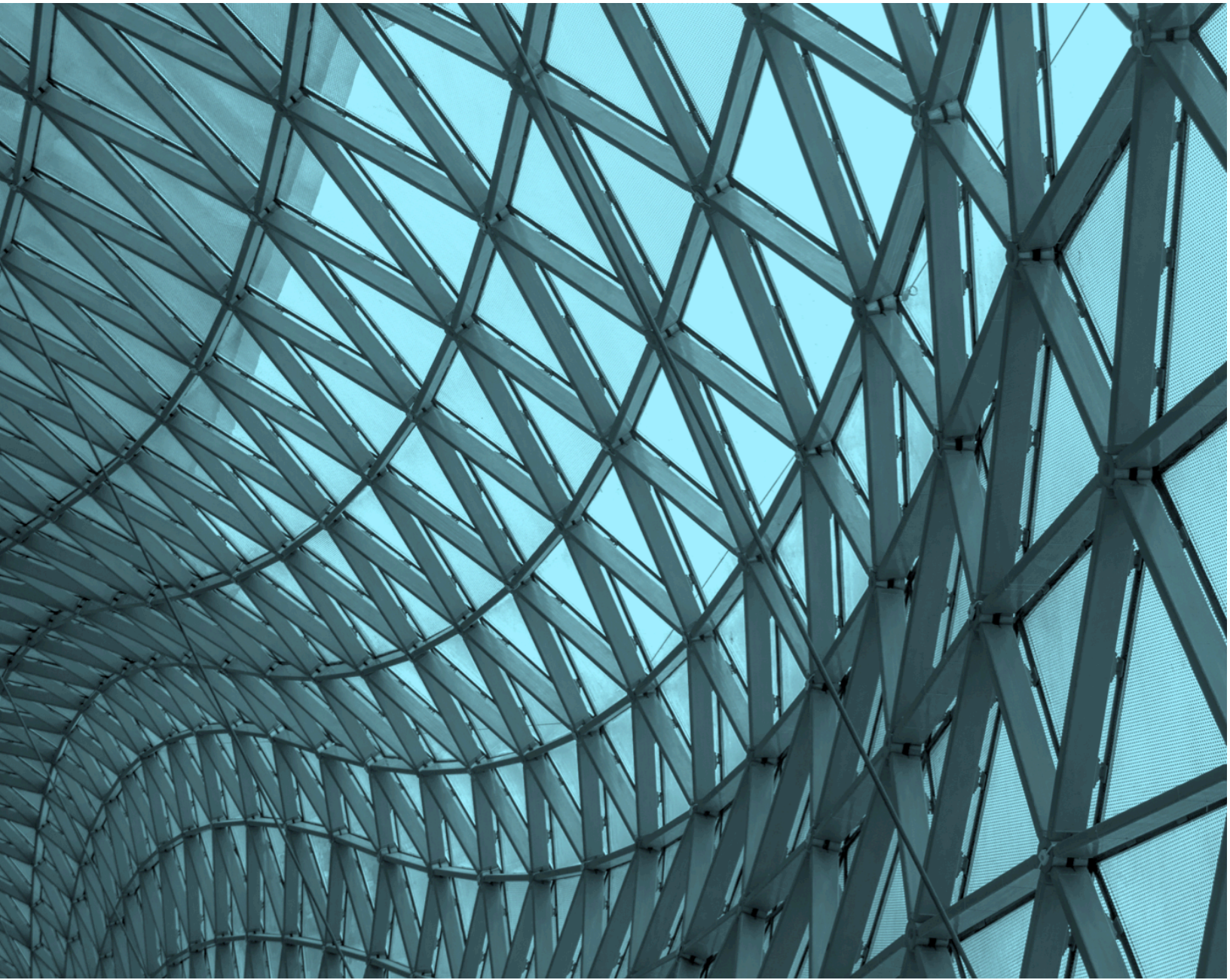# FIVE-YEAR REVIEW REPORT

SENATE GRADUATE AND RESEARCH COUNCIL

APRIL 2015

DIRECTOR'S MESSAGE

Should WICI be renewed?

This five-year report argues definitively yes. Since its formal beginning in 2010, the Waterloo Institute for Complexity and Innovation has had an enormously positive impact on both the University of Waterloo and broader communities by:

- creating a broad range of networking opportunities;
- creating widely used community resources;
- building capacity that allows scholars to respond to new and exciting research opportunities; and
- increasing the profile of the university within the GTA, across Canada, and around the world.

According to objective metrics, the Institute has consistently met or exceeded its annual goals, as it has met or exceeded the goals outlined in the original proposal to create the Institute in 2010.

WICI has also ensured that its mission, activities, and goals are in line with the university's new strategic plan, putting emphasis on transformational research, global prominence, and outstanding academic programming for an engaging student experience.

While these metrics point to WICI's success as a research centre, we argue that the Institute should ultimately be renewed for a larger reason: *the University of Waterloo is a place where complex systems research should and does thrive*. Complex systems science is a paradigm-shifting, transformative approach to scientific inquiry. Its underlying scientific world view coincides with the University of Waterloo's core identity as an innovative, forward-thinking intellectual and scientific leader among universities. The cutting-edge complex systems research taking place at UW is yet another way our community keeps itself one step ahead of its competitors.

As a cross-faculty centre, WICI allows UW to develop a critical mass in this vital research domain and to develop and harness networks that let us exploit emerging opportunities.

Renewal and financial support will ensure we can continue to fulfill this mission.

Dr. Dawn Cassandra Parker
Director, Waterloo Institute for Complexity and Innovation
Associate Professor, School of Planning, Faculty of Environment

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1. THE WATERLOO INSTITUTE FOR COMPLEXITY AND INNOVATION (WICI)

The Waterloo Institute for Complexity and Innovation (WICI) undertakes and facilitates rigorous, transdisciplinary, collaborative research that applies complexity science to problems at the core of human well-being in the 21st century.

Halfway through the second decade of the 21st century, surprise is no longer surprising. We are seeing a steadily higher incidence of unanticipated and sometimes catastrophic change, such as financial crises, pandemics, sharp spikes in food prices, disruptive meteorological events, and severe social and political unrest.

The 20th century's disciplinary-based approach to research and policymaking cannot address such problems effectively, because they are intrinsically transdisciplinary. Human beings are embedded in a nested and interconnected hierarchy of complex socio-ecological systems, including the biosphere and the global economy. These systems are increasingly perturbed by powerful, simultaneous and often interacting stresses, including rapid population growth, systemic imbalances in the global economy, enormous gaps between rich and poor classes, worsening scarcity of high-quality energy, and severe damage to Earth's environment.

In this context, innovative problem solving demands a complex-systems approach that integrates knowledge across disciplines. By bringing together scholars, practitioners, and policy makers working on both theoretical and applied complex systems problems, WICI is one of the few Institutes or Centres at the University of Waterloo that connects researchers and students from multiple faculties. It helps UW researchers and students create a shared understanding of complexity concepts, theories, and methods and connect with local stakeholders interested in these ideas. Beyond the immediate geographic scope of Southern Ontario, WICI uses online and interactive technologies to disseminate its findings and to engage vigorously with complexity researchers around the world.

By establishing the University of Waterloo as a leader in the use of complex-systems ideas to solve practical problems, the Institute furthers the university's goal to "bring(s) ideas and brilliant minds together, inspiring innovations with real impact today and in the future" (Who we are).

1.1 COMPLEX SYSTEMS

Complex systems are all around us. They are seen in the ways that migrating birds organize themselves into flocking formations and that ants communicate to successfully forage. They are seen in the ways in which humans form social networks, and in the patterns of communication, social capital, and reputation that emerge from these networks. They are seen in the emergent power-law or fractal structures of plants, snowflakes, landslides, and galaxies, as well as in similar structural patterns of wealth and income distribution, stock market fluctuations, population distributions between cities, and patterns of urban development. Complex systems are often referred to as "wholes that are more than the sum of their parts," wholes whose behaviour cannot be understood without looking at the individual components and how they interact.

WICI studies the formal aspects of complex systems, harnessing both quantitative and qualitative approaches. We investigate questions such as: What processes and structures define complex systems and characterize their outcomes? How can these be modeled and their implications understood? What real-world problems are best represented by complex systems, and what new insights are gained from a complex systems lens? Most importantly, how can our understanding of complexity help us innovate better to address the world's most intractable problems?

Complex behaviour arises from the interplay, in densely interconnected systems, between multiplicative causation and positive and negative feedbacks. A signature of such systems is radically disproportional causation (i.e., small causes do not always produce small effects) or what is often called "nonlinearity." Nonlinear systems can undergo sudden flips between stable states or equilibria. A second signature is the "emergence" of structured macroscopic patterns that are the outcome of the independent microscopic interactions of the entities in the system. These macroscopic patterns—be they hurricanes in Earth's atmosphere or boom-bust cycles in global financial markets—often have enormous causal power.

Complex adaptive systems—predominantly living systems, including human social systems—exhibit all these features; but, in addition, they survive and reproduce within dynamic selection environments. To do so, they have sets of embedded rules that guide their action in response to their external environments. These rules evolve under selection pressure.

The formal study of complex systems began in the mid-20th century in mathematics, physics, computer science, systems engineering (including cybernetics) and meteorology; more recently, ecology, social science and cognitive science have made important contributions. Researchers now apply the insights of complexity theory to the behaviour of systems as diverse as fresh-water lakes, mammalian immune systems, financial markets, social networks, the Internet, and the power grid.

Mathematically, complex adaptive systems are multi-state variable dynamical systems characterized by a moderate degree of structured interactions and interconnections. State variables in these systems are often characterized by heterogeneous parameter sets and updating rules. Spatial and network relationships are often non-uniform and violate mean field theory assumptions. As a result, mathematical representations of these systems often do not have analytical solutions. Further, system behaviour is characterized by path dependence, nonlinearities, bifurcations, and threshold behaviour. Higher-scale or aggregate output patterns are often characterized by power-law statistical distributions.

1.2 MISSION AND GOALS

WICI aims to:

- pursue and promote leading-edge research into complex natural and social systems;
- apply the theories, findings, and methods of complexity science to practical problems;
- create a university-wide research community in the field of complexity science;
- strengthen the university's national and international reputation in this field; and thereby,
- attract top-flight students and scholars to the University of Waterloo.

In each of its first five years, WICI has set forth specific goals to meet its mission of being a leader in the application of complexity science to real-world problems. Though goals were adaptively modified as priorities and opportunities changed, WICI has made consistent progress towards developing and maintaining WICI's institutional structure, building research groups, expanding networking and communication, and creating knowledge and tool infrastructure to support complex-systems related research. A full list of WICI's yearly goals can be found in Appendix C: WICI's Yearly Goals 2010-2015.

Moving into its next five years, WICI strives to strengthen and broaden our core research networks, supporting current members in pursuit of research funds, as well as facilitating development of new groups. WICI will continue its broad support for development of interdisciplinary research on complex systems through sponsoring talks, workshops, and working groups. We will enhance communication and outreach by continuing to expand our networks, promote WICI through traditional and social media, and host public lectures with high-profile speakers. We will work to leverage university-level, tri-council, foundation, and donor funds to increase the infrastructure for and depth of research scholarship supported by WICI. We believe that this suite of activities will continue to raise WICI's international profile and define its unique niche within—and contributions to—complex systems science.

1.3 OVERVIEW OF ACTIVITIES AND SERVICES

WICI offers a range of programs and activities for UWaterloo faculty and students, as well as external researchers and the public. These include:

1. Direct support for cross-faculty collaborative research:
    - Supporting the work of several distinct core research programs.
    - Committing in-kind and financial contributions for core members' grant applications, as well as grant-writing support.
    - Contributing to the training of highly qualified personnel with our core research projects
    - Hosting research and grant development workshops.
2. Providing support for development of a network of complex systems researchers on campus and beyond
    - Hosting a Speakers Series that brings experts in their field to the university and allows UWaterloo scholars working in the field to share their work.
    - Organizing public workshops and symposiums.
    - Publishing an occasional paper series.
    - Creating and disseminating software tools for analysis of complex systems through core research projects and challenges.
    - Facilitating and hosting working/reading groups at UWaterloo.
    - Engaging the community through talks, workshops, a WICI mailing list and social media accounts.
    - Identifying and connecting scholars working in complementary areas.

More detailed information about WICI's key achievements in each of these areas can be found in Section 2: The First Fives Years: Achievements and Results.

1.3.1 WICI'S CORE STRENGTHS

The developing field of complex systems is very broad and is characterized by a wide range of sub-fields and methodological challenges. As a cross-faculty Institute, WICI's activities and resources are available to support this full range. However, in a university setting, the core strengths of a research Institute are defined through the research activities of its principle faculty. Figures 1.1, 1.2 and 1.3 highlight key UWaterloo faculty and WICI members involved in some of our core current networks.
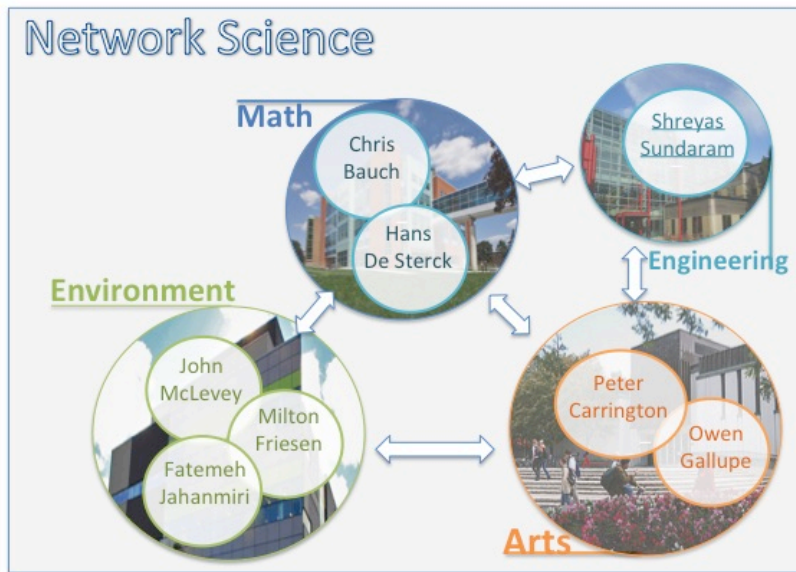
Figure 1.1: Current WICI Network Science Core Network

As discussed above, a key component of a complex system is its interactions, the dynamics that they create, and the implications that result. An evolving series of core research projects have developed under the WICI umbrella over the last five years. Collectively, these projects represent different aspects of humans' interaction in complex environments—their social, physical, and natural environments. These foci reflect the cutting edge of complex systems research at a global scale: for social interactions, areas such as big data and social networks; for the physical environment, navigation and interaction with the built environment and how this affects physical and social well-being; for environmental interactions, how human-environment interactions affect global environmental change. New funding programmes have emerged to support research in each of these areas—internationally, but increasingly also in a Canadian context.

Although all current core projects have a strong human element, they move beyond pure social
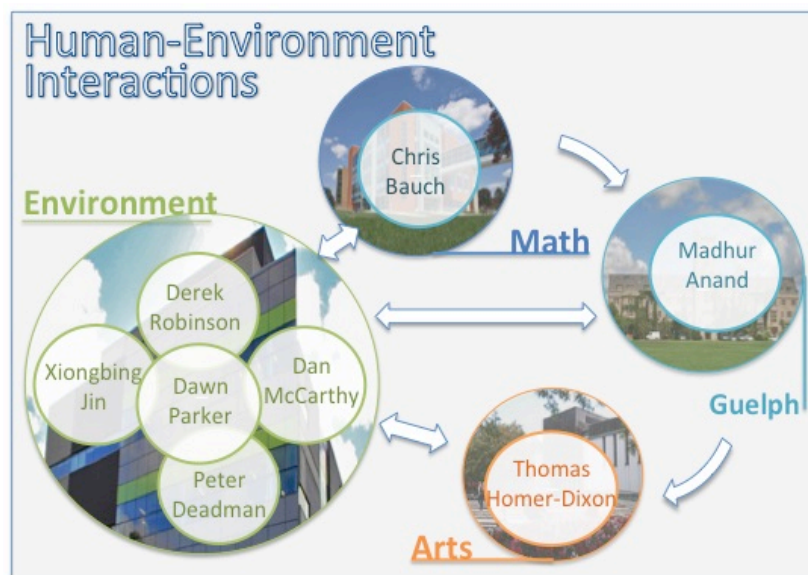
Figure 1.2: Current WICI Human-Environment Interactions Core Network

science, with leadership and active involvement by faculty in Arts, Engineering, Environment, and Math. The majority of projects involve cross-faculty collaboration. Thus these projects illustrate the fundamentally transdisciplinary nature of complex systems investigation.

Further, core projects work to make fundamental methodological advances to complex systems. These methodological innovations could be applied to problems in very different domains—not just to human interactions, but to complex interactions among nanoparticles, cells, or even galaxies. As WICI networks continue to build, new cross-faculty collaborations continue to emerge. We are constantly seeking out further opportunities for cross-fertilization and expansion of WICI's scope based on these core strengths.
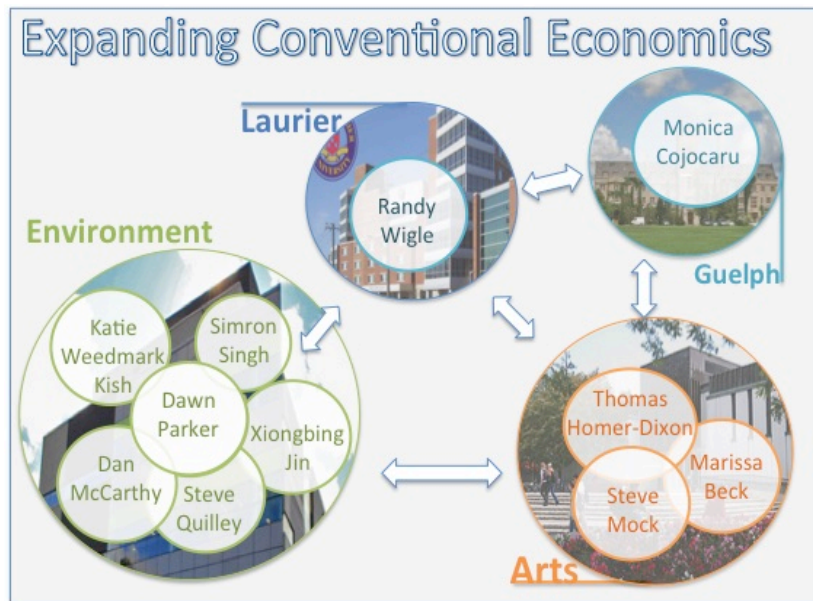
Figure 1.3: Current WICI Expanding Conventional Economics Core Network

One of the Institute's key priorities is facilitating core members' research programs. Over the past five years, the Institute has had six distinct research programs, currently in different stages of their life cycle. New groups are currently developing based on core members' research interests.

WICI's core research projects over the last six years have included:

- Robustness of Complex Networks;
- Open-Architecture Problem Solving;
- Comparative Threshold Behavior in Physical, Ecological, and Social Systems;
- Alternatives to Conventional Growth;
- Cognitive-Affective Modeling; Dimensions of Ideology; and
- Coupled Human-Environment Systems.

Detailed descriptions of each WICI research program can be found in Section 2.1.1 Core Projects. Core research projects under the WICI umbrella strive to make progress on technical challenges in complex systems theory in the context of addressing real-world, policy-relevant problems, as seen in the following examples:

LIGHT RAIL TRANSIT AND LAND-USE INTENSIFICATION: This project, funded through three SSHRC grants and matching government and industry partnerships, explores the causal processes driving the

relationships between construction of the new LRT and land-use intensification. It applies a complex systems approach, using computational simulation modeling to represent the interactions of heterogeneous actors through spatially complex land markets and the transit networks. It also develops statistical methods to analyze the complex, non-linear, power-law distributed data output from computational simulation models.

ROBUSTNESS OF NETWORKS: This project, funded by NSERC Discovery and Strategic grants, investigates the process of information diffusion through complex networks and how that process can be disrupted by malicious or extreme individuals. One real-world example is the massive spread of misinformation through online social networks after the Boston Marathon bombings of 2013 that led to the targeting of innocent individuals by the public and the media. A second example is the possibility of false-data injection cyberattacks in critical infrastructure (such as the power grid). The interplay between the structure of the underlying networks and the dynamics of the actors requires a complex systems approach. Technically, the project develops new metrics to characterize the robustness of networks, moving beyond traditional (static) measures such as connectivity and revealing new insights into the structure of networks that make them vulnerable (or robust) to failures and attacks.

IDEOLOGY AND CONFLICT RESOLUTION: The project, funded by the Centre for International Governance Innovation, advances knowledge of ideology's role in conflict. It synthesizes complexity science, which brings an understanding of the structure and dynamics of large multi-element systems, with cognitive science, which brings rich theories of mental representation. The project is producing a toolkit of methods and supporting software to help practitioners of conflict analysis, negotiation and resolution see the deep structure of diverse ideological perspectives, understand how these perspectives can contribute to conflict, and identify constructive pathways for ideological convergence, reconciliation, and change. Such a toolkit increases empathy during negotiations, locate points of miscommunication between parties, and open otherwise unrecognized pathways for compromise.

1.4 GOVERNANCE AND ADMINISTRATION

In this section, we outline the Institute's current governance structure, and we propose minor modifications to that structure that have implicitly evolved as our current, more streamlined operational model. WICI's initial administrative structure provided for broad oversight and input from both local and international complex systems scholars, with a very small day-to-day, hands-on, management team. Our modified structure maintains that oversight in a simplified format, while expanding the day-to-day management team. Given the interdisciplinary nature of WICI, administrative authority comes from the Office of Research rather than an individual Faculty. WICI's current governance structure is summarized in Figure 1.4.
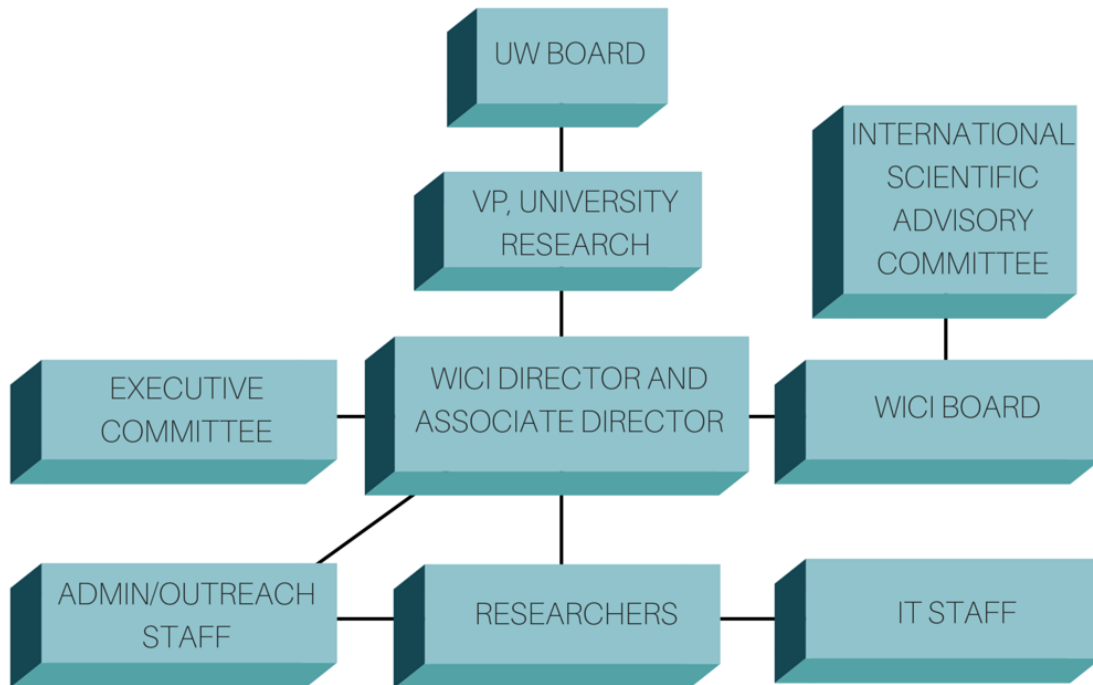
Figure 1.4: WICI's Original Governance Structure

1.4.1 DIRECTOR

WICI is led by a Director who reports to the Vice-President, University Research, and who is responsible for the management of the Institute, supervision of WICI staff members, and guiding of research and outreach agendas. The Director is appointed by the Vice-President Academic and Provost on the recommendation of the Vice-President, University Research for a term of up to three years, normally renewable once. WICI has had two Directors since being formally established in 2008: Dr. Thomas Homer-Dixon (2009-2012) and Dr. Dawn Parker (2013-Present).

**CURRENT WICI DIRECTOR
DR. DAWN PARKER**

1.4.2 ASSOCIATE DIRECTOR
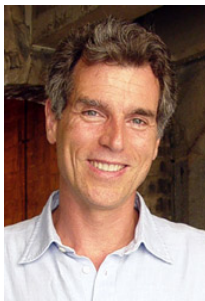
**CURRENT ASSOCIATE
WICI DIRECTOR
DR. THOMAS HOMER-DIXON**

The WICI Director is assisted by an Associate Director. The Associate Director is appointed by the Vice-President Academic and Provost on the recommendation of the Vice-President, University Research for a term of up to three years, normally renewable once. The Associate Director assists in guidance of research and outreach agendas, and normally consults with the director regarding resource allocation decisions. The Associate Director is also expected to contribute to WICI's networking and capacity building activities. WICI's current Associate Director is Dr. Thomas Homer-Dixon. The role was previously held by Dr. Dawn Parker, who has now assumed the role of WICI Director.

1.4.3 BOARD

The Institute's Board is designed to provide advice on the general and financial management of the Institute, as well as guidance regarding the Institute's operation and research directions. The Board discusses the Institute's infrastructure needs and new initiatives, assisting WICI is identifying new areas for future growth.

Members of WICI's board currently consist of:

- Vice-President Academic and Provost;
- Vice-President, University Research;
- WICI Director;
- Three Core Members or members representing participating faculties; and
- Three external members who are leaders in the fields of complexity science and innovation and members of the international scientific advisory council.

A list of WICI's current board members can be found in Appendix B.

1.4.4 EXECUTIVE COMMITTEE

WICI's Executive Committee is designed to provide advice to the Director, Associate Director, and the Vice-President, University Research on matters relating to the regular operations of WICI, including its annual budget. The committee is mandated to meet three or four times per year.

The Executive Committee currently consists of:

- Vice President, University Research or delegate;
- WICI Director;
- WICI Associate Director;
- Three Core Members; and
- Three additional members drawn from the university faculty, representing participating Faculties.

On renewal, we propose two changes to our governance structure: (1) replace the current executive committee with a smaller management committee, and (2) expand the membership of our internal board.

Over the past two years, WICI has established a management committee, consisting of the Director, Associate Director, our administrator, and two core members (Drs. Shreyas Sundaram and Steve Quilley). This small committee meets once or twice per year to plan strategic direction, major activities, and resource allocation. The committee also serves as a sounding board on a day-to-day basis to guide decisions regarding activities and resource allocation. On renewal, we propose to formalize this steering committee. In addition to the Director, Associate Director, and administrator, it will include 2-3

additional WICI core members representing different faculties, who are willing and able to provide feedback on WICI operations on a regular basis.

Practically, for the last several years, the Board and Executive committee have met in a joint meeting annually, with that being an opportunity for in-depth discussion of WICI activities and strategic directions. A list of current Executive Committee members can be found in Appendix B.

The proposed revised structure of the internal board is:

- Vice-President, University Research or delegate (Chair);
- Vice-President Academic and Provost or delegate;
- Deans or their representatives from the primary participating faculties;
- WICI Director;
- WICI Associate Director;
- Up to six steering committee members, other core Members, or additional members drawn from the university faculty, representing participating Faculties; and
- Three external members who are leaders in the fields of complexity science and innovation and members of the international scientific advisory council, ideally selected from the Southern Ontario region.

In selecting board members, the Institute will strive to obtain a diverse balance of disciplinary, research, and methodological perspectives. Further, the Institute will strive to establish and maintain gender and ethnic diversity in its oversight and membership.
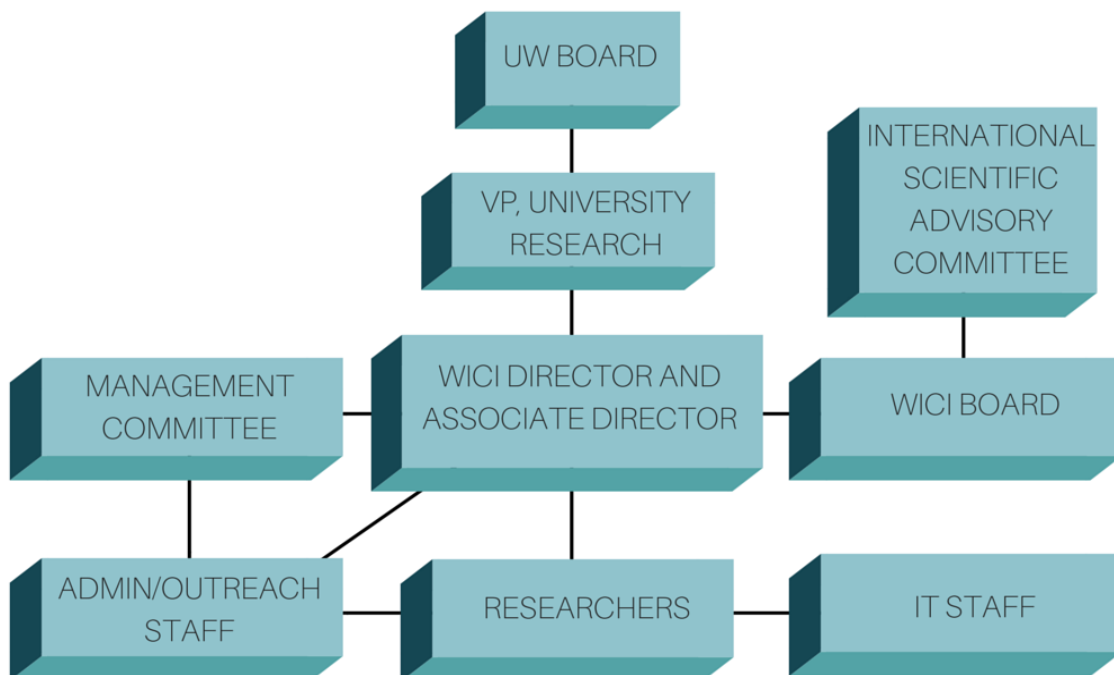
Figure 1.5: WICI's Revised Governance Structure

1.4.5 INTERNATIONAL SCIENTIFIC ADVISORY COUNCIL

WICI's International Scientific Advisory Council provides advice to the Board on the Institute's research priorities; it also assists WICI in establishing connections and maintaining its profile within the international complexity studies and innovation studies communities. The council is composed of outstanding complexity and innovation researchers from the university, Canada, and abroad who are Core or Affiliate Researchers of WICI. Current members of WICI's International Scientific Advisory Council are listed in Appendix B.

1.4.6 STAFF

The Institute employees an Administrative Assistant on a part-time basis, who reports to the Director and manages general office operations. Specific responsibilities include coordinating WICI's Speaker Series, workshops and symposium; organizing travel arrangements; managing the Institute's website; advertising WICI globally through the mailing list and social media accounts; providing support for writing and submitting external grant proposals; and assisting with the preparation of WICI's Annual Report. The Assistant handles the submission of pay claims to UW's Finance department, and maintains good records of the organization's spending and annual budget and serves as internal liaison with University of Waterloo academic departments and administrative units, especially Social Innovation Generation.

WICI also hires Information Technologists on an as-needed basis to assist with WICI's website and advance the Institute's suite of software and hardware tools. The Institute strives to hire UWaterloo students for these positions through the university's domestic and international Work Study programs when possible.

1.5 MEMBERSHIP

WICI's membership is composed of UWaterloo faculty, graduate students and undergraduate students, as well as external members who are leaders in the field of complexity science.

Since starting with 22 members, WICI has grown to a membership of 73 as of December 31, 2014. Figure 1.6 provides specific statistics on WICI's yearly membership.
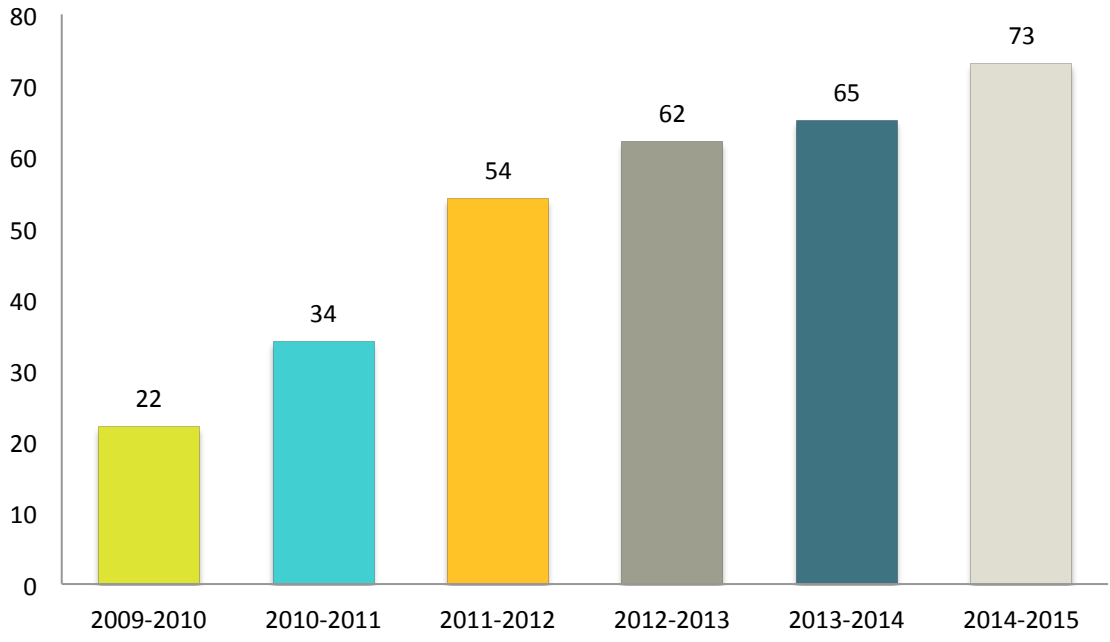
Figure 1.6: WICI Membership 2009-2014

As stated earlier, WICI is one of the few Institutes or Centres at the University of Waterloo that brings together researchers and students from multiple faculties. WICI members currently come from four of UWaterloo's faculties, though there is involvement from all faculties in WICI events. Figure 1.7 provides a breakdown of WICI membership by UWaterloo Faculty.
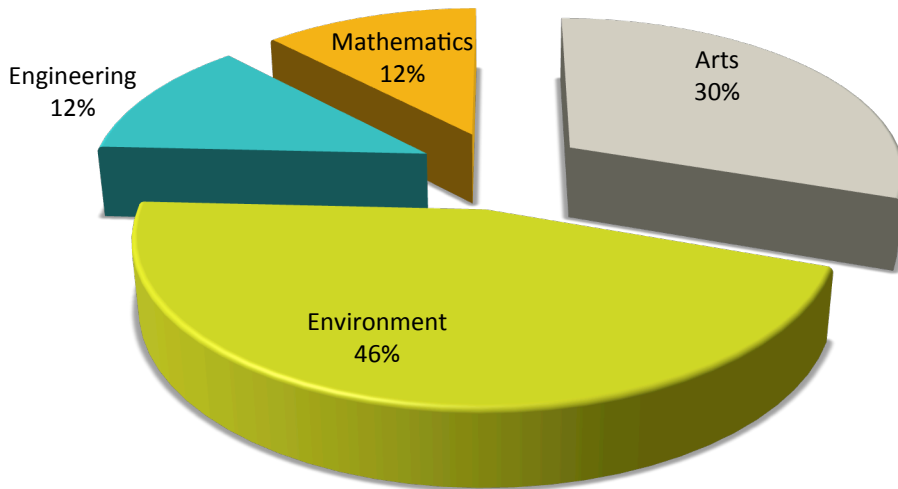

Figure 1.7: WICI Membership by UWaterloo Faculty

1.5.1 CATEGORIES

The four categories of membership recognize different types of participation in the Institute's activities and levels of commitment to WICI.

CORE MEMBERS are regular, research, or adjunct university faculty who lead a long-horizon research program under the Institute's auspices. Membership lasts for the duration of the member's active research within WICI. Core members are expected to be active in submitted WICI-related research funding proposals, and they are eligible to request support in grant preparation and matching contribution through WICI. Normally these grants will involve funding to train highly qualified personnel. Speaker and workshop proposals that closely align with core members' research agendas are prioritized for WICI funding when possible. Research websites are maintained for core projects on the WICI site. Core members are expected to actively contribute to WICI activities, such as network-building, suggesting and recruiting high-interest WICI speakers, helping to organize WICI working groups, reviewing for WICI challenges and the Occasional Paper series, and related activities.

AFFILIATE RESEARCHERS are regular, research, or adjunct university faculty or non-university researchers, including post-doctoral fellows, who actively participate in Institute activities, including its research projects or committees. Membership lasts for three years and is renewable.

PRACTITIONER MEMBERS include people in government, the voluntary sector, and private sector interested in the Institute's research and findings and who actively participate in WICI meetings, workshops, and conferences open to a general audience. Membership lasts for three years and is renewable.

STUDENT MEMBERS are students from the University of Waterloo or affiliated institutions working towards a degree on a topic of relevance to complexity science and innovation. Membership lasts for three years and is renewable.

Potential members can apply for membership by submitting a letter of inquiry and a CV, which are reviewed by WICI's steering committee. Particular individuals are often invited directly to become WICI members, often once they have participated in WICI events or been one of the experts featured in our Speakers Series. Potential members are also often identified by the WICI steering committee or other members. WICI events are also publicized through the New Faculty network. In any of these cases, potential general members (affiliate, practitioner, and student) are reviewed to ensure that their research activities reflect an interest in complex systems and that they are actively engaged in research. Membership in this category is designed to be open to serve the networking goals of WICI. Core members are invited by the Director in consultation with the Associate Director.

Figure 1.8 illustrates the breakdown of WICI membership by category. A current WICI membership list can be found in Appendix A: Membership List – Ordered by Affiliation.
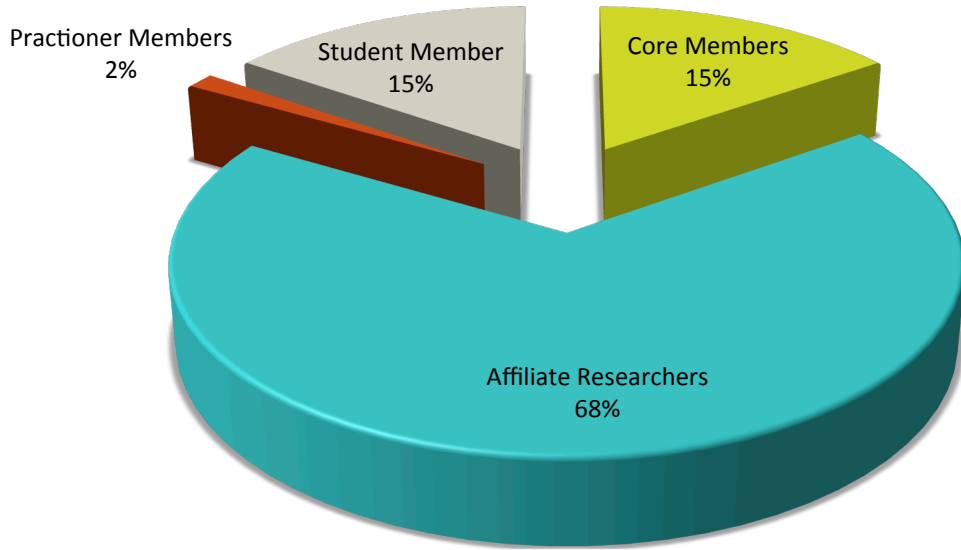
Figure 1.8: WICI Membership by Category

2. THE FIRST FIVE YEARS: ACHIEVEMENTS AND RESULTS

The following sections summarize WICI's achievements during its first term in the areas of: research activity and outputs; seminars, workshops and conferences; and education and training.

2.1 RESEARCH ACTIVITIES AND OUTPUTS

2.1.1 CORE PROJECTS

As discussed in the introduction, WICI has pursued six distinct research programs during its first five years. The last four represent WICI's current active focus.

COMPARATIVE THRESHOLD BEHAVIOUR IN PHYSICAL, ECOLOGICAL AND SOCIAL SYSTEMS (Co-PIs: Thomas Homer-Dixon and Lee Smolin) – This research program explores similarities and differences between theories explaining sharply nonlinear or "threshold" behaviour in physical, ecological, and social systems. It applies this knowledge to better explain sudden shifts in behaviour of social systems.

OPEN-ARCHITECTURE PROBLEM SOLVING "MASS-COLLABORATIVE GOAL GOVERNANCE: USING INFORMATION TECHNOLOGIES TO ADDRESS HUMANITY'S TOUGHEST PROBLEMS" (PI: Thomas Homer-Dixon) – This research program seeks to identify processes for enabling collective problem solving in response to critical global challenges. Of particular interest are applications of open-source methods to large-scale collaborative problem solving—especially methods that might improve democratic practice.

NETWORK SCIENCES (PI, Shreyas Sundaram) – This research program studies the structure and dynamics of complex networks (including social, economic, biological, ecological and engineered networks). The goal of the program is to develop mathematical models for complex networks, identify fundamental metrics and universal properties that characterize the efficacy and resilience of networks, and propose mechanisms to leverage the structure and dynamics to improve the functioning of the overall system. Two projects are currently underway within this theme: 1. "SOCIAL IMAGING: GPS Data tracking, spatial proximity, and social capital density" (PhD research of Milton Friesen, with Dawn Parker); and 2. "ROBUSTNESS OF COMPLEX NETWORKS: Reaching agreement despite stubborn and malicious adversaries."

This project has led to several new insights about the structure of complex networks. For example, it has revealed that certain commonly studied random graph models for large-scale networks inherently possess much stronger robustness properties than previously recognized. In particular, such networks can tolerate the removal of a large number of nodes while still remaining connected, and furthermore, facilitate certain classes of social opinion dynamics and information diffusion processes. Other groups around the world have now started to explore these properties in other classes of networks.

This project was initiated by a grant from WICI, and has benefitted greatly from WICI support and exposure. Dr. Sundaram, the project's PI, has given two WICI talks on the project; he was invited to the Guelph Biomathematics and Biostatistics Symposium in 2012 based on these talks, and was subsequently invited to present the work at Boston University by another attendee of the Symposium. During that visit, the PI also presented the work at Northeastern University, which subsequently led to an invitation to give a talk at the "Controlling Complex Networks" workshop at the flagship Network Science conference in 2014. Dr. Sundaram and students have also benefitted from the Network Science reading group that was operated under the WICI umbrella, and has led to new projects on the study of multi-layer networks.

> WICI was very beneficial to me when I was an assistant professor at Waterloo. I very much appreciated the opportunity to interact with complexity researchers from other departments. WICI significantly expanded my network, both within Waterloo and at other institutions.
>
> *-Dr. Shreyas Sundaram*
> *Core Member*

IDEOLOGICAL CONFLICT PROJECT (ICP) (Co-PIs: Thomas Homer-Dixon, Steve Mock, and Paul Thagard) – The Ideological Conflict Project (ICP) develops and applies new methods to advance understanding of the role of beliefs, ideas and emotions in conflict behaviour, as well as the processes underlying rapid belief change. It uses concepts drawn from complexity theory to model the structure and impact of beliefs as multi-level systems involving interaction between individual minds and social institutions, thereby integrating insights from the cognitive and social sciences to develop improved tools for conflict analysis, negotiation, and resolution.

Methods developed through the collaboration of the ICP team over the past five years include:

1) Cognitive-Affective Mapping (CAM): a method for depicting beliefs as networks of concepts that interact in a manner akin to the neural networks that process them. It offers a quick and easy means for depicting ideas as data, including the emotions attached to concepts that are crucial to decision making.

2) Ideological State Space: a series of methods for classifying beliefs according to the fundamental dimensions on which they differ. This allows us to visualize how ideologies cluster around certain "attractors," offering explanations for why seemingly unrelated or even contradictory positions bundle into coherent ideologies, how belief systems co-evolve in relation to one another, why they are resistant to change, and why change can be so rapid and dramatic when it does happen.

3) Catastrophic Dehumanization: the application of catastrophe theory to model the rapid psychological changes that enable groups of individuals to overcome their aversion to committing violence against particular others during eruptions of conflict.

WICI was the venue around which the interdisciplinary research team that formed the ICP was first assembled, and continues to provide both the institutional structure and the theoretical tools to enable

the ICP to examine the phenomenon of shared belief across the necessary disciplinary categories and levels of analysis.

ALTERNATIVES TO CONVENTIONAL GROWTH (PI: Steve Quilley) – This group is investigating the technical, social, and ethical implications of various pathways of change towards economic systems with radically reduced material and energy throughput. In this context, it is specifically investigating the relationship between energy input and societal complexity. We have just completed a Metcalf-funded project entitled "Green prosperity and the (re)Maker Society: Integrating the low growth economy with community self-development, artisanal skills and enhanced cultural participation" (PI: Steve Quilley [WICI/ERS]; CO-PIs: Rob Gorbet [CKI], Marcel O'Gorman [Critical Media Lab]) – details on www.remakersociety.com. As well as waiting to hear the outcome of a large follow-up SSRHC Partnership Grant application, the reMaker Society group is in the process of planning a workshop at the Canadian Society for Ecological Economics (CANSEE) conference in October and writing a University of Waterloo LITE grant application to begin work with Lewis Dartnell (following his successful WICI talk) developing Maker curricula for schools and universities. Stephen Quilley has just submitted a chapter on the problem of growth and complexity to a book edited by Peter Victor.

COUPLED HUMAN-ENVIRONMENT SYSTEMS – The future health of both human populations and natural systems depends on the two-way interaction between human systems and our environment: what humans do influences the environment, but the resulting changes in the environment in turn influence our perceptions and behaviour. Humans and their environment together thus form a single, coupled nonlinear system. Many traditional approaches in the sciences study environmental systems but ignore the coupling to human populations, or conversely they study human populations but ignore their coupling to environmental dynamics. On sufficiently long timescales, however, the coupling cannot be neglected. The study of coupled human-environment systems is concerned with improving our understanding of these systems, how they respond to disturbances, and how both human health and ecosystem health emerge out of the coupled dynamics.

Two WICI core research initiatives are underway under this umbrella: Land-use Change in Urban and Suburban Environments and Mathematical Modelling of Human-Environment Interactions.

LAND-USE CHANGE IN URBAN AND SUBURBAN ENVIRONMENTS: Led by Dawn Parker, this research develops agent-based residential land use and transportation models that explore linkages between socioeconomic and cultural characteristics of residents; their choices in housing markets, daily transport decisions, and environmental management of their properties; the goals and behaviour of developers; the constraints placed on both groups by policy makers and planners; and the macro-scale emergent patterns of urban form and transit network function that result. A secondary focus in the research theme is the development of methods and on-line tools for analysis of the complex data output from computational simulation models. Three projects are currently underway.

"Spatial Land Use Change and Ecological Effects (SLUCE): Interactions of Exurban Land Management and Carbon Dynamics" (US NSF; PI: Dawn Parker [with D. Brown, (PI)]; Co-PIs W. Currie, J. Nassauer, S. Page, R. Riolo U. Michigan; WICI Collaborators, Derek Robinson, Shipeng Sun, and Qingxu Huang) has

explored the effects of ex-urban residential development on carbon sequestration in S.E> Michigan, USA. The UW team investigated how aspects of land markets—preferences, budgets, and the competitive bidding environment—affect modeled land-use change outcomes. We found that full land market representation, including the heterogeneity of buyers and sellers, is critical to correctly represent and understand land-use change dynamics. We are currently developing new approaches to use simulated land markets to project land-use change outcomes from hedonic regression models. The LUXE model (see tools) has been publically distributed and is now in wide use, including within our ABM working group. We also found that both reforestation and convergence of land-use patterns (potentially due to social norms and neighbour imitation) is occurring over time in these landscapes, representing a significant source of carbon sequestration.

Parker and Robinson have both given WICI talks on this work, and Parker's land market modeling has benefitted from discussion with WICI external board members including Farmer, Testfatsion, and Arthur during and subsequent to their WICI visits. Parker plans to spend time with Farmer's at the Institute for New Economic Thinking group at Oxford during sabbatical to explore incorporating land market models into their large-scale macroeconomic models.

"URBAN INTENSIFICATION vs. SUBURBAN FLIGHT: An Integrated Residential Land-Use and Transportation Model to Evaluate Residential Land-Market Form and Function" (PI: Dawn Parker; Co-PI, Jeff Cassello) is developed agent-based models to analyze the patterns of change in residential development and transportation usage that might result from K-W's new light rail transit. With Markus Moos from Planning, we are also collaborating with partners from the Region, cities, and real estate industry to explore the policy implications of LRT, through another partnership development grant. Early student theses related to this project form building blocks of the modeling effort, focused on understanding and representing the key actors. Emma DeFields (MA) found that while a fairly high proportion of residents of homes with private green space would be willing to relocate to smaller residences, having some access to small private or public green space remained a high priority for them. Jason Neudorf (MA) created location-specific access cost curves that represented the incremental cost of accessing additional jobs from a particular location via the least-cost travel model. He found that while job access via transit is currently high for lower income areas, that accessibility could be threatened if intensification relocates lower-income residents to the suburbs. This research has benefited from direct WICI support for the PDG grant, as well as from students' participation in the ABM working group.

"Digging into Data: NEW METHODS FOR VISUALIZATION, ANALYSIS, COMMUNICATION AND DECISION SUPPORT USING COMPLEX SYSTEMS DATA: Closing the Loop of the Scientific Method for the 'Third Way of Science'" (Lead PI: Dawn Parker; Collaborating lead PIs: C. Michael Barton, Arizona State University, USA Tatiana Filatova the University of Twente, NL (PI) and Terence P. Dawson the University of Dundee, and J. Gary Pohill, the James Hutton Institute, UK; WICI collaborators Xiongbing Jin and Kirsten Robinson) is developing a cloud-based community platform that will allow computational modellers to post model output data and analysis algorithms, as well as to run and download others' algorithms. While in its early stages, our team has gathered extensive input from the modeling community on their current analysis techniques and platform needs, and two papers on these topics are

in progress. The project benefited from extensive WICI administrative support for grant development, discussions with participants from the Complex Data Visualization and Analysis symposium, and the hiring of a Work Study student through WICI.

MATHEMATICAL MODELLING OF HUMAN-ENVIRONMENT INTERACTIONS: Professor Chris Bauch's research group in the Department of Applied Mathematics at the University of Waterloo is pursuing research on using mathematical modelling approaches to better understanding the dynamics of coupled human and natural populations. His group is also interested in how these feedbacks can mitigate or improve intervention effectiveness. Study systems include forest-grassland mosaics, forest pest infestations, vaccine scares and disease eradication programs. His group's research has a common focus on applying empirically motivated theoretical modelling to tackle problems of policy or fundamental scientific interest. Theoretical techniques include differential equations, agent-based models, and network models, all of which can capture the coupled nonlinear dynamics that characterize these systems. Much of this work is carried out in collaboration with Professor Madhur Anand, a WICI Affiliate Researcher in the School of Environmental Sciences at the University of Guelph.

In the past five years, the Bauch Lab has advanced the science of understanding vaccinating behaviour during vaccine scares by validating coupled disease-behaviour models against empirical data on historical vaccine scares for childhood infectious diseases, and showing that it is possible for relatively simple mechanistic models to demonstrated predictive power. Continued work in this area will help develop a vaccine scare index that can indicate which populations are more vulnerable to vaccine scares, and thus should be targeted for focused risk communication. This work has been disseminated widely through invited talks and the media. His lab has also contributed to better understanding human decision-making in forest-grassland mosaic ecosystems. In particular, they have investigated conditions under which interventions to conserve forest or sequester carbon could stabilize, or indeed, de-stabilize, the coupled human-environment dynamics of these systems. This research has covered the gamut from field research to development of sophisticated mathematical and computational models. In both the case of vaccines and forest-grassland mosaics, we have identified exactly how interventions should be designed to work in harmony with injunctive social norms, social learning, and individual memory effects in order to be optimally effective.

Chris Bauch has given a seminar at WICI (2013) and has attended several WICI seminars since joining the faculty at the University of Waterloo. His graduate students have also attended a number of WICI seminars related to their research area. He was active in the Complex Health Innovation Working Group, contributing to group discussions and suggesting topics. He is currently planning further WICI activities with Dawn Parker and Madhur Anand, in particular, symposia on modelling coupled human-environment systems, and initiatives such as an NSERC CREATE grant to support PhD students working in the area of human-environment systems. He has also had informal research discussions with various WICI core and associate members, including Madhur Anand, Edward Thommes, and Thomas Homer-Dixon, much of which has helped inform the research which goes on in his lab.

2.1.2 SCHOLARLY PUBLICATIONS AND OUTPUTS

As seen in Table 2.1, WICI core projects have consistently produced healthy numbers of peer-reviewed publications, as well as disseminating findings through conference presentations and communications through the general media.

Table 2.1 - Scholarly Publications/Output

OUTPUT TYPE	2011-12	2012-13	2013-14	2014-15
PAPERS PUBLISHED	10	11	19	12
PAPERS IN PRESS	2	3	2	1
PAPERS IN REVIEW	3	4	4	13
PAPERS IN REVISION		3		
PAPERS CONDITIONALLY ACCEPTED		1		6
PAPERS IN PROCESS FOR SUBMISSION		1		10
BOOKS CHAPTER PUBLISHED	2	3	5	1
BOOK CHAPTERS IN PRESS	4	3	5	1
BOOK CHAPTERS IN REVIEW	1	1		
CONFERENCE SPEAKER/PRESENTATION	17	26	18	8
PAPER PRESENTATION	13	6	15	2
WORKSHOP/SYMPOSIUM PRESENTATION	1	7	5	1
OP-EDS	3	3	11	5
BOOK EDITOR	1	0		
RADIO/PRINT INTERVIEW	2	0	4	3
SUBMISSION TO THE UNITED NATIONS		1		
COMMUNITY OUTREACH		2	5	
ORGANIZATION OF WORKSHOP	1	5	3	1

Note: WICI began formally gathering outputs in 2011-12 and summarized these accomplishments in each year's Annual Report. Data for each year covers outputs from July 1-June 30 except for 2014-15 which covers July 1, 2014 to December 31, 2014.

2.1.3 WICI OCCASIONAL PAPERS

In order to provide a venue for dissemination of research findings for core projects and other local complex systems scholars, WICI established an "occasional paper series" in 2012. Papers are reviewed by WICI core staff, undergo copyediting, and are posted for public download. Table 2.2 lists the papers published to date, highlighting their very high readership counts. Again, this series demonstrates that junior scholars associated with WICI are producing high-impact complex systems research. WICI is also publishing a series of climate change briefs by former WICI PhD student, Dr. Manjana Milkoreit.

Table 2.2 - WICI Occasional Papers

	TITLE AND AUTHOR	VIEWS
JANUARY 2012	**"**A Complex Systems Approach to the Drug War in Mexico: Resources, Violence and Order" -Michael Lawrence (Student Member, Dr. Homer-Dixon's current PhD Student)	2293
FEBRUARY 2012	**"**Green Complexity Economics: Modeling Global-Scale Environmental, Resource and Ecological Challenges" -Dawn Parker and Thomas Homer-Dixon, (Core Members)	1847
AUGUST 2012	"Why the Mind Matters: A Cognitive Agenda for World Politics"***** -Manjana Milkoreit (former Student Member, Affiliate Researcher, Dr. Homer-Dixon's former PhD Student)	2072
JANUARY 2013	"Twenty-First Century Snake Oil: Why the United States Should Reject Biofuels as Part of a Rational National Security Energy Strategy" -Captain T.A. "Ike" Kiefer	2994
JUNE 2013	"Exploring the State Space of Ideological Possibility"***** -Matto Mildenberger (Student Member, Dr. Homer-Dixon's current PhD Student)	1779
JANUARY 2015	"Exergonic Innovations: The History of Britain's Coal Exploitation" -Clayton J. M. Dasilva (Student Member, Dr. Homer-Dixon's current PhD Student)	N/A

Note: Papers marked with an *asterisk indicate publications that report on/inform WICI core research. Views statistics from Issu up to December 31, 2014.

2.1.4 SOFTWARE TOOLS

Recognizing development of visualization and analysis methods for complex systems has not kept up with the soaring availability of data, WICI sponsored a Data Challenge competition and subsequently awarded a CDN$10,000 prize for tools and methods designed to improve the exploration, analysis, and visualization of complex-systems data in summer 2013. A data symposium followed the prize award in fall 2013, in order to publicize the work of the winner and runners-up from the contest and to provide a forum where other interested researchers on campus can present new work, engage in conversation, and coordinate to develop on-campus research in this area. Three runners-up also chose to post their submissions for public dissemination through our website. One of these products, the "Early Warning Signals" toolbox, was subsequently used as a supporting material for a summer 2014 Women in Math public lecture.

WICI has also prioritized the internal creation and dissemination of software tools for analysis of complex systems. Software tools, such as Empathica and LUXE, have been developed through WICI core research projects.

Table 2.3 lists two software tools developed through WICI core research projects, as well as the winning and runner-up entries from WICI's 2013 Data Challenge.

Table 2.3 – Software and Tools

SOFTWARE/TOOL	DESCRIPTION
EMPATHICA	This software program is designed to help people understand and resolve conflicts. It is based on the hope that increasing empathy (mutual understanding of values and emotions) between people can help to overcome impasses in disputes in many domains: organizations, politics, personal relationships, and so on. EMPATHICA uses the idea of Cognitive-Affective Maps (CAMs) developed by Paul Thagard in collaboration with Thomas Homer-Dixon, Scott Findlay, and others.
LUXE (LAND USE IN AN EXURBAN ENVIRONMENT)	LUXE is an agent-based model of land-market interactions, which allows the user to explore the effects of land market elements (preferences, budget constraints, and competitive bidding) on patterns of land-use and land-value in an abstract urban setting.
FAST VISUALIZATION OF RELEVANT PORTIONS OF LARGE DYNAMIC NETWORKS*	The winners of the WICI Data Challenge, Przemyslaw Grabowicz, Luca Aiello and Fil Menczer, developed a fast algorithm that selects subsets of nodes and edges that best represent an evolving graph and visualize it by either creating a movie, or by streaming it to an interactive network visualization tool.
EARLY WARNING SIGNALS TOOLBOX: A NOVEL APPROACH FOR DETECTING CRITICAL TRANSITIONS*	A newly developed Early Warning Signal Toolbox designed for the WICI Data Challenge by Vasilis Dakos and Leo Lahti for estimating and visualizing fingerprints of upcoming critical transitions based on time series data. The toolbox is easy to use through a user-friendly interface developed in R, an increasingly popular open-access statistical language for scientific computing.
JUST: A NETWORK SIMULATION TOOLKIT FOR COMPLEX SYSTEMS RESEARCHERS*	JUST – a software framework designed by Jon Mackay for the Data Challenge to help researchers rapidly develop custom simulation models of networks. JUST is not just a framework to develop and run simulations, but a complete package that gives users the ability to visualize their models, share them with others and export the data they generate to other packages for analysis.
VISUALIZING ARGENTINE ANTS: THE USE OF DANCE TO VISUALIZE COMPLEX DATA*	Complex systems data, regardless of their dimensions, are usually communicated on two-dimensional surfaces, such as in texts, statistics, equations, graphs, flowcharts and feedback diagrams. These classical means of data communication, though explicit and unambiguous, can often be difficult to interpret because of the dense formal language conventions of science and math. Dance and movement, as a means to personify complex data, facilitates audience investment in the issues presented, as well as room for creative interpretation of them. Sarah Hogland and Elliott Miller suggest movement simulations of complex systems can also be an accessible educational tool because of its appeal to diverse learning styles.

*Note: Software/Tools marked with *asterisk were Data Visualization and Analysis Tools submitted to WICI's 2013 Data Challenge.*

As of December 31, 2014, our Research Tools webpage on which Empathica and LUXE are referenced has been viewed **369 times,** and LUXE code has been downloaded **275 times**. The WICI Data Challenge page has garnered **572 views**, and the Data Visualization & Analysis Symposium page has been viewed **877 times** on our Wordpress website. There have been **579 downloads** from the MediaFire account on which our Data Challenge tools are stored.

2.2 FUNDRAISING SUCCESS

As discussed in the introduction, since WICI is a research centre, all WICI related grants have historically been submitted by member PIs through their home units. WICI has supported these applications by assisting with grant preparation, offering in-kind and financial contributions, and facilitating connections between researchers working in complex systems.

As illustrated in Table 2.4, WICI core projects have demonstrated consistent effort and increasing success in obtaining external research funding. Several applications have received tri-council full funding, and others have received A4 status. Funding has also been obtained through CIGI. Further, submitted, pending and successful proposals demonstrate broader national and international collaborations (NSCERC CREATE, SSHRC Partnership development and Partnership grants as well as the international Digging into Data grant). These projects demonstrate WICI's success in network and capacity building, which has left us prepared to respond to large-scale calls for proposals with relatively short turn-around times.

Table 2.4 - Grants Submitted and Obtained

	GRANTS SUBMITTED (UNFUNDED UNLESS OTHERWISE NOTED)	GRANTS OBTAINING FUNDING
2010-11	N/A	N/A
2011-12	• *Ideology:* James S. MacDonnell Foundation • *Open Architecture:* CIGI Strategic Grants Research Initiative (RESUBMISSION INVITED) • *Human-Environment Systems ("new methods…"):* James S. McDonnell Foundation Scholar Award in Complex Systems Science Program • *Human-Environment Systems*: NSERC CREATE program in Modeling Human-Environment Sustainability • *Network Science ("Social Imaging…"):* Google	• *Human-Environment Systems ("urban intensification vs. suburban flight"):* **$320,521** from SSHRC
2012-13	• *Open Architecture:* Google Faculty Support; Banting Post-Doctoral	• *Ideology:* **$30,000** from CIGI CRA Research Initiative; **$8,000**

	Fellowship; SSHRC IDG	from UW to reapply to SSHRC IDG application receiving 4A evaluation
	• *Alternatives to Growth:* "Green prosperity and the (re) Maker Society: Integrating the low growth economy with community self-development, artisanal skills and enhanced cultural participation"	• *Alternatives to Growth:* **$36,800** from Metcalf Grant (Green Prosperity Program) for "Green prosperity and the (re) Maker Society"
	• *Network Science:* Google	• *Open-Architecture:* **$8,000** from UW to reapply to SSHRC application receiving 4A evaluation
		• *Alternatives to Growth:* **$20,000** from SSHRC Partnership Grant
2013 – 14	• *Ideology:* $290,000 grant from CIGI for Ideological Conflict Project. A collaborative research project between WICI and the BSIA.	• *Human-Environment Systems:* **$125,000** from SSHRC, part of **$567,000 (USD)** from DiD
		• *Human-Environment Systems:* **$199,930** from SSHRC Partnership Development Grant for project "LIGHT RAIL TRANSIT AND CORE-AREA INTENSIFICATION: Unpacking Causal Relationships"
		• *Human-Environment Systems:* **$198,000**, Partnership Development Grant for project "Hedgelaying in Ontario's Greenbelt: A multicriteria assessment of social-ecological innovation and novel ecosystems"
		• *Alternatives to Growth:* **$2,495,651** from SSHRC Partnership Grant for "Economics for the Anthropocene" (Lead institution McGill with York University and Vermont where students will be trained; WICI contribution $3,370)
2014-15		• *Coupled Human-Environment Systems - Mathematical modelling of human-environment interactions:* **$250,000 ($50,000 per year for**

			5 years) from NSERC Individual Discovery Grant for "Dynamics of coupled human-environment systems"	

2.3 SEMINARS, WORKSHOPS AND CONFERENCES

WICI offers a regular program of seminars, workshops, and symposia as shown in Table 2.5. Each year WICI organizes a Speakers Series, which brings experts in their field to UWaterloo to speak on topics of their choice relevant to complexity science, and also offers local scholars a chance to showcase their work. Audiences are generally made up of faculty and students from various departments as well as members of the local community. These talks stimulate discussion on a range of topics and advance awareness, communication, and exploration between researchers from many different faculties.

These talks have highlighted the work of some of the founding members of complexity science, including Stuart Kaufmann, Doyne Farmer, Leigh Testfatsion, Marten Scheffer, Michael Batty, Brian Arthur, and Saudner Van der Leuw. These talk have exposed UW faculty, students, staff, and community members to pioneering work in complex systems approaches to sustainability, economics, and social dynamics. Video archives also allow audience members to explore and draw links between different topics. These high-level talks are supplemented by talks by local-area scholars, facilitating connections between local scholars for collaboration and mentoring.

While high-profile scholars have consistently drawn large crowds, numbers for our regular talks are growing, and attendance is often at or beyond the capacity of a regular seminar room. Additional community feedback regarding WICI talks is available in Section 2.5: Communications, Engagement and Feedback.

Table 2.5: Frequency of Seminar, Workshop, and Conference Events Held by WICI

	SEMINAR/TALK	WORKSHOP	CONFERENCE/SYMPOSIUM	TOTAL
2008-2009	9			9
2009-2010	10		1	11
2010-2011	9	1		10
2011-2012	10	1		11
2012-2013	5	5		10
2013-2014	7	1	1	9
2014-2015	9	2		11

Seminars, talks and workshops also allow us the opportunity to support, develop, and disseminate research from WICI's core projects as shown in Tables 2.5 and 2.6.

Table 2.6 - WICI Seminars that Report On/Inform WICI Core Research Projects

SPEAKER(S)	SEMINAR TITLE	DATE PRESENTED	WICI RESEARCH GROUP AFFILIATION
Frances Westley	Complexity Approach to Change and Transformation	Feb. 2009	CAM/Ideology
Dawn Parker	Market Activity, Landscaping Behavior, and Carbon Sequestration in Ex-Urban Landscapes	Oct. 2009	Human-Environment Systems
Mark Tovey, Michael Nielsen & Hassan Masum	Open Source Democracy	Feb. 2010	Open-Architecture Problem Solving
Steve Purdey	Steady State Economics	Mar. 2011	Alternatives to Economic Growth
Shreyas Sundaram	Diffusing Information and Reaching Agreement in Networks: Convergence and Resilience	Sept. 2012	Network Science
Steve Mock	The End of Economic Growth: Social Regression or New Beginning?	Feb. 2012	Alternatives to Economic Growth
Shreyas Sundaram	Reaching Agreement in Complex Networks: Avoiding the Influence of Extreme Agents	Mar. 2012	Network Science
Matto Mildenberger	Exploring the Possibility Space of Ideological Change	Mar. 2012	CAM/Ideology
Dawn Parker	Tracing the Impacts of Land-Market Structures on Urban Growth	Nov. 2013	Human-Environment Systems
Paul Thagard	Creative Cognition in Social Innovation	Dec. 2013	CAM/Ideology
Derek Robinson	Discovering the Themes of Complexity Science in Land use Modelling	Feb. 2014	Human-Environment Systems
Dawn Parker and Sarah Tolmie	Bridges Lecture: Dancing the Math of Complex Systems	Mar. 2014	Human-Environment Systems/ Embodied Cognition

Table 2.7 - Workshops that Pertain to WICI's Core Research Projects

DATE	WORKSHOP TITLE AND WICI MEMBER(S) [WICI HOSTED EVENTS MARKED WITH AN *ASTERISK]	WICI RESEARCH GROUP AFFILIATION
2010-2011	"Think with your Feet"; Affiliate Researchers Sarah Tolmie & Mark Hancock	Embodied Cognition
2010-2011	"Science and Technology Innovation Workshop, Health Canada"; Thomas Homer-Dixon	Alternatives to Growth/Threshold
2011-2012	*BSIA Ideational Conflict Project Workshop; Steve Mock and Thomas Homer-Dixon	Ideology/CAM
2011-2012	"Mapping the Transition from the Growth Model to	Alternatives to Economic Growth

	the Steady-State Model in the International Political Economy"; Steve Purdey	
2011-2012	"The Way Ahead: Global Governance, Complex Adaptive Systems and Societal Transformations"; Steve Purdey	Alternatives to Economic Growth
2012-2013	*"WICI Ideology Workshop"; Thomas Homer-Dixon, Matto Mildenberger, Manjana Milkoreit, & Steve Mock	Ideology/CAM
2012-2013	* "WICI Ideology Workshop: Integrating Complexity Theory"; Thomas Homer-Dixon, Matto Mildenberger, Manjana Milkoreit, Steve Mock, & Paul Thagard	Ideology/CAM
2012-2013	*"Alternatives to Economic Growth"; Thomas Homer-Dixon, Steve Quilley & Steve Mock	Alternatives to Economic Growth
2012-2013	*"Alternatives to Economic Growth: 2nd Meeting"; Thomas Homer-Dixon, Steve Quilley, Steve Mock, & Steve Purdey	Alternatives to Economic Growth
2012-2013	International Congress on Environmental Modelling and Software, Workshop H6: Human decisions in agent-based models (ABM) for natural resource use need for protocols; Dawn Parker	Human-Environment Systems
2012-2013	National Center for Atmospheric Research Agent-Based Modeling of Land Use Change Workshop on Climate Change Impacts and Integrated Assessment; Dawn Parker	Human-Environment Systems
2012-2013	*Collaborative Democracy Camp; Mark Tovey, Hassan Massum, Steve Quilley, Thomas Homer-Dixon	Open-Architecture
2012-2013	Genome Canada Disruptive Technologies Workshop; Steve Quilley	Open-Architecture
2012-2013	Banff Workshop on Asymptotics of Large Scale Networks; Shreyas Sundaram	Network Science
2012-2013	Bellairs Workshop on Distributed Signal Processing; Shreyas Sundaram	Network Science
2013-2014	*"WICI Ideology Workshop: Ideological Conflict Project"; Thomas Homer-Dixon, Matto Mildenberger, Manjana Milkoreit, Steve Mock, & Paul Thagard.	Ideology/CAM
2013-2014	*Data Visualization and Analysis Symposium	All
2014-2015	The Knowledge: Curriculum Development Workshop; Steve Quilley	Alternatives to Economic Growth

WICI records most of its speakers' talks and posts those on our website, allowing viewers from all over the world to engage with the ideas presented. As of December 31, 2014, the total number of views for *all* video recordings of WICI talks available on our website is **4,437**. A full list of statistics for WICI videos can be found in Appendix D: WICI Seminars and Video Recording Statistics.

These data show that WICI talks have healthy play/view counts, with the most successful rating in the hundreds or even thousands. It is important to note that while, as expected, talks by senior complexity scholars (Testfatsion, Scheffer, Batty, Solomon) have very high view counts, many talks by junior scholars on the University of Waterloo campus (Larson, Sundaram, Lizotte, Schröder, Mildenberger, Mock) also have very high view counts, highlighting the recognized contributions of local junior scholars to complex systems science.

2.4 EDUCATION AND TRAINING

WICI core research activities have contributed to the training of highly qualified personnel. WICI core projects have graduated several students and WICI has supported many full-time UWaterloo students and post-docs with their research.

2.4.1 STUDENTS GRADUATED AND EMPLOYED

Between 2010 and 2013, WICI core projects graduated three masters and three PhD students as shown in Table 2.8. WICI core funding has also supported four post-doctoral fellows (see Table 2.9).

Table 2.8 - Students Graduated

NAME	DEGREE AWARDED	YEAR COMPLETED	WICI RESEARCH GROUP AFFILIATION
Dasilva, Clay	MA	2010	Alternatives to Economic Growth
Milkoreit, Manjana	PhD	2013	CAM/Ideology
Tjornbo, Ola	PhD	2013	Open-Architecture Problem Solving
Zhang, Haotian	MSc	2012	Robustness of Complex Networks
DeFields, Emma	MA	2013	Human-Environment Systems
Huang, Qingxu	PhD	2013	Human-Environment Systems
Fata, Elaheh	MASc	2013	Robustness of Complex Networks
Neudorf, Jason	MA	2014	Human-Environment Systems

Table 2.9 - Postdoctoral Students Employed to work on WICI Research Groups

NAME	YEARS EMPLOYED	WICI RESEARCH GROUP AFFILIATION
Mock, Steven	2010-present	CAM/Ideology
Sun, Shipeng	2010-2012	Human-Environment Systems
Gostolli, Umberto	2012-2013	Human-Environment Systems
Jin, Xiongbing	2012-present	Human-Environment Systems
Nowack, Shane	2014-present	Mathematical Modelling of Human-Environment Interactions

In recent years, WICI has received three inquiries from early-career scientists seeking to join WICI as post-doctoral fellows or research scientists. The qualifications of these candidates are very strong, and this interest indicates that WICI would be able to attract a very strong cohort of early-career complex systems scholars, if we were able to find resources to support them.

2.4.2 STUDENT FUNDING

WICI provides full-time University of Waterloo students with the opportunity to seek funding from the Institute to pursue complexity related activities that will further their own research. To date, WICI has funded the following students:

- Manjana Milkoreit: $750 to attend a POLNET workshop in June 2013 in Germany;
- Fatima Jahanmiri: $1000 to attend an agent-based modeling workshop; and,
- Maren Pauly (MSc Candidate): $500 to fund fieldwork in August 2014 in the Great Barrier Reef, Australia.

2.4.3 WORKING/READING GROUPS

WICI has facilitated faculty and student research and discussion through three previous and on-going reading/working groups held at UWaterloo.

COMPLEX HEALTH INNOVATION UNDER RESOURCE CONSTRAINTS WORKING GROUP: Started Spring 2013 term in response to Rob Robson of the Healthcare System Safety and Accountability group reaching out to WICI and asking for help in creating a space to discuss complexity and healthcare issues. This group is providing a useful bridge for WICI into Applied Health Sciences.

NETWORK SCIENCE READING GROUP: Following on from J.P. Onnela's presentation in January 2010, as part of WICI's seminar series, this reading group was developed on campus, led by former PhD student (Management Sciences Faculty) Jon McKay, in collaboration with Phd Student and Cardus (external research think tank) Research Fellow Milton Friessen and Professor Shreyas Sundaram (WICI Affiliate Researcher & UW Assistant Professor in Electrical and Computer Engineering).

AGENT-BASED MODELING WORKING GROUP: The ABM working group was started in Fall 2013 in response to interest from UW students. The working group is organized by WICI Affiliate Researcher Xiongbing Jin and Student Member Kirsten Robinson. Activities include weekly group meetings (every semester) and ABM tutorials (Summer 2014 and Winter 2015). The *group meetings* have a regular attendance of 6 to 10 people, and feature general discussions and frequent presentations from members on their recent modelling work and ideas. The *ABM tutorials*, organized by Jin, teach the development of agent-based models using a popular ABM platform. These tutorials have a regular attendance of 5 to 10 people, with 5 people successfully completing the first series of tutorials in Summer 2014, and another session ongoing in Winter 2015 with 26 initial signups.

The ABM group meetings and tutorials attracted participants from a wide range of disciplinary backgrounds including Planning, Geography, Ecology, Engineering, Sociology, Public Health, International Affairs and other areas, and from both inside and outside the University of Waterloo. Presentations and discussions cover a wide variety of topics including farmers' behaviour in the Amazon, dynamic formation of cities and social organizations, land markets, transportation choices and substance use in cities among others. Through the tutorials and group meetings, students and researchers learn how to develop agent-based models in their field of study, and also get feedback and extensive help from other group members on building models, developing presentations, and writing publications and theses.

> I love how genuinely interdisciplinary it is. I've made some very interesting connections with people in CS and other parts of campus.
>
> *-Dr. John McLevey*
> *Affiliate Researcher*

The group provides ongoing support for several current PhD, Master's and Honour's thesis research. One of the early participants and regular attendees, also a Student Member of WICI, Fatemeh Jahanmiri, just successfully defended her ABM-based thesis in February 2015. Discussions are underway to develop a formal ABM course, in collaboration with Professors Derek Robinson (Environment), Kim Cuddington (Science), Brian Ingalls and Chris Bauch (Math).

2.4.4 EDUCATIONAL MATERIALS AND LINKS

Two educational resource sites were established to provide materials and links related to the study of complexity science, including:

(i) Complexity Reading List: Key readings for those new to complexity science (viewed on Issuu **1,669 times**)**.**

(ii) Complexity-Related Courses at UW: Undergraduate and graduate courses taught at the University of Waterloo which recent entrants to the complexity field might find useful. Graduate course list viewed on Issuu **638 times.** Undergraduate course list viewed on Issuu **848 times.**

2.5 COMMUNICATIONS, ENGAGEMENT AND FEEDBACK

WICI strives to maintain good two-way communication with its membership. This section first describes our mechanisms for communicating with our constituents, then reports on efforts over the last year and a half to gather feedback from constituents in preparation for renewal.

The first feedback activity was an open meeting held in Fall 2013 to (a) get feedback on current WICI programs and activities; (b) brainstorm suggestions for new or enhanced activities; and (c) set longer-term goals for WICI. We also conducted a survey of seminar participants and held intensive discussions with the Board in 2013-2014. In early 2015 we also conducted a member survey. Results from the first three efforts are summarized in Section 2.5.2, with full details provided in the 2014 budget renewal

application. More detailed results of this year's member survey are summarized here, with full results in Appendix F.

2.5.1 COMMUNICATIONS TO CONSTITUENTS

WICI's website continues to be the primary source for information relating to the Institute. It is used to share news about upcoming events, profile WICI members, and recruit researchers and staff. As discussed earlier, software, tools, publications and other educational resources are available on our website. As of December 31, 2014, the WICI website has had **61,700** views. Additional statistics on the WICI website can be found in Appendix E: Website Statistics.

WICI has a Mail Chimp email list with **410** active subscribers and utilizes a corresponding social media platform to engage the broader community in our activities. Events and news are publicized using WICI's Facebook page, Twitter feed and LinkedIn company page and link back to the main WICI website.

WICI ONLINE ENGAGEMENT

67,000 WEBSITE VIEWS

NEWS OF WICI EVENTS, PROJECTS, ONLINE TOOLS AND PUBLICATIONS NOW REACHES **410 MAILING LIST SUBSCRIBERS**

REACHING 650+ FOLLOWERS THROUGH SOCIAL MEDIA

10,000+ DOWNLOADS OF WICI OCCASIONAL PAPERS

4,437 ONLINE VIEWS OF WICI TALKS

1000+ DOWNLOADS OF DATA VISUALIZATION CHALLENGE TOOLS AND OTHER TOOLS FROM WICI.CA

Figure 2.1: WICI Online Engagement

2.5.2 2013 USER COMMUNITY SURVEYS AND BOARD FEEDBACK

Attendees at the 2013 open meeting reported that WICI had created a diverse set of benefits and opportunities for them. These include:

- The WICI occasional papers and videos. Several participants had read and/or viewed many or all of these. One participant commented, "The occasional papers help you see how people apply these techniques in different ways." The biofuels occasional paper by Captain T.A. 'Ike' Kiefer was mentioned as an excellent example of complex systems analysis applied to a practical problem. Videos by Brian Arthur, J. Doyne Farmer, Stuart Kauffman, and Martin Scheffer (all pioneering senior complex systems scholars) were mentioned in particular. The range of topics and intuitive examples provided by the videos was mentioned. One participant noted:

"Listening to Marten Scheffer explain critical transitions is really as good as it gets in this field." Another participant mentioned the talk providing examples that he had used in discussions with health managers to illustrate the downside of linear models of thinking, that don't acknowledge thresholds and irreversibility, commenting that the talks provide "examples people can relate to."

- Participants mentioned the value of networking opportunities created by WICI. The following anecdotal illustration gives some examples of how WICI has facilitated development of these networks:
  - Connections made between Professor Dawn Parker (WICI Director) and Professor Monica Cojacaru, along with others in Math, illustrates this process. Professor Cojacaru (University of Guelph, WICI Executive Member) originally located Professor Parker through the WICI website and invited her to participate in a local conference session for an international applied mathematics and computer science conference. She also introduced Professor Parker to Professor Madhur Anand, an applied ecologist from Guelph, who presented a WICI talk and led an NSCERC CREATE (unfortunately unfunded) multi-institution proposal on which Professor Parker participated. Professor Cojacaru also introduced then University of Guelph Professor Chris Bauch to WICI activities, and he was invited to join as a member.
  - WICI subsequently invited Professor Cojacaru to present a WICI talk, which was attended by University of Waterloo Math Professor Hans De Sterk. Professor Cojacaru's talk was also viewed by a social science professor at Guelph, who contacted Professor Cojacaru and instigated a collaborative project. Professor De Sterck subsequently wrote to Professor Homer-Dixon about the work of one of his graduate students on conflict issues. Post-doc Steven Mock and Professor Homer-Dixon sat down with both Professor De Sterck and his student shortly afterwards to discuss their collaborative project and findings. Subsequent to this meeting, WICI invited Professor De Sterck to sit as a WICI board member.
  - Professor Shreyas Sundaram's involvement with WICI is another example. He was awarded a small WICI grant in 2011. Subsequently he became involved with WICI as a core member, helping oversee the Network Science reading group and participating in PhD student supervision and grant authorship with Professor Parker. His talk at WICI also led him to an invitation to speak at the Fields Institute Guelph Biomathematics and Biostatistics Symposium, University of Guelph in June 2012 by Professor Chris Bauch from Guelph, who is now himself in the Math Faculty at Waterloo.
  - Professor Stephen Quilley's connections provide yet another example. HIs research collaboration with Professors Peter Brown (McGill) and Professor Peter Victor (York) was established through the Alternatives to Conventional Growth Symposia (2012/13). This collaboration has proven fruitful in a number of ways -leading to a WICI contribution to a major SSHRC funding application (Education for the Anthropocene) and contributing to the Metcalf grant. With regard to teaching, the collaboration with Professor Brown has contributed to a decision to develop a core undergraduate course in Big History in

the Department of Environment and Resource Studies (Professor Quilley is in this case working with Professor Stephen Murphy).

- Students expressed appreciation for the networking and educational support provided by WICI. One student commented that complex systems research is challenging because it requires development of technical skills in many areas beyond her core research area. WICI support for workshop participation helped her developed needed expertise in programming. Other students have benefited through participation in the network science and agent-based modeling working groups, which give them an opportunity for structured interaction with students who share common interests in cases where supporting coursework is not available. Students expressed interest in creating more such opportunities (see below for recommendations).

- Respondents to our paper survey provided relatively fewer comments, but suggested topics such as integration with design disciplines, political theories and complexity, more focus on quantitative work and hypothesis testing, reflecting WICI's broad audience. On participant simply commented: "You guys are awesome! I hope you remain enthused with the interdisciplinarity in the sciences and continue to encourage the integration of different paradigms in modern science. Thank you for existing!"

From all three sources, we received many useful suggestions for future progress, highlighted here:

COMMUNICATION AND NETWORK BUILDING: All feedback sources provided helpful suggestions for expanding faculty networks and involvement, improving communication with students, and communicating with external communities. There is consensus that a bottom-up network-building strategy will be most successful, whether through students or faculty.

Suggestions emerged regarding new ways to engage undergraduates that we have followed up on, including targeting student societies, returning to paper posters for WICI events, and issuing small challenge prizes. We have also opened WICI membership to undergraduates.

> WICI excels because of its focus on system based thinking, allowing for big ideas and processes to be boiled down into their constituent parts and relationships -- making these ideas digestible and transferable across disciplines."
>
> *-Robert Babin*
> *Student Member*

In response to the success of the open discussion forum of the open meeting, we have also instituted a half-hour coffee prior to official seminar. With a little active network building by the director and the speaker, this is providing to be quite successful as a means of building the WICI community.

ACTIVITIES: Many new activities were suggested. Some would strengthen WICI's current activities, whereas others would move WICI in expanded direction. We have not yet been able to implement most of these, but they provide a great agenda for WICI activities moving forward.

EDUCATION: We received many creative and exciting suggestions for ways in which WICI could support complex-systems education. We were encouraged to keep the list of UW campus complex-systems related courses and key

complex-systems readings up to date. WICI could facilitate posting of course materials outside of the course management system environment for these courses, as an extension of that activity. Undergraduates in particular stressed the utility of short, introductory items. One student suggested a series of blog posts on basic complex systems concepts and examples. Another suggested that we post classic complex systems data sets available for analysis for class projects. WICI members could also indicate their availability to serve as guest speakers in classes. A suggestion was made to create extended learning modules, using key WICI talks as a resource. This could be developed into a general entry-level complex systems courses, perhaps even an on-line course with core members covering different modules.

RESEARCH: In response to encouragement to better highlight and publicize the research activities occurring under the WICI umbrella, we are creating new WICI research pages, which will include a linked bibliography of project outputs. We have also now been approved for work-study positions and have hired students to support core projects through WICI.

CHALLENGES: Although the previous challenges (grants programs, data challenge) were appreciated, we were also encouraged to "think small" for new challenge formats, especially when trying to engage undergraduates. Small hacking challenges were suggested, with short turn-around time and small awards to attract students. An open tools or help session once a month was also suggested. The usefulness of the student travel grant was reinforced.

2.5.3 2015 WICI MEMBERSHIP SURVEY

In early 2015, WICI sent a survey to all current members to gage their past interaction with the Institute and solicit their thoughts on our direction moving forward. Eighteen active WICI members completed the survey. 16.67% of the responses were from Core Members; 50% from Affiliate Researchers; and 33.33% from Student Members. The full results can be found in Appendix F.

The results showed that the vast majority of respondents have attended the WICI Speakers' Series, with the majority also presenting a talk and suggesting speakers. A third of respondents have been involved in a WICI-related research project and/or participated in WICI workshops. Fewer respondents organized or participated in WICI working groups.

94.4% of survey respondents suggested that WICI's greatest value lies in its network-building for complex systems research on campus and beyond. Members also valued the speakers' series and occasional papers, as they offer an opportunity to learn more about other members' current research. Direct support for cross-faculty collaborative research was stressed as a core value by over half the respondents. 62.5% of respondents felt WICI could continue to strengthen its support of cross-faculty collaborative research and facilitate even more network-building. More than half the respondents said training and education through workshops, reading groups or working groups should continue to be a focus.

When respondents were asked to discuss WICI's comparative advantage, many emphasized its network building capacity and cross-collaborative focus. Several members also stressed WICI's uniqueness in this

region, including WICI Affiliate Researcher Dr. Derek Robinson, who responded WICI has set the foundation to "become the region's center for the study of complex systems."

Members were also asked about possible areas of improvement. Respondents felt WICI could do even more to promote itself to UWaterloo faculty and students. One respondent said a key problem is the lack of cross-faculty and cross-department infrastructure to support some activities (i.e. interdisciplinary PhD programs). Another area for improvement is clarifying WICI's purpose to those outside of the Institute. As stated by student member Kirsten Robinson, "Many don't know who we are or what we do. Projects sometimes start and then loose momentum. It can be difficult for outsiders to find meaningful ways to engage beyond attending public talks."

When asked for suggestions moving forward, members offered the following ideas:

- Continue bringing in high quality speakers;
- Offer more applied and technical workshops;
- Identify opportunities to bring interdisciplinary researchers together to pursue research funding;
- Hold international conferences in complex systems research;
- Improve engagement with faculties that are not currently as involved in WICI;
- Work on focusing and differentiating the Institute;
- Find ways to engage external members more regularly; and
- Extend communication efforts to reach a wider audience for WICI talks, workshops, and challenges.

3. WHY RENEW WICI? BUILDING ON A SUCCESSFUL FOUNDATION

As detailed in the proposal body and appendix, in its first five years, WICI has built a solid foundation of networks, activities, products, and notable research achievements. Continued support will allow us to build on this foundation to take WICI to the next level of growth. In this section, we summarize WICI's current and potential contributions, highlighting concurrence with the university's strategic plan, and set forward a vision for specific goals and activities to move WICI forward.

3.1 ACHIEVEMENTS AND ALIGNMENT WITH UW STRATEGIC PLAN

Based on the content presented in this request, we reiterate our original arguments:

- WICI has met goals outlined in the original proposal and has consistently met or exceeded a high proportion of its annual goals. We have a consistent track record of forward progress towards our stated mission and goals. Further, we have produced products, activities, and resources not originally anticipated at the time of our establishment.

- WICI has had a positive impact on the community at large, both inside and outside the University of Waterloo. WICI has contributed by:

    o *Creating networking opportunities* in the form of in-person seminars, working groups, workshops, graduate travel opportunities, and exposure through the WICI website;

    o *Creating useful community resources* such as an online video archive, the occasional paper series, online tools for complex systems analysis, and educational materials;

    o *Building capacity that allow scholars to respond to opportunities* to connect with other complex systems scholars for the purposes of workshop and conference organization, graduate student committees, and small grants; and further, to connect in larger groups on campus and beyond to respond to major funding initiatives; and,

    o *Increasing the profile of the university, both within the GTA and beyond* through provision of high-quality seminars, working papers, research group output, and tools and methods.

- *WICI-supported activities have facilitated training of HQP and success in obtaining new resources to support research*, as demonstrated by the successful supervision and thesis completion of graduate students and post-docs and through increasing success in obtaining competitive grant funding.

- Finally, we argue that WICI's goals, mission, and activities are *in line with the university's new strategic plan*:

- o Transformational research. Due to the highly novel and interdisciplinary nature of complex systems research, our successes as outlined above contribute to the university's primary objectives in this category:
    - Be recognized internationally for excellence and innovation in education, research and scholarship (p. 31);
    - Enable conditions which support research excellence and impact (p. 22);
    - Identify and seize opportunities to lead in new/emerging areas (p. 22);
    - Increase interdisciplinary and transdisciplinary research at the global, national and local scale (p. 22);
    - Strengthen the relationship between research and teaching at the undergraduate level (p. 22); and
    - Build wider awareness and understanding of Waterloo's research productivity and impact (p. 22).
- o Global prominence. The recognition that WICI's activities are achieving contributes to the following objectives:
    - Be recognized internationally for excellence and innovation in education, research and scholarship (p. 31); and
    - Build further exemplary international research networks of elite institutions and individuals that utilize the intellectual and physical assets of the institution (p. 22).
- o Vibrant student experience/outstanding academic programming: Through opportunities to participate in seminars and working groups, WICI already makes some contributions in this area. The enhancements and new activities suggested as part of this year's WICI feedback will further strengthen WICI's contributions to the following objectives:
    - Educate graduates uniquely prepared to address the challenges and opportunities of the 21st century (p. 28); and
    - Build a community of communities by providing an environment where students, faculty and staff can connect (p. 33).

Continued funding of WICI would therefore contribute to the following proposed supporting actions from the strategic plan:

- Encouraging research networks which build on partnerships with internationally recognized universities (p. 22);
- Providing and facilitating opportunities for interdisciplinary and transdisciplinary research (p. 22);
- Providing opportunities for undergraduate students to engage in research across all disciplines (p. 22);
- Building further exemplary international research networks of elite institutions and individuals that utilize the intellectual and physical assets of the institution (p. 22);
- Encouraging faculty members to integrate their research and the process of research into course activities (p. 28); and

- Providing the means for students to interact across different programs (p. 33).

3.2 THE NEXT FIVE YEARS: STRATEGIC DIRECTIONS FOR 2016-2020

WICI's strategic directions for the next five years falls under five categories, each aimed at building on current strengths to raise the productivity and profile of WICI.

3.2.1 STRENGTHENING CORE NETWORKS

A research centre such as WICI will survive and thrive only if it has a group of core participants, who are active in envisioning research, obtaining funding, and training HQP, as well as willing and able to participate in centre management.   To address our core networks:

- We will continue to actively support current core projects and members through grant writing assistance and complementary activities such as talks, workshops, and working groups. Our revised membership criteria, however, asks for more active involvement from core members in return.
- We will look for existing opportunities on campus to expand core membership. Opportunities to achieve this exist currently in WICI's network of core and affiliate researchers. WICI's core networks by topic include (as of Dec. 2014):
  - **Network science**: Engineering: Shreyas Sundaram; Math: Chris Bauch, Hans De Sterck; Environment: John McLevey, Milton Friessen, Fatemeh Jahanmiri; Arts: Peter Carrington, Owen Gallupe.
  - **Human-environment interactions**: Environment: Derek Robinson, Peter Deadman, Dawn Parker, Dan McCarthy, Xiongbing Jin; Math: Chris Bauch; Arts: Thomas Homer-Dixon; Guelph: Madhur Anand.
  - **Expanding conventional economics**: Environment: Dawn Parker, Xiongbing Jin, Steve Quilley, Simron Singh, Dan McCarthy, Katie Weedmark Kish; Arts: Thomas Homer-Dixon, Marissa Beck, Steve Mock; Laurier: Randy Wigle; Guleph: Monica Cojucaru.
  - **Complexity and non-rational drivers of behavioural change:** Environment: Stephen Quilley, Sarah Wolfe, Dan McCarthy; Arts: Marcel O'Gorman; Rennison College Waterloo: Doug Cowan); Brock University: Jason Hawreliak; Laurier: Anne Wilson.
  - **Psychological Dynamics of Catastrophic Dehumanization**: Environment: Thomas Homer-Dixon, Steve Mock; Arts: Mike Lawrence; Arizona State University: Manjana Milkoreit.
  - **Rapid Ideological Change/Ideological Conflict:** Environment: Thomas Homer-Dixon, Steve Quilley, Steve Mock, Marisa Beck; Arts: Paul Thagard, Mike Lawrence; Arizona State University: Manjana Milkoreit; Potsdam Applied Sciences: Tobias Schröder; Yale University: Matto Mildenberger.
  - **Embodied Cognition:** Arts: Sarah Tolmie; Environment: Dawn Parker; Engineering: Mark Hancock.

- As new faculty members join the university, new opportunities for expanding our networks also emerge.

While WICI core membership now demonstrates critical mass, in a dynamic university environment, efforts must always be in place to maintain and renew it. Further, at a global scale, exciting complex systems research is occurring in the natural and health sciences. Ideally WICI should also reflect this scope. With this goal in mind, we will also strive to:

- Work with faculty units and deans to identify opportunities for new hires whose research has a complex systems focus.
- Seek out particular opportunities to establish core WICI members in under-represented faculties (AHS and Science).

3.2.2 FACILITATING INTERDISCIPLINARY RESEARCH

As outlined in Section 2, WICI has been very successful in facilitating interdisciplinary research. WICI will continue its work in that area by

- Hosting talks and workshops, striving to maintain a balance between bringing in global leaders in complex systems and highlighting local complex systems scholarship;
- Supporting working groups, allowing their focus and scope to evolve with the interests and needs of membership; and
- Offering support for grant development.

We anticipate that WICI core members will continue and expand their success with tri-council funding. WICI also now has the opportunity to apply for grants as a centre. As a centre, we will identify and pursue large competitive grant programmes such as NSCERC Create (for graduate student funding) or programs through the James S. McDonald foundation (for general support of complex systems research).

3.2.3 ENHANCING PUBLIC ENGAGEMENT

We are currently working to improve WICI's web and social media presence by improving organization and navigability of the site, and developing and maintaining web pages for WICI core research projects. We also plan to develop and post a set of introductory "What are complex systems?" materials, potentially through a series of small challenges; and to seek out members willing to write regular blogs or maintain Twitter feeds on complex-systems news and issues.

We will continue to highlight WICI work when possible through press releases and will actively engage with the media when opportunities arise.

We have begun hosting additional evening public lectures in conjunction with academic talks by high-profile guest or local speakers, following models such as the Bridges and Perimeter public lecture series. For example, last year we hosted an evening lecture and reception with TED speaker Marcin Jakubowski,

founder of Open Source Ecology. This year we hosted a public talk and book signing by best-selling author and TED speaker Lewis Dartnell at THEMUSEUM, and we will co-host another evening lecture at CIGI by Jack Goldstone. Next year we plan to continue such events, for example, by potentially hosting another evening lecture at THEMUSEUM with Melanie Mitchell, a pioneer in complex systems who has agreed to visit us next year.

We will continue the informal half hour coffee prior to WICI talks that we started this year. With a bit of help from WICI staff and the speaker, this has proven to be an excellent way to better engage attendees and find opportunities to strengthen their networks. It also provides a venue for interaction with the speaker outside formal Q and A.

Finally, we will continue to host an annual "open house" opportunity for community input and discussion. The first was highly successful in terms of input and outreach.

3.2.4 ENHANCING WICI'S RESOURCE BASE AND LONG-TERM VIABILITY

During its next five years, WICI will prioritize efforts to obtain higher-level, external support in the form of endowment funds. We will work with the faculty and university advancement offices to pursue funding beyond tri-council sources that will allow us to establish and support programs such as:

- A staffed resource lab to support members at all levels conducting computer-based modeling and analysis;
- Funding for a graduate fellows programme for outstanding junior complex systems scholars, who would participate in appropriate PhD programmes around campus;
- A competitive post-doctoral research scholar programme;
- Funding for short-term (sabbatical or study leave) positions for more senior complex systems scholars;
- Expanded funding for at least one full-time administrator, who would assist with promotional materials, grant preparation, and project management, in addition to existing duties; and
- A common physical space to house these activities, to provide opportunities for face-to-face interaction and communication.

In order to meet these goals, it makes sense to pursue hybrid strategies. Success in obtaining resources in any one realm will increase the probability of success in another. For example, WICI already has core strength in coupled complex human-natural systems modeling. Several WICI members have obtained funds to support these activities from both national and international funding agencies, and others have found success from sources such as the James S. McDonald foundation.

Drs. Parker, Bauch, Anand, and Robinson envision targeted efforts in this area to increase funding for research and student support, while leveraging supporting academic content and programs in the Math and Environment faculties. Such efforts could include a second NSERC CREATE application to provide PhD studentships, an additional application to the James S. McDonald foundation, solicitation of some matching support for PhD students through representative faculties, submission of an Ontario Centre of Excellence proposal, and development of a graduate certificate program in modeling complex human-

environment systems. Similar examples could be given for other areas of current critical strength in WICI.

3.2.5 RAISING PROFILE

We expect that these current and proposed activities should contribute to an increasing upward profile for WICI, especially as new successful grant initiatives produce significant academic and public policy findings. Yet, we are cognizant that we must actively work to make WICI's achievements visible through both academic and general media outreach, while also highlighting WICI's unique contributions at a national and global scale.

3.3 WHY SUPPORT WICI'S CENTRE RENEWAL REQUEST?

WICI's founders and current core executive staff are passionately committed to complex systems science. Many of us have built our careers as innovators and pioneers in what we believe to be an emerging shift in the scientific paradigm. The University of Waterloo is well positioned to provide resources that serve as a catalyst for substantive, high-impact scientific progress in this area. The track record from WICI's first five years of support indicates that we are well on our way towards this goal. We therefore ask that the university continue WICI's mandate to help shape the complex systems science of the 21st century.

Thank you for your attention,

Dr. Dawn Parker

Director, Waterloo Institute for Complexity and Innovation
Associate Professor, School of Planning, Faculty of Environment

Dr. Thomas Homer-Dixon

Associate Director, Waterloo Institute for Complexity and Innovation
CIGI Chair in Global Systems, Balsillie School of International Affairs; Professor in Faculties of Environment and Arts, University of Waterloo

ADMINISTRATION AT UNIVERSITY OF WATERLOO		
Ian Orchard	UW VP Academic and Provost	
George Dixon	UW VP, University Research	
FACULTY OF ENVIRONMENT		
Thomas Homer-Dixon	WICI Associate Director; CIGI Chair, BSIA	Core
Dawn Parker	WICI Director; Associate Professor, School of Planning	Core
Stephen Quilley	WICI Director of Development; Associate Professor, SiG, Department of Environment and Resource Studies	Core
Mark Weber	Associate Professor of Management and Organizations, UW	Core
Frances Westley	Director, Social Innovation Generation	Core
Neil Craik	Director, SEED	Affiliate Researcher
Peter Deadman	Associate Professor and Chair, Georgraphy and Environmental Management, UW	Affiliate Researcher
George Francis	Distinguished Professor Emeritus, Department of Environment & Resource Studies, UW	Affiliate Researcher
Xiongbing Jin	Post-doctoral Fellow, School of Planing, UW	Affiliate Researcher
Dan McCarthy	Faculty Member, SiG, Associate Professor, Faculty of Environment, UW	Affiliate Researcher
John McLevey	Assistant Professor in Centre for Knowledge Integration, UW	Affiliate Researcher
Derek Robinson	Assistant Professor in the Department of Geography & Envirnomental Management, UW	Affiliate Researcher
Mark Tovey	Lead Researcher, SiG@Waterloo	Affiliate Researcher
Tara Vinodrai	Associate Professor in SEED and the Department of Geography & Environmental Management, UW	Affiliate Researcher
Fatemeh Jahanmiri	Masters program, Urban Planning, UW	Student
Milton Friesen	Ph.D. candidate, School of Planning, UW	Student
FACULTY OF ENGINEERING		
Keith Hipel	Professor, Systems Design Engineering, Coordinator of the Conflict Analysis Group, UW	Core
Mark Hancock	Associate Director of Research Training, The Games	Affiliate Researcher

	Institute, UW	
Ed Jernigan	Professor, Department of Systems Design Engineering, UW	Affiliate Researcher
Kirsten Robinson	Ph.D. candidate, Systems Design Engineering, Researcher for WISIR, UW	Student
FACULTY OF MATH		
Chris Bauch	Professor, Department of Applied Mathematics, UW	Core
Hans De Sterck	Professor, Department of Applied Mathematics, UW	Core
Dong Eui Chang	Associate Professor, Department of Applied Mathematics	Affiliate Researcher
John Lang	Ph.D. candidate, Applied Mathematics, UW	Student
FACULTY OF ARTS		
Paul Thagard	Professor of Philosophy and Director of the Cognitive Science Program, University of Waterloo	Core
Peter Carrington	Professor, Department of Sociology and Legal Studies	Affiliate Researcher
Owen Gallupe	Assistant Professor, Department of Sociology and Legal Studies, UW	Affiliate Researcher
Steve Mock	Co-PI at the Ideational Conflict Project, BSIA	Affiliate Researcher
Sarah Tolmie	Associate Professor, Department of English Language and Literature	Affiliate Researcher
Clayton Dasilva	MA graduate, Balsillie School of International Affiars	Student
Marisa Beck	Ph.D candidate, Balsille School of International Affairs	Student
Michael Lawrence	Ph.D. candidate, Balsillie School of International Affairs	Student
Ola Tjornbo	Ph.D. graduate, Balsille School of International Affairs	Student
EXTERNAL WICI MEMBERS		
Lee Smolin	Perimeter Institute; Adjunct Professor, Dept. of Physics, UW	Core
Shreyas Sundaram	WICI Research Node Coordinator; Assistant Professor, Department of Electrical and Computer Engineering	Core
Madhur Anand	Associate Professor, School of Environmental Sciences, University of Guelph	Affiliate Researcher
Brian Arthur	External faculty member, Santa Fe Institute	Affiliate Researcher
Rob Axtell	Department Chair, Department of Computational Social Science, George Mason Univeristy	Affiliate Researcher

Yaneer Bar-Yam	President, New England Complex Systems Institute	Affiliate Researcher
Mike Batty	Professor of Planning, University College London	Affiliate Researcher
Megan Bean	Adult Education	Affiliate Researcher
Eric Beinhocker	Executive Director, Institute for New Economic Thinking's INET@Oxford	Affiliate Researcher
Monica Cojocaru	Associate Professor, Department of Mathematics & Statistics, University of Guelph	Affiliate Researcher
Niall Douglas	Principal Architect in Boost C++ libraries, MaidSafe	Affiliate Researcher
J. Doyne Farmer	External Professor, Santa Fe Institute	Affiliate Researcher
Bill Flanik	Assistant Professor of Political Science - Colorado Mesa University	Affiliate Researcher
Carl Folke	Science Director, Stockholm Resilience Centre	Affiliate Researcher
Ian Goldin	Director, Oxford Martin School, Oxford University	Affiliate Researcher
Scott Heckbert	Adjunct Professor, University of British Columbia | Environmental Economist at Alberta Innovates Technology Futures	Affiliate Researcher
Matthew Hoffman	Associate Professor of Political Science, University of Toronto	Affiliate Researcher
Eric Lambin	Professor and Senior Fellow, Woods Institute for the Environment	Affiliate Researcher
Hassan Masum	Policy and technology strategist	Affiliate Researcher
Anthony Masys	Defence Scientist, Defence Research and Development Canada	Affiliate Researcher
Manjana Milkoreit	Post-doc, Global Institute of Sustainability, Arizona State University	Affiliate Researcher
Michele-Lee Moore	Assistant Professor, University of Victoria	Affiliate Researcher
Michael Nielsen	Scientist; Writer; Programmer	Affiliate Researcher
Jukka-Pekka Onnela	Assistant Professor, Department of Biostatistics, Harvard School of Public Health	Affiliate Researcher
Stephen J. Purdey	University of Toronto (retired)	Affiliate Researcher
Felix Reed-Tsochas	Director, Oxford Martin Programme on Complexity	Affiliate Researcher
Andre Roy	Dean of Environment	Affiliate Researcher
Marten Scheffer	Acquatic Ecology and Water Quality Management, Wageningen Unversity	Affiliate Researcher
Tobias Schröder	Post-doctoral Fellow, Centre for Theorectical Neuroscience, UW	Affiliate Researcher

Robert Spekkens	Theoretical Physicists, Perimeter Institute	Affiliate Researcher
Mohamed Tawhid	Department of Mathematics and Statistics, Thompson Rivers University	Affiliate Researcher
Leigh Tesfatsion	Professor of Economics, Mathematics, and Electrical & Computer Engineering, Dept. of Economics, Iowa State	Affiliate Researcher
Edward W. Thommes	Health Outcomes Manager, GlaxoSmithKline Canada	Affiliate Researcher
Gerrit Van Wyk	Consultant Urologist, Full-time Private Practice, Moose Jaw	Affiliate Researcher
Jan Wouter Vasbinder	Lead Researcher, SiG@Waterloo	Affiliate Researcher
John Whalley	Chair in International Trade, Professor of Economics, University of Western Ontario	Affiliate Researcher
Glenn Smith	Director, Project Management, Digital Media, Communitech	Practitioner
Sami Houry	Senior research officer & project manager, Office of Institutional Studies, Athabasca University	Student
Matto Mildenberger	Ph.D. candidate, School of Forestry and Environmental Studies, Yale University	Student
Leah Stokes	Ph.D. candidate, Environmental Policy & Planning, MIT	Student

BOARD

Ian Orchard	UW VP Academic and Provost
George Dixon	UW VP, University Research
Dawn Parker	WICI Director; Associate Professor, School of Planning, UW
Keith Hipel	Professor, System Design Engineering, UW
Matt Hoffmann	Associate Professor, Political Science, University of Toronto
Jean Andrey	Acting Dean, Faculty of Environment, UW
Monica Cojocaru	Associate Professor, Department of Mathematics & Statistics, University of Guelph
Lee Smolin	Perimeter Institute; Adjunct Professor, Dept. of Physics, UW
Hans De Sterck	Professor, Department of Applied Mathematics, UW

EXECUTIVE COMMITTEE

George Dixon	UW VP, University Research
Dawn Parker	WICI Director; Associate Professor, School of Planning
Thomas Homer-Dixon	WICI Associate Director; CIGI Chair, BSIA
Stephen Quilley	WICI Director of Development; Associate Professor, SiG, Department of Environment and Resource Studies
Shreyas Sundaram	WICI Research Node Coordinator; Assistant Professor, Department of Electrical and Computer Engineering
Paul Thagard	Professor of Philosophy and Director of the Cognitive Science Program, University of Waterloo
Frances Westley	Director, Social Innovation Generation
Neil Craik	Director, SEED
Sarah Tolmie	Associate Professor, Department of English Language and Literature
Peter Deadman	Chair, Department of Geography

INTERNATIONAL SCIENTIFIC ADVISORY COUNCIL

W. Brian Arthur	External Professor, Santa Fe Institute
Robert Axtell	Professor and Chair, Dept of Computational Social Science, George Mason University
Yaneer Bar-Yam	President, New England Complex Systems Institute
Mike Batty	Professor of Planning, Director, Center of Advanced Spatial Analysis, University College London
Eric Beinhocker	Executive Director of the INET@Oxford research program, Oxford Martin School, University of Oxford
J. Doyne Farmer	External Professor, Santa Fe Institute
Carl Folke	Science Director, Stockholm Resilience Centre
Ian Goldin	Director, Oxford Martin School, Oxford University
Monica Cojocaru	Associate Professor, Mathematics, University of Guelph
Matt Hoffmann	Associate Professor, Political Science, University of Toronto

Eric Lambin	Professor, Dept. of Geography, University of Louvain; Professor, School of Earth Sciences, Stanford University
Jukka-Pekka Onnela	Assistant Professor of Biostatistics, Department of Biostatistics, Harvard School of Public Health
Marten Scheffer	Professor, Aquatic Ecology, Wageningen University
Leigh Tesfatsion	Professor of Economics, Mathematics, and Electrical & Computer Engineering, Dept. of Economics, Iowa State
Felix Reed-Tsochas	Co-Director of the CABDyN Complexity Centre University of Oxford
Jan Wouter Vasbinder	Director of the Complexity Program at the Nanyang Technological University at Singapore

WICI sets forth specific goals each year and then assesses progress towards those goals in the following year's Annual Report. As illustrated below, WICI has consistently achieved the majority of goals set forth in each report. In some cases, goals were accomplished a year later than planned, and in others, some goals were set aside in favour of others, as priorities and opportunities changed.

*Note: Completed goals are marked with *asterisk*

2009-2010:

1. *Clarify the mission and goals of WICI through development of a formal Institute proposal;
2. *Obtain UW Senate approval of the Institute;
3. *Expand the community of scholars associated with WICI;
4. *Continue the successful monthly WICI Speaker series;
5. *Expand the speaker series to include a range of less formal weekly activities; and,
6. *Continue to build the WICI research community, working towards a new portfolio of funded research projects.

2010-2011:

1. *Establish formally the WICI Board and Executive and Scientific Advisory Committees;
2. Move the WICI budget from Social Innovation Generation to the Office of Research;
3. *Hire a part-time WICI administrative assistant;
4. *Build formal partnerships with existing complexity-related centres inside the University of Waterloo;
5. *Continue informal networking and community development on campus – especially targeting computer science, other math, and public health;
6. *Further develop the WICI brand and implement a full WICI website;
7. *Continue the WICI Talks, WICI Seminars, and the WICI Forum;
8. Develop a short prospectus of ongoing research for each current WICI member; host an open forum with short presentations by WICI members on their ongoing and planned research; archive results on web site.
9. Begin to develop a Web-based archive of complex systems syllabi and teaching materials;
10. Submit at least two major research project funding requests;
11. Establish a development committee and design a prospectus for endowment fundraising; and,
12. Build on the graduate course offered this year to create a suite of undergraduate and graduate courses, based in different faculties, departments, and centres at the University, but clearly linked to WICI's goal of deepening the scholarly and practical understanding of complexity and innovation.

2011-2012:

1. *Submit at least two research-project funding requests;
2. Develop contacts in the Math and Science faculties;

3. Develop a short prospectus of ongoing research for each current WICI member; host an open forum with short presentations by WICI members on their ongoing and planned research; archive results on web site;
4. Begin to develop a Web-based archive of complex systems syllabi and teaching materials; and,
5. *Establish a development committee and design a prospectus for endowment fundraising.

As a result of discussions in the fall of 2011, the WICI Executive Committee decided to emphasize goals 1 and 5 above in addition to the following five:

6. *Complete the process of filling positions on the WICI Board, Executive Committee, and International Scientific Advisory Council;
7. *Complete WICI branding and full development of the WICI website;
8. *Develop a template for, and begin to publish, WICI Occasional Papers;
9. *Provide small grants for leading-edge complexity research; and,
10. *Further promote WICI through on-campus and off-campus networks.

2012-2013:

1. *Continue development of research grant applications in WICI's ideology, open-architecture, and alternatives to conventional growth research programs;
2. *Develop contacts in the Math Faculty;
3. *Execute the challenge prize competition;
4. *Plan the visualization colloquium;
5. *Begin to develop a Web-based archive of complex systems syllabi and teaching materials;
6. Work further with key campus stakeholders on a long-term development prospectus; and,
7. *Identify complexity-related and complexity-relevant undergraduate and graduate courses at UW across faculties and departments, listing them on WICI's website, and engaging with their instructors to create a broader pedagogical complexity community on the UW campus.

2013-2014:

1. Establish the new core members' research projects within the wider WICI Research Program
2. Continue to develop links with the Games Institute, with the prospect of developing new WICI core research areas. Two potential directions are seen for this:
   o Movement research; collaborating with motion capture researchers on campus (potential CFI target). Professor Dawn Parker and Professor Mark Hancock were collaborators on an SSHRC grant submitted by Professor Sarah Tolmie to support this work in October 2012, requesting $480,000, but funding was not awarded.
   o *Collaborate with the Social Innovation lab modeling group on simulation and visualization software for participatory decision making
3. Host a workshop on Norm Evolution
4. *Host the Data Visualization and Analysis symposium
5. *Investigate infrastructure grant options to support a dedicated WICI computer lab
6. *Continue to support additional grant applications to fund WICI core research projects

7. *****Continue dissemination of scholarly activities through the Occasional Paper series and through academic presentation and publication
8. *****Continue dissemination of scholarly activities and outreach through the seminar series
9. Investigate interest in starting two new WICI working groups:
   - *****Agent-based modeling (Kirsten Robinson and Xiongbing Jin)
   - "Dance your PhD" (Dawn Parker and Sarah Tolmie)
10. Continue to support small student funding requests, as resources and proposal quality allow
11. *****Hold an open members meeting in Fall 2013 with the following agenda items:
    - *****Get feedback on current WICI programs and activities
    - *****Brainstorm suggestions for new or enhanced activities
    - *****Set longer-term goals for WICI as we plan for our five year renewal
12. Prepare for the five year renewal:
    - *Meet with deans to gain support letters
    - *Produce the necessary documents
    - *Present renewal case to relevant audiences

2014-2015:

By Board consensus, planning for this year has focused on five-year renewal. See section 3.2, "Strategic Directions" for specifics.

	TITLE AND SPEAKER	PLAYS*	VIEWS**
OCTOBER 2008	The Evolution Of Economic Wealth And Innovation Stuart A. Kauffman	242	1337
NOVEMBER 2008	Changing Minds About Climate Change Paul Thagard	301	1826
DECEMBER 2008	Applications Of Complexity Science To Healthcare Brenda Zimmerman	421	1156
JANUARY 2009	Ingenuity Theory: Adaptation Failure And Societal Crisis Thomas Homer-Dixon	258	519
JANUARY 2009	Trade Versus The Environment: Strategic Settlement From A Systems Engineering Perspective Keith Hipel	60	227
FEBRUARY 2009	Complexity Approach To Change And Transformation Frances Westley	789	1269
FEBRUARY 2009	Governance Avalanches: A Self-Organized Criticality Perspective On Innovation In Global Governance Matthew Hoffman	372	2003
MARCH 2009	Symmetries In Economic Models And Their Consequences Lee Smolin	223	323
APRIL 2009	World And Other Systems: A Challenge To WICI George Francis	49	313
OCTOBER 2009	Market Activity, Landscaping Behavior, And Carbon Sequestration In Ex-Urban Landscapes Dawn Parker	64	651
OCTOBER 2009	Is Our Concept Of Moral Responsibility Newtonian? Karen Houle	459	2120
NOVEMBER 2009	Revitalizing Central Place Theory: Cities As Experiments On A Dynamic Fitness Landscape Brad Bass	187	777
NOVEMBER 2009	Responsive Environments: Transitional Fields Philip Beesley	111	531
DECEMBER 2009	Laws Of Technological Progress J. Doyne Farmer	267	7703
JANUARY 2010	Will Ecology Dominate The 21st Century? Speaker: Thomas Homer-Dixon, Stephen Bocking, And Robert Gibson	N/A	N/A
JANUARY 2010	Revitalizing The Georgian Bay Fisheries: Complicated, Complex, Contested, And Confused Speakers: David Robinson, Ivan Filion, And Kirsten Robinson	N/A	N/A
FEBRUARY 2010	Open Source Democracy Speakers: Mark Tovey, Michael Nielsen, And Hassan Masum	106	1233
MARCH 2010	Can Information Technology Really Help Save The Planet? Speaker: Victor Galaz	119	489
MARCH 2010	A Wildfire Case Study In The Canadian Rocky Mountains Speaker: Mike Stone	N/A	N/A
MARCH 2010	Testing Institutional Arrangements Via Agent-Based Modeling: A U.S. Electricity Market	326	1489

	Speaker: Leigh Tesfatsion		
JANUARY 2010	Harnessing Network Science To Reveal Our Digital Footprints Jukka-Petta Onnela, Harvard Medical School	27	1,025
OCTOBER 2010	On Ranking Merit: Applying The Page-Rank Algorithm To The Electoral Process Robert Spekkens	N/A	N/A
OCTOBER 2010	Simulation-Based Engineering Of Complex Systems John R. Clymer	105	1,113
NOVEMBER 2010	From DNA To Complex Cognition: How We Learn, Discover, And Create The World Kevin Dunbar	48	781
MARCH 2011	Early Warning Signals For Critical Transitions Marten Scheffer, Wageningen University	176	6,504
MARCH 2011	Steady State Economics Steve Purdey	125	1,143
MARCH 2011	Complexity, Scaling And Cities Mike Batty, The Centre For Advanced Spatial Analysis, University College London	152	3,510
FEBRUARY 2011	How Does Technological Innovation Happen? W. Brian Arthur	N/A	N/A
FEBRUARY 2011	Land Change Science Seminar Christophe Le Page	17	630
FEBRUARY 2011	Land Change Science Seminar Peter Deadman	28	800
FEBRUARY 2011	Land Change Science Seminar Raymond Cabrera	26	829
FEBRUARY 2011	Land Change Science Seminar Eric Lambin	137	1,089
SEPTEMBER 2011	Diffusing Information And Reaching Agreement In Networks: Convergence And Resilience Shreyas Sundaram	69	1,946
OCTOBER 2011	Objective And Subjective Factors: Modelling Consumer Behaviour From Individual To Population Scale Monica Cojocaru	84	1,326
NOVEMBER 2011	Leveraging Physical Actions To Interact With Digital Surfaces Mark Hancock	21	409
DECEMBER 2011	Social Distance Games Katherine Larson	80	1,612
JANUARY 2012	Modeling Complex Healthcare Environments Using Discrete-Event Simulation: A Case Study Of Mass Immunization Clinics Michael Beeler	52	781
FEBRUARY 2012	Clearing The Fog Of Geriatrics: Applying Complex System Thinking To The Health And Care Of Older Adults Joshua Armstrong	41	587
FEBRUARY 2012	The End Of Economic Growth: Social Regression Or New Beginning? Steve Mock	134	1,210
MARCH 2012	Reaching Agreement In Complex Networks: Avoiding The Influence Of Extreme Agents	117	1490

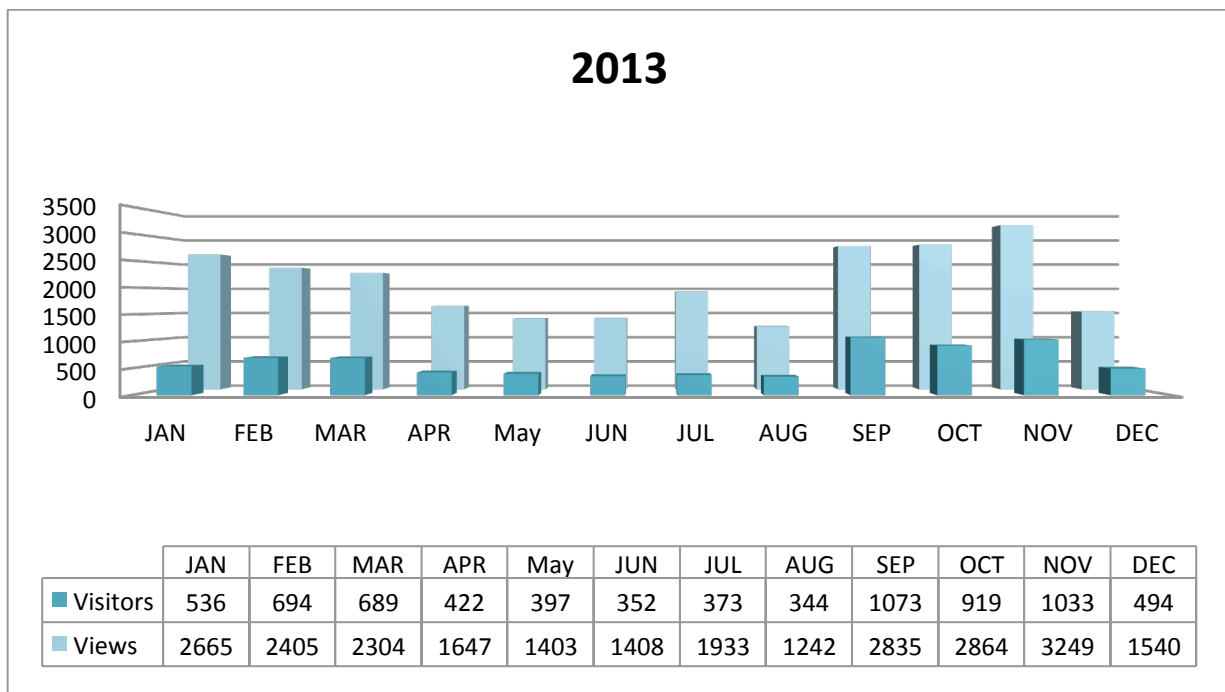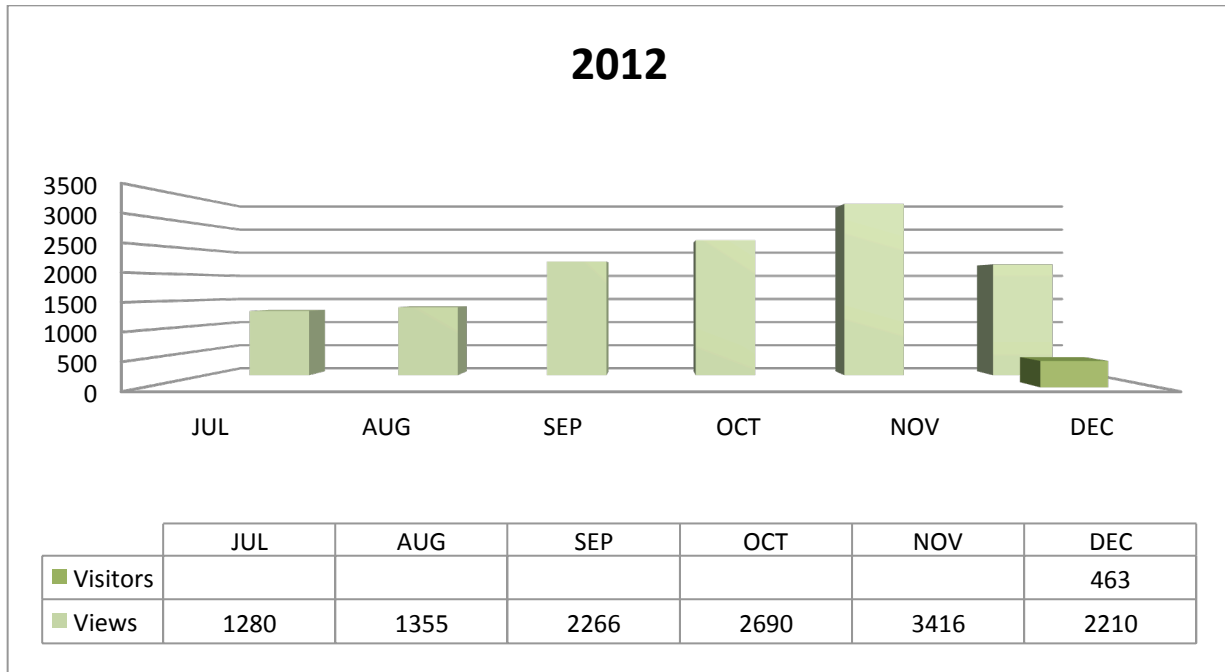|			
	Shreyas Sundaram		
MARCH 2012	Exploring The Possibility Space Of Ideological Change Matto Mildenberger	31	1,050
APRIL 2012	The Interdependence Of Forest Transition Pathways At The Household Level In Yunnan, China Darla Munroe	20	340
NOVEMBER 2012	Human-Environment Sustainability And Alternative Stable States In Mosaic Ecosystems Dr. Madhur Anand	N/A	N/A
JANUARY 2013	Possible Futures: Complexity In Sequential Decision-Making Dan Lizotte	48	1,546
FEBRUARY 2013	How Mathematics Can Help Explain Vaccine Scares And Associated Disease Dynamics Chris Bauch	55	1,064
FEBRUARY 2013	Changing Minds About Cars: Modeling The Adoption Of Innovations In Transportation Tobias Schröder	25	875
APRIL 2013	Leadership: It's Pretty Simple… By Itself Marc Hurwitz	36	3,615
OCTOBER 2013	Traps And Transformations Of Social-Ecological Systems: Commentary From The Caribbean Brian Neff	45	659
OCTOBER 2013	Afraid Of The Dark: Humanity At The Crossroads Sheldon Solomon	382	8079
OCTOBER 2013	Handling The Complexities Of Large-Scale Brain Models Chris Eliasmith	168	1,378
NOVEMBER 2013	Data Visualization And Analysis Symposium Terry Stewart- Validating Models Of Cognition	20	313
NOVEMBER 2013	Data Visualization And Analysis Symposium Brian Ingalls - Local And Global Sensitivity Analysis Connect Model Parameters To System Behaviour In A Model Of Beta- Cell Metabolism	5	314
NOVEMBER 2013	Data Visualization And Analysis Symposium Dawn Parker - Tracing The Impacts Of Land-Market Structure On Urban Growth	10	309
NOVEMBER 2013	Data Visualization And Analysis Symposium Mike Hudson - Problems In Cosmology And The Upcoming Data Avalanche	2	306
NOVEMBER 2013	Data Visualization And Analysis Symposium Przemyslaw Grabowicz - Fast Visualization Of Relevant Portions Of Large Dynamic Networks	24	1,238
NOVEMBER 2013	Data Visualization And Analysis Symposium Steve Williams - A Framework For Decision Making In Social Innovation Lab Processes	13	346
NOVEMBER 2013	Data Visualization And Analysis Symposium Kirsten Robinson - Using Models In Social Innovation Labs: Prototype Models Of Agro-Economic Systems In Southern Ontario To Support Innovation In Food System Policy	28	300
NOVEMBER 2013	Data Visualization And Analysis Symposium Elliott Miller & Sarah Hogland - Visualizing A Complex System:	85	957

	The Use Of Dance As A Data Visualization Tool		
NOVEMBER 2013	Data Visualization And Analysis Symposium Sheelagh Carpendale - Interactive Visualization	3	286
DECEMBER 2013	Creative Cognition In Social Innovation Paul Thagard	82	218
MARCH 2014	Reach Control Problem Mireille E. Broucke	215	3,472
MAY 2014	Open Source Ecology: Towards the Open Source Economy Marcin Jakubowski	199	1,279
MAY 2014	Agent-Based Modelling And GIS: Applications To Land Use Change And Environmental Modelling Scott Heckbert	79	216
DECEMBER 2014	Collaborating On-Line: An Analysis of Communication Networks for Linux Kernel Developers John McLevey		
JANUARY 2015	Invention and Innovation: The Long Term Sander van der Leeuw	N/A	N/A
JANUARY 2015	Mathematical modelling of social spreading processes Hans De Sterck		
FEBRUARY 2015	Discovering the Themes of Complexity Science in Land Use Modelling Derek Robinson	N/A	N/A
MARCH 2015	Knowledge and Civilization: Technical and Theoretical Considerations Lewis Dartnell	N/A	N/A
MARCH 2015	The Knowledge: How To Rebuild Our World From Scratch Lewis Dartnell	N/A	N/A
MARCH 2015	Bridges Lecture – Dancing the Math of Complex Systems Dawn Parker and Sarah Tolmie		
APRIL 2015	Democracy and Development: Getting away from Linear Thinking to True Understanding Jack Goldstone	N/A	N/A

Plays are defined as: A play is counted each time someone pushes the play button on a video (i.e. the number of viewers). Views statistics from Vimeo up to December 31, 2014.
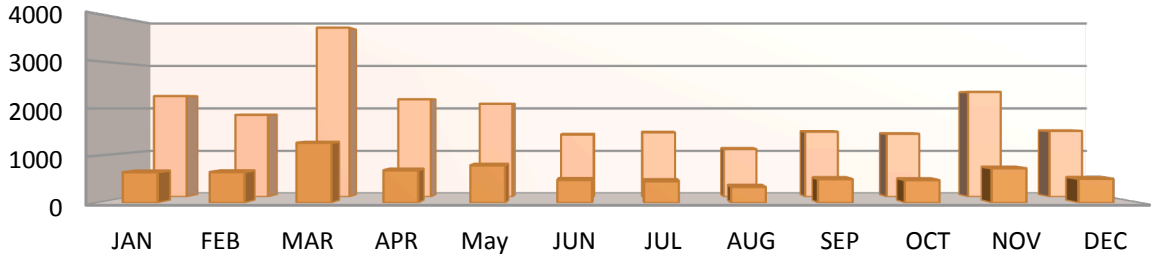
**Views are defined as: A view is counted each time the video player loads on any page, either on Vimeo.com or wherever a video is embedded (i.e. spread of the video to new potential audiences).*

Website Views and Visitors, July 2012-December 2014

2012

	JUL	AUG	SEP	OCT	NOV	DEC
■ Visitors						463
■ Views	1280	1355	2266	2690	3416	2210

2013

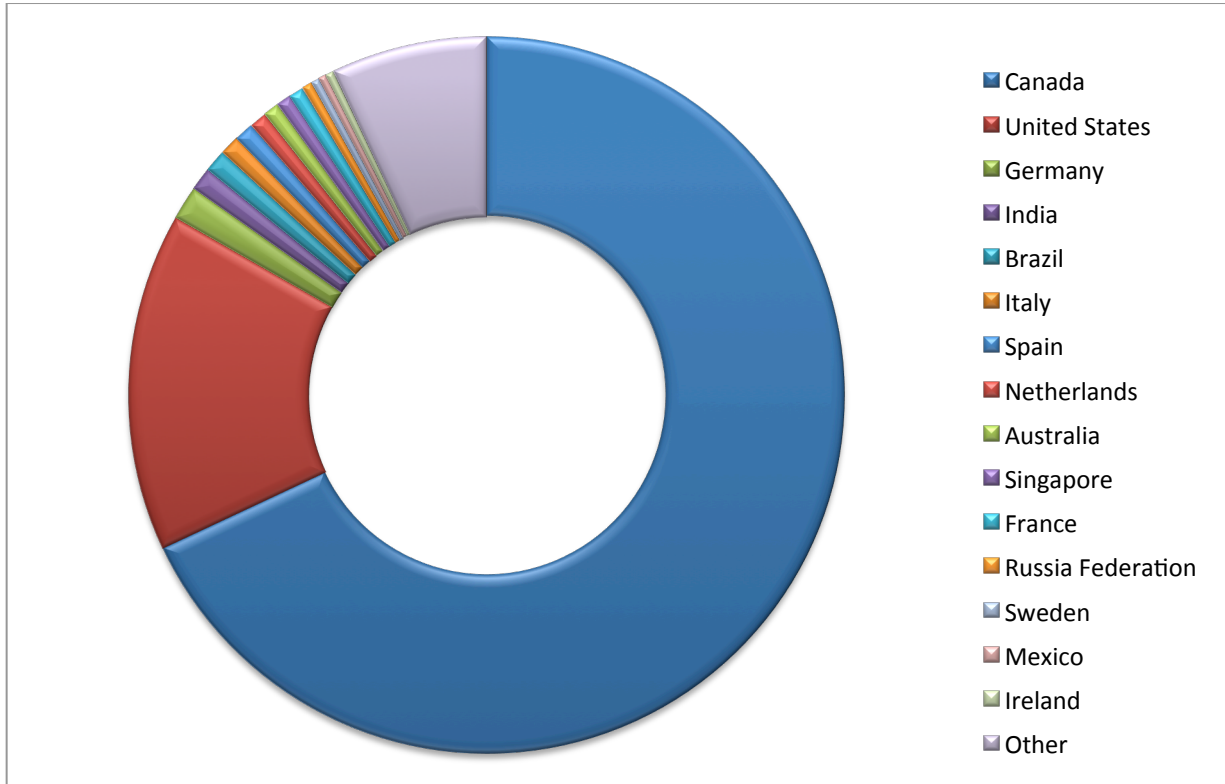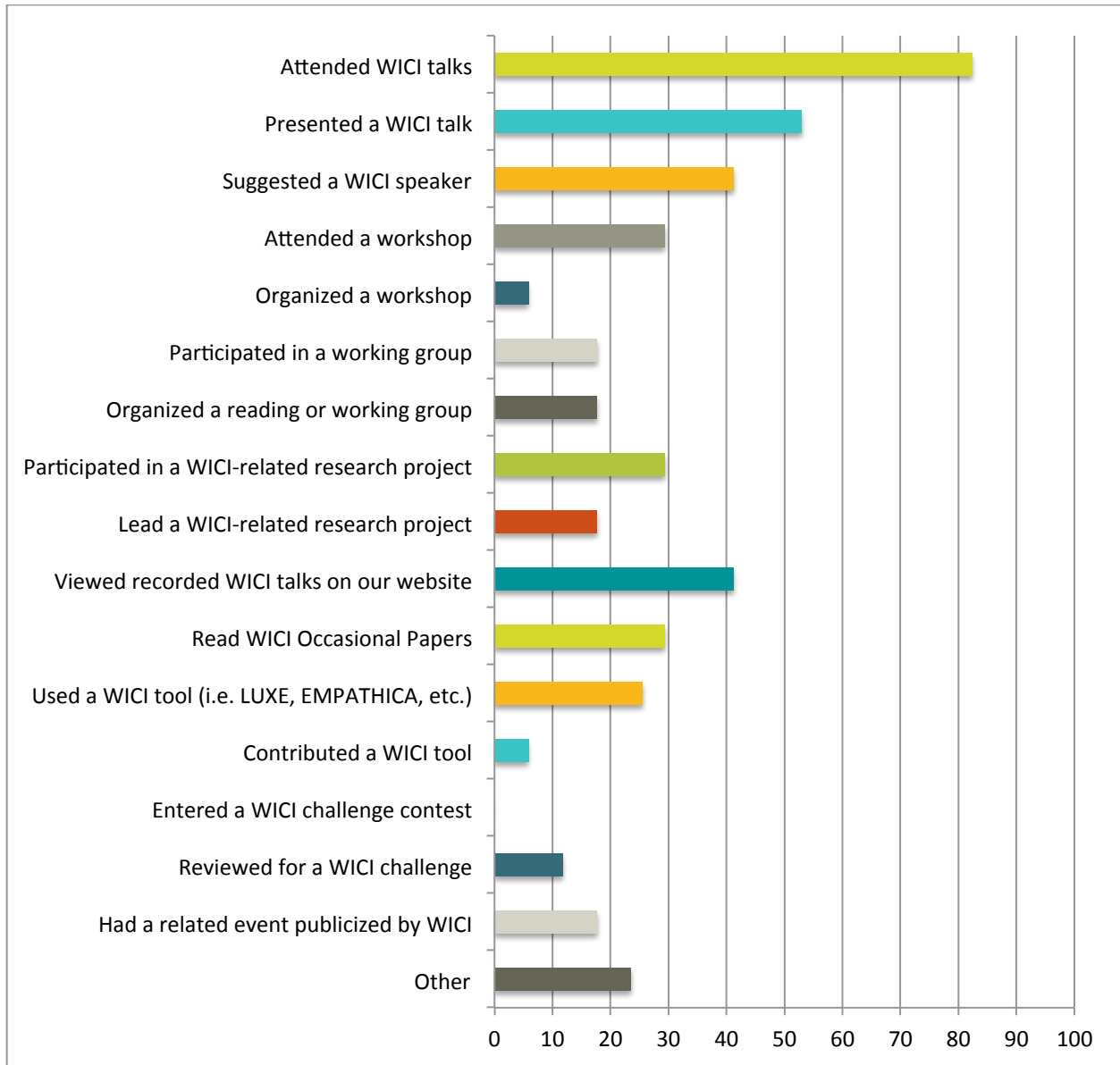|	JAN	FEB	MAR	APR	May	JUN	JUL	AUG	SEP	OCT	NOV	DEC
■ Visitors	536	694	689	422	397	352	373	344	1073	919	1033	494
■ Views	2665	2405	2304	1647	1403	1408	1933	1242	2835	2864	3249	1540

2014

	JAN	FEB	MAR	APR	May	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Visitors	651	655	1275	693	797	487	462	341	506	483	734	512
Views	2280	1856	3821	2208	2104	1411	1459	1083	1475	1427	2373	1492

Visitors to WICI's Website by Country

- Canada
- United States
- Germany
- India
- Brazil
- Italy
- Spain
- Netherlands
- Australia
- Singapore
- France
- Russia Federation
- Sweden
- Mexico
- Ireland
- Other

1. **How have you engaged with WICI in the past? Please select all that apply.**


Other responses included partaking of a MOOC that was found through WICI and having an occasional website published by WICI.

2. In which areas do you see WICI providing value, for yourself or others in the community? Please select all that apply.
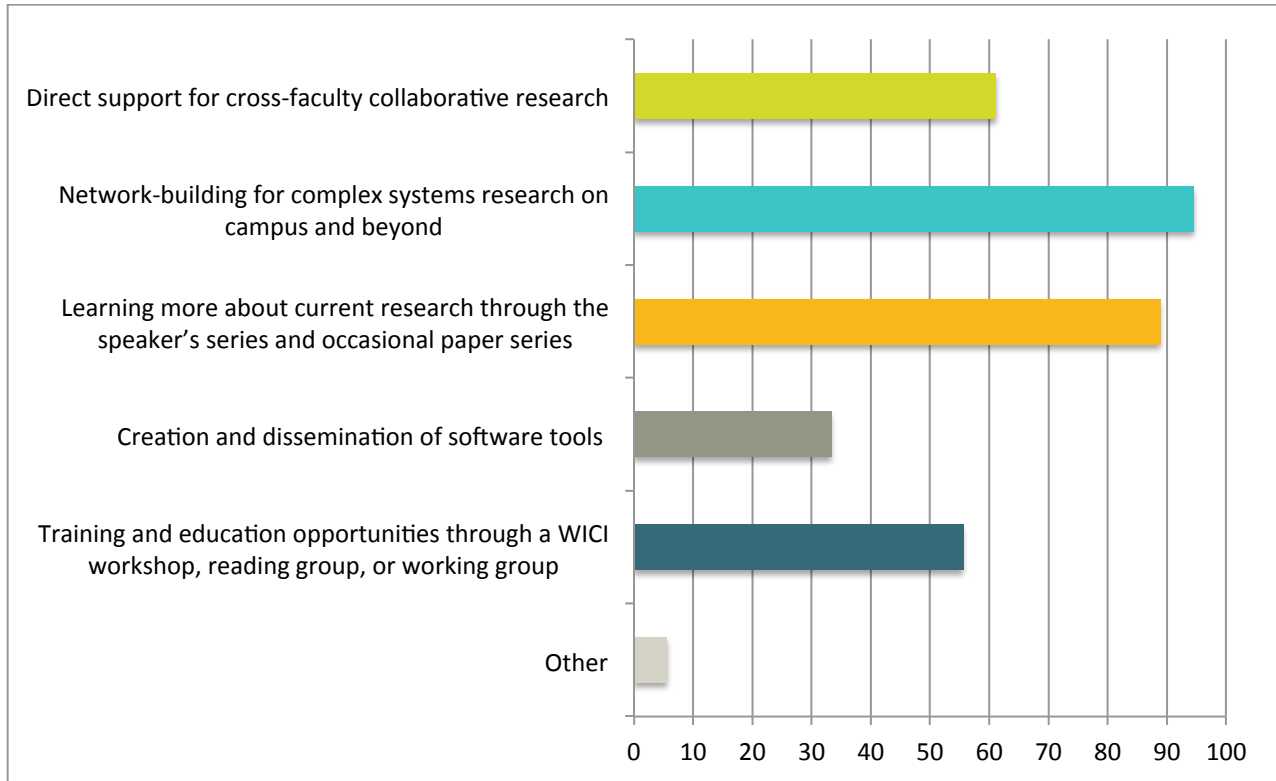
Other: Research related to real-world problems.

3. In which of these areas do you think WICI could strengthen their activities?
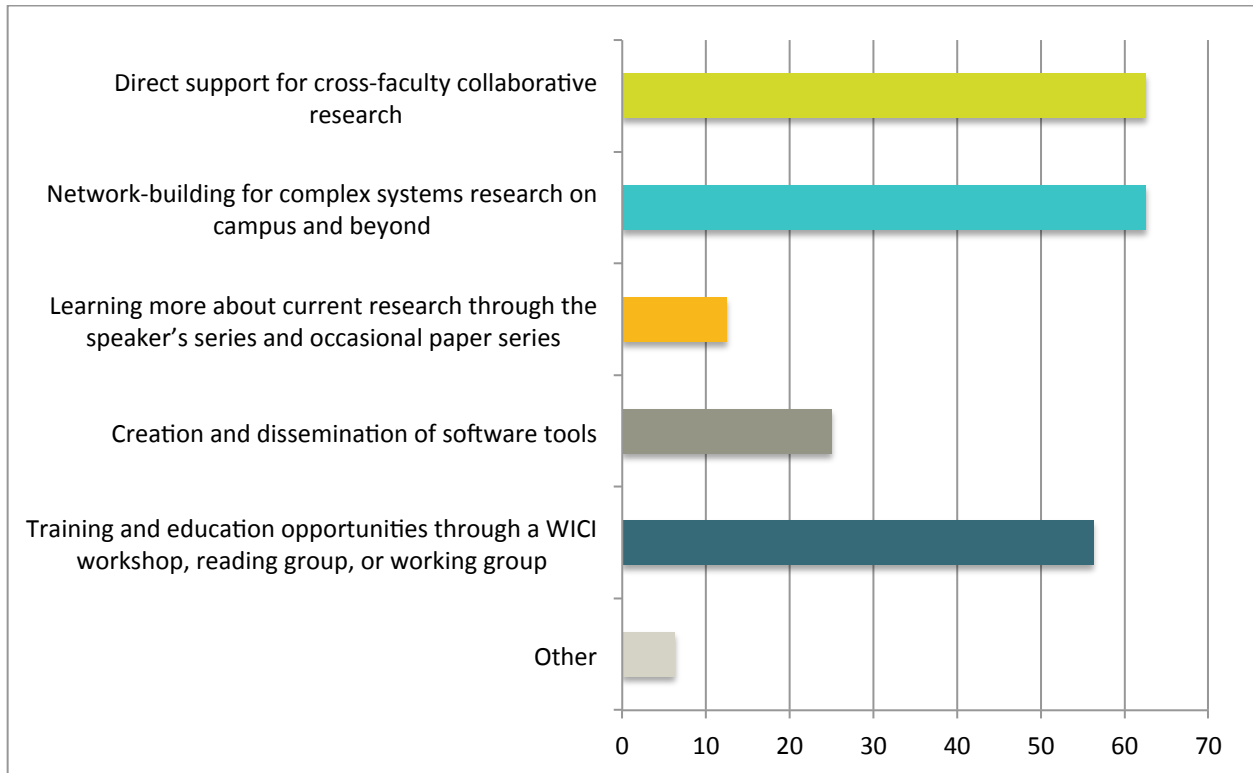
Other: One survey respondent suggested WICI do more beyond teaching methods on-campus. This may involve concentrating on specific complex challenges; picking more speakers with value beyond the campus (like Lewis Dartnell and last year's Open Source Ecology speaker); or working with affiliate members and other problem-solvers for mutual benefit.

4. How would you describe the mission and scope of WICI to someone outside WICI?
   a. To fuel understanding and research in complex systems and issues observed in life.
   b. I would describe the mission and scope as -- an interdisciplinary organization designed to foster the generation and dissemination of complex ideas and methods across campus and beyond.
   c. To bring together complexity researchers to advance our understanding of complex systems.
   d. Facilitating transdisciplinary and collaborative research that promotes innovation and resilience within human complex adaptive systems.
   e. The major mission is to promote complex systems research in cross disciplines.
   f. To pursue socially significant interdisciplinary research.
   g. Convening scholars and students who are interested in and make use of complexity science approaches in their work.

h. WICI is an interdisciplinary research centre that brings together people interested in complex systems, network science, and innovation.
i. It focuses on the study of complex systems, especially on the study of social systems and of the relationship between social and ecological systems. Since these systems have many parts interacting in non-trivial ways over space and time, they can be difficult to understand and predict, so using computer models to simulate their behaviour plays an important role. WICI has an active community. There are talks, seminars, and working groups.
j. It would be very hard... bringing together those with a scientific interest in studying the themes of complexity science
k. A consortium of researchers working in complex systems research. A dynamic network involved with interesting projects.
l. Network building for complex networks researchers

5. **What do you see as WICI's comparative advantage?**
    a. The understanding that the world's systems are complex, cross-collaborative, and still relatively un-explored. The requirement for this "new" thinking.
    b. In all things 'syn' -- it's synthetic, synoptic, synergetic in approach. It tries to make links and see connections where others don't, and to take the broadest of views on any subject.
    c. WICI excels because of its focus on system based thinking, allowing for big ideas and processes to be boiled down into their constituent parts and relationships -- making these ideas digestible and transferable across disciplines.
    d. Unique in its mission in the region.
    e. Network of scholars interested in complexity and complex adaptive systems.
    f. It provides a platform for researchers involved in complex systems study to collaborate and communicate.
    g. Strong group of active and open minded participants.
    h. High profile core and affiliate members, not being hindered by a "silo mentality"
    i. Potential for strong crossover amid the UWaterloo community directly and the secondary contacts that represents.
    j. I love how genuinely interdisciplinary it is. I've made some very interesting connections with people in CS and other parts of campus.
    k. Applied complex systems The study of social and ecological systems The ability to leverage the concentration in math and engineering at The University of Waterloo
    l. Diverse UW-campus seminar and workshop series on complexity-related methods.
    m. Complexity science is cuts across all disciplines and now the foundation is set to become the regions center for the study of complex systems. There is an extra challenge of competing and complementing other long established complexity research centers and it may prove useful to identify some core themes like human-environment interactions or social networks depending on the strength of the core and affiliate members on campus. Given such a focus, we may even attract attention from existing complexity Institutes who would want to see more unique and specific research in a topic area. This is partly what is leading to the rapid and global success of http://www.sesync.org/

n. Don't really know of anything like it in Ontario.

o. Compared with what?

6. What do you see as WICI's weakest aspects?

a. Not being known through the whole Waterloo campus; i.e. I don't think the Architecture faculty know about this group at all, but we are kind of isolated from everything on main campus, so perhaps the rest of UW do know about your organization!

b. I would have to say advertising would be the weakest aspect. Many students I know would enjoy and benefit from the talks and workshops; however, most people I speak to simply don't know the organization exists. I would think this is a common problem across organizations on campus, and don't really know which outlets would reach the people who would benefit (maybe a greater social media presence?).

c. The network, as a complex adaptive system, is not working well at present. It seems to me as if everyone is working on their own, or linked to networks outside the Institute, which takes away from the possible impact. That is somewhat in contradiction to what we assume human systems to be.

d. It has offered limited opportunities to attract more researchers around the world instead of UW and some collaborative institutions.

e. Fairly small attendance at lectures. Lack of theoretical cohesion.

f. lack of cross-faculty and cross-department infrastructure to support activities (e.g. interdisciplinary PhD programs)

g. The mix of presentations can be somewhat technical in some presentations. That is important but can lead some to conclude it is only for certain specialists. Having more round table and informal collaboration sessions would be valuable.

h. I don't think I know WICI enough to answer this question.

i. Many don't know who we are or what we do. Projects sometimes start and then loose momentum. It can be difficult for outsiders to find meaningful ways to engage beyond attending public talks.

j. Relevance beyond the campus, and relevance to tackling complex global challenges (rather than simply cross-fertilizing methods within UW). This is especially striking when considering the policy engagement of Prof Homer-Dixon and of many of the affiliate members - assets that might be better supported and harnessed in service of tackling complex global challenges.

k. Lack of a physical center and dedicated faculty and course offerings, need to use the CSCS structure at the university of michigan if WICI wants to provide a large and sustainable basin of attraction

l. Needs more followers/audience/outreach.

m. Since joining 9 months ago, I haven't heard much from it or about it.

7. What specific suggestions might you offer for WICI, as we move into our second five years?

a. Try and present yourself to the satellite campus' as well. I would like to feel that cross-collaboration is really obviously working and celebrated.

b. Continue bringing in high quality speakers. Maybe offer more applied/technical workshops. Somehow disseminate information about upcoming events more widely/strategically.

c. Identify opportunities and methods to bring interdisciplinary researchers together to pursue research funding.

d. If we believe in complexity and adapting, there should be ways for researchers to communicate with each other academically more efficiently. If have little knowledge of what others do and what interest them, and no-one knows what I am doing. How would we know if there are shared interests if we don't talk to each other? Joining the new group as an outsider coming in is challenging.

e. 1. To create more chances to get contact with the related researchers around the world. 2. Try to hold some international conferences in complex systems research.

f. See point #6. also, more engagement with math and engineering.

g. Continue to extend and improve communication to generate wider awareness. Possibly pair WICI functions with other complimentary workshops, conferences, and themes on campus.

h. It would be great if WICI could occasionally hold training sessions on specific methods or tools, perhaps held by WICI members for other WICI members. I would be interested in learning more about how to do ABM, for example.

i. We need to focus and to differentiate ourselves.

j. See answers to #3 and #6 above.

k. Create a physical center and presence on campus

l. Try to get noticed a bit more. Highlight all faculty activities.

m. Send more news about WICI activities to affiliate researchers such as myself.

INCOME

	May 1, 2010-April 30, 2011	May 1, 2011-April 30, 2012	May 1, 2012-April 30, 2013	May 1, 2013-April 30, 2014	May 1, 2014-March 1, 2015
Provost	50,000.00	50,000.00	50,000.00	50,000.00	50,000.00
Sponsorship Income			2,000.00	18,000.00	48,000.00
Workshop Facilitation					2,000.00
TOTAL INCOME	**50,000**	**50,000.00**	**52,000.00**	**68,000.00**	**100,000.00**

EXPENSES

	May 1, 2010-April 30, 2011	May 1, 2011-April 30, 2012	May 1, 2012-April 30, 2013	May 1, 2013-April 30, 2014	May 1, 2014-March 1, 2015
Staffing	16,356.68	24,865.96	29,798.41	37,431.11	45,298.96
Convening costs for WICI Speakers Series, workshops, symposium and meetings	14,690.56	2,894.92	2,244.20	2,989.74	1,512.91
Speaker and Guest Travel		3,702.27	5,963.80	5,444.060	3634.56
Research Funding (*includes grant development, challenge grants, research travel and student research funding*)	3,200.00	9,298.57	2,483.67	18,287.23	500.00
Equipment and Hosting Costs	1,249.97	58.49	254.19	530.31	297.44
Contracted Services (*includes website development and professional editing services*)	545.00	5,406.82	1,291.00	2,614.00	105.00
Miscellaneous		103.11	110.87	33.00	18.27
TOTAL EXPENSES	**360442.21**	**46,330.14**	**42,146.14**	**67,329.45**	**51,367.14**
Carryforward	*13,957.79*	*17,627.86*	*27,481.86*	*28,152.55*	*See next page*

CURRENT AND ANTCIPATED EXPENSES FOR 2014-15

	Current May 1, 2014- March 1, 2015	Anticipated March 2, 2015- April 30, 2015	Total
Staffing	45,298.96	16,800.00	62,098.96
Convening costs for WICI Speakers Series, workshops, symposium and meetings	1,512.91	3,300.00	4,812.91
Speaker and Guest Travel	3634.56	1,700.00	5,334.56
Research Funding (*includes grant development, challenge grants, research travel and student research funding*)	500.00	1,000.00	1,500.00
Equipment and Hosting Costs	297.44	175.00	472.44
Contracted Services (*includes website development and professional editing services*)	105.00	0.00	105.00
Miscellaneous	18.27	150.00	168.27
TOTAL EXPENSES	**51,367.14**	**23,050.00**	**74,492.14**
Carryforward			*53,660.41*

Note: Carryforward for 2014-15 due to:

1. *Administrative Assistant salary for post-April 30th in case of renewal delay;*
2. *High profile speakers invited for 2014-15 Speakers Series who deferred to next year—Melanie Mitchell, David Christian, Raissa D'Souza, and Eric Beinhocker;*
3. *Dr. Parker's PDG contributions – a PhD student hired for Spring 2015 term;*
4. *Dr. Steven Mock's salary up to July 31, 2015;*
5. *A workshop planned by Dr. Thomas Homer-Dixon.*

APPENDIX H: LETTERS OF SUPPORT

UNIVERSITY OF WATERLOO

FACULTY OF ENVIRONMENT | Office of the Dean
519-888-4567 | fax 519-746-2031
uwaterloo.ca/environment

March 13, 2015

Professor George Dixon
Vice President, University Research
University of Waterloo

Dear George:

I write to express my support for the application of the Waterloo Institute for Complexity and Innovation (WICI) for a five-year centre renewal.

As Environment's previous Dean (André Roy) noted last year, in his support of WICI's funding extension for 2014-15, WICI has focused on the development and application of new interdisciplinary approaches to scientific problems and provides a unique perspective on problem solving by using a complexity theory lens. The interdisciplinary manner in which WICI approaches scientific issues is widely shared across the Faculty of Environment.

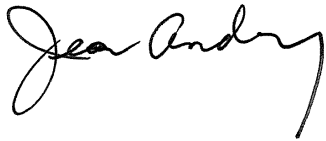Examples of WICI's impact, interdisciplinary involvement, and future direction are:

- Several ENV faculty members lead WICI's core research projects. These projects have benefited from WICI support for grants through WICI-sponsored grant development workshops, administrative support for grant development, and matching support. This support has lead to several substantive SSHRC projects through the Partnership Grant, Partnership Development Grant, and international Digging into Data initiatives, as well as funding from CIGI (Parker, Quilley, and Homer-Dixon).

- WICI has facilitated the development of network connections between ENV researchers and researchers in the Math, Engineering, and Arts faculties on campus, as well as connections with other universities. These networks cover broad, cross-disciplinary topics such as complexity economics, network science, coupled human-natural systems, cognitive modeling, complex health systems, and thresholds in natural and social systems.

- ENV students, both undergraduate and graduate, have been active participants in WICI seminars and WICI-sponsored working groups (the network science reading group and the agent-based modeling working group). These activities have provided them with exposure to the work of global scholars, increased their awareness of the work of complex systems scholars on campus, and provided them with direct training to support their research.

- WICI has provided networking and outreach opportunities for junior scholars in ENV through membership, participation in WICI events, and the opportunity to present WICI

seminars. In particular, there is substantial overlap between the research and methodological interests of junior faculty from Knowledge Integration and the new Master's of Climate Change program and WICI (involving Derek Robinson, Peter Johnson, Vanessa Schweitzer, John McLevey, and Sarah Burch).

- WICI's goals for renewal include activities that are potentially complementary to ENV's mission and strategic vision. For example, if successful, a proposed NSCERC CREATE application around coupled human-natural systems modeling proposed by Parker (ENV), Bauch (Math) and Adnan (U. Guelph) could provide valuable support for the PhD research of ENV students interested in sustainability and global environmental change issues. ENV would also expect to benefit through strengthened networks between ENV and other faculties, which would prepare members of the faculty to quickly respond to emerging collaborative opportunities.

In all, I believe WICI continues on an upward trajectory and that its increasing impact and activities bode well for the future. I hope you are in agreement that WICI is providing added recognition and impact to highly original research projects, and that you are able to support its bid for renewal.

Sincerely,

Jean Andrey,
Interim Dean, Faculty of Environment

UNIVERSITY OF WATERLOO

FACULTY OF ENGINEERING | Office of the Dean
519-888-4567, ext. 32718 | fax 519-746-1457
dean.engineering@uwaterloo.ca | uwaterloo.ca/engineering

MEMORANDUM

To: George Dixon, Vice President, University Research

From: Anwar Hasan, Associate Dean, Research & External Partnerships, Faculty of
Engineering

cc: Pearl Sullivan, Dean of Engineering
Dawn Parker, Director, Waterloo Institute for Complexity and Innovation

Date: March 19, 2015

Ref: Waterloo Institute for Complexity and Innovation

On behalf of the Faculty of Engineering I extend my support for the renewal of the Waterloo
Institute for Complexity and Innovation (WICI).

Since receiving the first approval from Senate in 2010, WICI has seen its academic activities --
including seminars, workshops, research papers, and collaborations -- grow considerably. The
institute's research is multi-disciplinary and as of today it has more than seventy members.

Over the past few years, several WICI seminars and workshops were given by our faculty
members, including Professor Mark Hancock of Management Sciences and Processor Keith
Hipel of Systems Design Engineering. Engagements of this nature present opportunities for new
research collaborations and can be beneficial to our participating faculty.

I take this opportunity to wish WICI continued success with it goals and objectives.

Sincerely,

Anwar Hasan

UNIVERSITY OF WATERLOO

FACULTY OF MATHEMATICS | Office of the Dean
519-888-4567, ext. 33474 | fax 519-888-4302
deanmath@uwaterloo.ca | uwaterloo.ca/math

March 13, 2015

Dr. George Dixon
Vice President, University Research
University of Waterloo

Dear Dr. Dixon,

I am pleased to submit this letter in support of the renewal of Waterloo Institute for Complexity & Innovation (WICI). WICI addresses important issues in the application of complexity science to various problems. This focus is in line with the research interests of some colleagues in Applied Mathematics and Computer Science.

Although the Faculty of Mathematics is a relatively small participant in WICI involving two core faculty members and one student, these colleagues have been active and highly value their role in WICI activities. Prof. Chris Bauch (Applied Mathematics) has given a seminar at WICI (2013) and has attended several WICI seminars since joining the faculty at the University of Waterloo. His graduate students have also attended a number of WICI seminars related to their research area. He was active in the Complex Health Innovation Working Group, contributing to group discussions and suggesting topics. He is currently planning further WICI activities with Profs. Dawn Parker and Madhur Anand, in particular, symposia on modelling coupled human-environment systems, and initiatives such as an NSERC CREATE grant to support PhD students working in the area of human-environment systems. He has also had informal research discussions with various WICI core and associate members, including Profs. Madhur Anand, Edward Thommes, and Thomas Homer-Dixon, much of which has helped inform the research which goes on in his lab.

Similarly, Prof. Hans De Sterck (Applied Mathematics) has been involved in WICI since 2011, regularly attending WICI seminars, and has given a WICI seminar (2015) on social network analysis. He has interacted with WICI core and associate members, in particular Prof. Thomas Homer-Dixon, and this connection through WICI has resulted in important input for his work with PhD student John Lang on modeling of political revolutions. John Lang is a student member of WICI and this has benefited John's work significantly. Prof. De Sterck has participated in several other WICI initiatives, including the 2013 WICI Data Visualization & Analysis Symposium, where Prof. Brian Ingalls (Applied Mathematics) also spoke. Network science, which is one of the focus areas of WICI, is of increasing importance in broad areas of research. This is true in particular also for research being conducted in the Waterloo Applied Mathematics department, where an increasing number of faculty members develop research activities in this area. In interdisciplinary fields like this, it is important to establish research connections across faculty boundaries, and WICI is instrumental in achieving this for research in the broad area of complex systems.

In addition to these colleagues in Applied Mathematics, there are possible collaborations with faculty members in Cheriton School of Computer Science in the areas of agent systems and game theory.

Sincerely,

Ian Goulden
Dean of Mathematics

UNIVERSITY OF WATERLOO

FACULTY OF ARTS | Office of the Dean
519-888-4567, ext. 38246
dean@watarts.uwaterloo.ca | uwaterloo.ca/arts

March 18th, 2015

I am writing to communicate my support of the renewal of the Waterloo Institute for Complexity and Innovation. Committed to better understanding complex systems and to research that is inspired by and can address real-world problems, this institute has brought together a broad group of scholars and projects from across the uWaterloo campus, including the Faculty of Arts. The institute has demonstrated its ability to promote leading-edge research that addresses natural and social systems, and to apply this research to practical issues. Since its inception in 2010, the Waterloo Institute for Complexity and Innovation has pursued six distinct research programs; disseminated knowledge through peer-reviewed publications, conference presentations, seminars, and workshops; and trained graduate students. The Institute's work clearly contributes to research efforts broadly at the University of Waterloo, and enriches scholarly work in the Faculty of Arts.

Sincerely,

Doug Peers
Dean, Faculty of Arts