complex systems theory applies to modeling how products survive and evolve in the marketplace.

**Morgan Liu** is a cultural anthropologist studying urban spatiality, social imaginaries, and Islamic knowledge in postsocialist states of central Eurasia. Theoretically, his interests include space, phenomenology, agency, emergence, and ethnographic complexity. He is Assistant Professor at OSU in the Department of Near Eastern Languages and Cultures, Department of Comparative Studies, and Department of Anthropology. Before that, he was a postdoc at the Society of Fellows, Harvard University. His Ph.D. is from the University of Michigan in Anthropology. His next project concerns the link between Islamic piety and economic prosperity in southern Kyrgyzstan during its second decade of post-Soviet independence. He wishes to investigate how Central Asians believe Islam, usually seen as focused on individual conduct and attitudes, could address structural problems such as “corruption” in society that may exhibit emergent complexity.

**Yuan Lou** received his PhD in 1995, in Mathematics from University of Minnesota. He has post-doctoral training from Mathematical Sciences Research Institute at Berkeley (1995-96) and the Department of Mathematics at University of Chicago (1996-98). He was Assistant Professor (1998-2003) and Associate Professor (2003-2008) at the Department of Mathematics, Ohio State University. He is currently Professor of Mathematics in the Department of Mathematics at The Ohio State University, and Associate Director of Mathematical Biosciences Institute. He has published more than 50 papers and his research is currently supported by National Science Foundation. He also serves as the Co-Editor-in-Chief for Discrete and Continuous Dynamical Systems, Series B. His recent research mainly focuses on applications of partial differential equations to mathematical ecology, population genetics, and disease dynamics. More information is available at: http://www.math.ohio-state.edu/~lou/

**Nicanor I. Moldovan** obtained an M.S. in Biophysics and a Ph.D. in Cell Biology and Pathology from the University of Bucharest, Romania. He has post-doctoral training in the Department of Biochemistry of SUNY at Buffalo, and in the Department of Cardiology at Johns Hopkins University, Baltimore. After moving at Ohio State University in Davis Heart and Lung Research Institute, he became a Research Scientist and then Assistant Professor in the Departments of Internal Medicine (Division of Cardiology), Biomedical Engineering and Ophthalmology. Dr. Moldovan’s research interests are the study of intercellular cooperation and of redox-controlled biomechanical factors in neovascularization of regenerating tissues, during cell therapy and tissue engineering with stem/progenitor cells, and in cancer progression. In the process, he identified robustness of biological structures as an emergent property dependent on hydrophobic interactions, which he is now studying both experimentally and in silico, using cellular automata and agent based modeling. He is also interested in complexity and emergence in systems with few elements. Dr. Moldovan organized at OSU an International Symposium and edited a book on “Novel Angiogenic Mechanisms-Role of Circulating Endothelial Progenitor Cells” (Kluwer, 2003). Currently he is an Assistant Editor to the Journal of Cellular and Molecular Medicine. More information at: http://network.nature.com/profile/UD3291110

**Mark Moritz** is an Assistant Professor in the Department of Anthropology. His research focuses on the transformation of African pastoral systems. He has investigated how FulBe pastoralists in
the Far North Province of Cameroon have adapted to changing ecological, political and institutional conditions that affect their lives and livelihoods. He continues to research herder-farmer conflicts, intensification of pastoral systems, and pastoral development. Recently, he has begun a new interdisciplinary study of complex social-ecological systems that is funded by the National Geographic Society and a Faculty Early Career Development (CAREER) Award from the National Science Foundation. Specifically, the study examines how mobile pastoralists in the Logone floodplain in the Far North Province of Cameroon coordinate their movements to avoid conflict and overgrazing in a land tenure system that is commonly described as open access, a situation generally regarded as leading to a tragedy of the commons. The hypothesis is that this management system is best understood as a case of emerging complexity, in which individual decision-making, coordination of movements among pastoralists, and participation in a information sharing network result in the emergence of a complex adaptive system in which access to and use of grazing resources is managed. The hypothesis will be tested in a multidisciplinary study of pastoral mobility that integrates spatial and ethnographic analyses as well as multi-agent simulations and analytical modeling. Understanding how these emergent systems work is critical for the management of rangelands across West Africa, most of which have some form of open access. More information is available at: http://anthropology.osu.edu/faculty/pages/Moritz.php

**Hazel A. Morrow-Jones** is an associate professor of City and Regional Planning and Associate Dean of Graduate and Professional Education in the College of Engineering at Ohio State. Dr. Morrow-Jones’ research career has focused on the complex systems of housing and neighborhoods in metropolitan areas and how the choices made by different kinds and groups of people interact with that system. Among other research topics, Dr. Morrow-Jones has worked on issues of suburban sprawl; downtown housing development; density and neighborhood choice; race, homeownership and neighborhood; the racial gap in homeownership; and the ability of US communities to cope with an aging population.

**Darla Munroe** is Assistant Professor of Geography at The Ohio State University. Munroe received her PhD in 2000 in Geography at the University of Illinois. She received her MA in Applied Economics at the University of Michigan. She has been a grant reviewer for several programs at the US NSF and has served on the review panel for DDRI proposals in Geography/Regional Science. Her research focuses on the ways in which economic change, shaped by policy and social relations, is distributed on the landscape in the form of land-use change. She has a particular interest in measuring and modeling such changes. Recent research has examined the impact of economic restructuring on urban decentralization, and forest regrowth in peri-urban areas in the Midwest. Munroe has authored articles in several disciplinary and interdisciplinary journals, including contributions to geography, urban planning and land economics.

**Kevin M. Passino** received his Ph.D. in Electrical Engineering from the University of Notre Dame in 1989. He is currently a Professor of Electrical and Computer Engineering at The Ohio State University. He was the Director of the OSU Collaborative Center of Control Science that is funded by AFOSR and AFRL/VA. He has served as the Vice President of Technical Activities of the IEEE Control Systems Society (CSS); was an elected member of the IEEE Control Systems Society Board of Governors; was the Program Chair of the 2001 IEEE Conf. on Decision and

Craig Volden received his Ph.D. from Stanford University's Graduate School of Business, and is currently Professor of Political Science at Ohio State. He pursues research and teaching interests in American politics, and quantitative and formal methods. His work explores legislative politics and the complexities of interactions among political institutions, with a specific focus on legislative-executive relations and on federalism. He is co-author of Revolving Gridlock: Politics and Policy from Jimmy Carter to George W. Bush (Westview, 2006), and has published numerous articles in such journals as American Political Science Review, American Journal of Political Science, Journal of Politics, Legislative Studies Quarterly, Journal of Law, Economics & Organization, and Publius: The Journal of Federalism. Current projects include studies of innovation and policy diffusion across states and localities, an examination of business-government relations regarding product quality regulations, and an analysis the legislative effectiveness of individual members of Congress.

Keith Warren (Ph.D., University of Texas at Austin, 1998, postdoctoral fellow, University of Wisconsin-Madison, 1998-2000) is Associate Professor in the College of Social Work at The Ohio State University. His research centers on interpersonal interactions in settings of interest to social workers. He has studied cooperative interactions in mutual aid-based interventions for substance abuse, the emergence of segregation and suburbanization in the face of competing residential preferences, and the interpersonal outcomes of the implementation of recovery-oriented practices in residential psychiatric facilities. His current focus is primarily on the application of agent-based models and social network analysis to understand the dynamics of cooperative behavior in residential therapeutic communities for substance abuse. His research has been supported by the Ohio Department of Mental Health, the Families and Schools Together National Training Center and the National Science Foundation.

Bruce A. Weinberg got his Ph.D. from the University of Chicago in 1996 before joining the faculty at the Ohio State University, where he is now Associate Professor of Economics and (by courtesy) of Public Administration. His research, which includes a focus on how youth behaviors, including employment, delinquency, cognitive development, and risky behaviors, are affected by their families and peer groups has been published in journals including /The/ American Economic Review, The Journal of Political Economy/, and/ The Review of Economics and Statistics/. He is a Research Associate at the Institute for Labor (IZA), Bonn and a Faculty Research Fellow at the National Bureau of Economic Research Cambridge,
Massachusetts and an associate editor of /Regional Science and Urban Economics/.
His research has been supported by the Federal Reserve, the National Institutes of Health, the National Science Foundation, and the Templeton Foundation.

David Woods (Ph.D., Purdue, Cognitive Psychology, 1979) is Full Professor in Integrated Systems Engineering at the Ohio State University. He has developed and advanced the foundations and practice of Cognitive Systems Engineering since its origins in the aftermath of the Three Mile Island accident in nuclear power. This field combines concepts and techniques from cognitive psychology, computer science, and social sciences to study how people cope with complexity. His studies have focused on human systems in time pressured situations such as critical care medicine, aviation, space missions, intelligence analysis, and crisis management. He designs new systems to help people find meaning in large data fields when they are under pressure to diagnose anomalies and re-plan activities. His latest work is model and measure the adaptive capacities of organizations and distributed systems to determine how they are resilient and if they are becoming too brittle in the face of change. His H-index (measure of research impact) is 40 (with 13 publications cited over 100 times)* Multimedia overviews of his research are available at url: http://cse-eng.ohio-state.edu/woods/ and he is co-author of the books Behind Human Error (1994) and A Tale of Two Stories: Contrasting Views of Patient Safety (1998), Joint Cognitive Systems: Foundations (2005), Joint Cognitive Systems: Patterns (2006), and Resilience Engineering (2006). Dr. Woods has served on several National Academy of Science and other advisory committees including Aerospace Research Needs (2003), Engineering the Delivery of Health Care (2005), and Dependable Software (2006). He has testified to U.S. Congress on Safety at NASA and on Election Reform. He was a board member of the National Patient Safety Foundation during its startup, Associate Director of the Midwest Center for Inquiry on Patient Safety of the Veterans Health Administration, and advisor to the Columbia Accident Investigation Board. Dr. Woods has been President of the Human Factors and Ergonomic Society. He is a Fellow of that society as well as the American Psychological Society and the American Psychological Association. He has shared the Ely Award for best paper in the journal Human Factors (1994), a Laurels Award from Aviation Week and Space Technology (1995) for research on the human factors of highly automated cockpits, the Jack Kraft Innovators Award from the Human Factors and Ergonomics Society (2002), an IBM Faculty Award (2005), a Google Faculty Award (2008), and five patents for computerized decision aids.

Ningchuan Xiao is Assistant Professor in Department of Geography. He has a broad range of research interests in geographical information science. His work was published in such journal as Journal of Land Use Science, Annals of the Association of American Geographers, Computers, Environment and Urban Systems, International Journal of Geographical Information Science, Geographical Analysis, Cartography and Geographical Information Science, Geographical & Environmental Modeling, and others. He develops efficient computational approaches to solving decision problems that have spatial components. He is also interested in designing effective visualization methods for understanding complex spatial information. Some of his recent research activities include the use of remotely sensed data to understand regional impact of land use change in Southeast Asia.

Richard W. Yerkes is Professor of Anthropology at Ohio State University. He received his BA in Anthropology from Beloit College, and his MA and Ph.D. in Anthropology from the
University of Wisconsin-Madison. He has taught 10 archaeological field schools in the USA, Cyprus, and Hungary, and has 30 years of research experience in North America, Egypt, Cyprus, Greece, Hungary, and Israel, funded by multiple grants from NSF, Wenner-Gren and Ohio State. He has over 60 publications on the transition to food production, ancient land use and settlement patterns, microwear analysis, craft specialization, emergent social complexity, GIS applications in archaeology, and zooarchaeology. He is Co-Director of the multidisciplinary international Körös Regional Archaeological Project in southeastern Hungary.
April 2, 2009

Professor Mark Moritz  
Department of Anthropology  
4034 Smith Laboratory  
Campus

Dear Mark:

I am pleased to approve your request for a one-time award of $10,000 in matching funds in FY10 from SBS in support of your proposal for an Innovation Group dedicated to the study of complex systems. This funding is contingent on your proposal receiving funding from OAA in this year’s competition. I understand that the funds would be used to help defray the costs of the planned seminar series and quarterly one-day workshops, including but not limited to travel expenses for external researchers, promotional materials, catering of workshops, honoraria for workshop leaders, and copies of agent-based modeling software for workshop participants.

Best wishes for success in this competition. If and when your proposal is awarded funding from OAA, please contact Tom Conrad to arrange access to the SBS matching funds.

Sincerely,

Robert L. Kaufman  
Associate Dean, College of Social and Behavioral Sciences  
and Professor of Sociology
April 13, 2009

Professor David Woods
Department of Integrated Systems Engineering
210 Baker Systems
woods.2@osu.edu
614 946-0123

Dear David:

I am pleased to approve your request for a one-time award of $10,000 in matching funds in FY2010 from College of Engineering in support of your proposal for an Innovation Group dedicated to the study of complex systems in natural, social and engineered systems. This Innovation Group is well-aligned with the College’s strategic goals. Engineering models are increasingly being applied to social and natural systems and in turn models of biological/ecosystems/social dynamics, and this application has stimulated new ways to approach the societal challenges of the 21st century. This joint proposal is exciting because it links activities over multiple colleges. It is an example of the kinds of trans-disciplinary collaborations that can be catalyze by researchers in an “Integrated Systems” department.

This funding is contingent on your proposal receiving funding from OAA in this year’s competition and will be based on resources available through the Department of Integrated Systems Engineering.

Good luck with your proposal.

Sincerely,

Randolph Moses
Associate Dean for Research, College of Engineering
and Professor of Electrical and Computer Engineering

cc: Professor Mark Moritz
Department of Anthropology
4034 Smith Laboratory
April 8, 2009

Virginia A. Folcik Nivar, Ph.D.
Department of Internal Medicine
473 W. 12th Street
Columbus, OH 43210

Dear Virginia,

In support of your collaborative proposal to form an Innovation Group to study “Complexity in Human, Natural and Engineered Systems”, the College of Medicine will pledge a one-time contribution of up to $10,000 for approved activities of the Innovation group award for the funding period. This pledge of matching funds is contingent upon the success of the proposal in obtaining an award from the Office of Academic Affairs and the Office of Research. It is understood that the funds will be accessible for approved travel expenses and honoraria of invited workshop leaders and external advisors, promotional materials for workshops, and other expenses such as computer software or hardware that will help the group to work together to perform high impact research and to obtain external funding.

We are excited about this program and are confident that you will use this mechanism to generate important papers, education and extramurally funded research and educational applications.

I wish you and the group the best of luck in this endeavor.

Sincerely,

Clay B. Marsh, MD
Professor and Director, Pulmonary, Allergy, Critical Care and Sleep Medicine
Director, Center for Critical Care
Vice Chairman for Research, Department of Internal Medicine
Deputy Director, Respiratory and Critical Care Research,
Dorothy M. Davis Heart and Lung Research Institute
Dear Dr. Hamilton,

This letter confirms the financial support being offered by units inside the College of Biological, Mathematical, and Physical Sciences to your proposed Innovation Group for the Study of Natural, Human, and Engineered Complex Systems. The amount of support funds offered total to $10,000 and are broken down as follows:

- $4,500 from the Mathematical Biosciences Institute
- $2,000 from the College of Biological Sciences
- $2,000 from the Department of Mathematics
- $1,500 from the Department of Statistics

The amounts were reached in agreement with the directors of each of these BMPS units. The funds may be used to cover seminar and workshop costs that you and your fellow group leaders initiate.

Your Innovation Group seeks to bring together scientists, from diverse academic backgrounds, to study the non-linear modeling problems that overlap these different areas of traditional study. Both the ubiquity of non-linear problems in these areas and the quality of the faculty members you have attracted to this group project mark your proposed Innovation Group as interdisciplinary work of the highest caliber. The broad support of the units within the BMPS College is a testament to the regard your colleagues hold for your efforts here. The College office would like to add its best wishes for your Group’s continued success.

Sincerely yours,

Jeffery D. McNeal