E^{N}COMPASS: Collaborative Observatories for Management, Policy, & Science for Society

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Summary

E^NCOMPASS is a multi-national, transdisciplinary, and multi-sector initiative to adopt systematic and science-based approaches to societal tradeoffs. The project leverages existing relationships and infrastructure with partners in the Americas. A cyberinfrastructure is proposed for a pilot-case that integrates earth resource informatics with socio-technical tools for a geothermal basin in northern Chile. Research builds from existing data to establish the schema for dynamic data collection, real-time modeling of energy-water systems, and design for citizen science education. This proposed work has practical implications for resource allocation, strategic planning, and science policy.

Statement of Objectives

Once launched, the E^NCOMPASS project will generate a cyberinfrastructure to develop and share topical research in areas for Earth, Energy, Environment, Education, and Engagement (E^N) within Collaborative Observatories for Management, Policy, And Science for Society (COMPASS). Cyberinfrastructure (CI) refers to technological systems that enable large-scale research. CI may be comprised of numerous components including hardware, software, algorithms, computing systems, data storage systems, advanced instruments, data repositories, and visualization environments to enable large-scale research (Atkins et al, 2003).

The E^NCOMPASS initiative engages stakeholders with earth resource concepts through sciences and community problem-solving – as well as serving as a platform to involve local communities in the decision making process. A pilot case is already being crafted for El Tatio Geothermal Field (ETGF) in Chile to generate a virtual observatory for thermal and hydrologic data. Located in the Atacama region of Northern Chile, ETGF is the largest geyser basin in the southern hemisphere, and it is an isolated environment that exhibits sensitivity to climate fluctuations. Research at the site is a foundational element for the larger E^NCOMPASS initiative. Once launched, initial research for the Tatio Observatory will center on the following research question:

How can the use of physical science information improve social decisions regarding the sustainable exploitation and conservation of natural resources to foster socioeconomic development?

This overarching research question requires the use of mixed-methods from organizational behavior, economics, and geosciences. Research results will be incorporated into a larger vision of CI,that will help identify designs for communities in developing countries. In turn the CI will enable interactions so that scientific and socioeconomic data from different countries have the potential to inform sustainable use of natural resources throughout the region.

Research questions that are proposed as part of this Fulbright Nexus application are largely methodological and key to addressing how people understand and use scientific information to manage energy and earth resources. By selecting ETGF as the E^NCOMPASS pilot location, research will build on prior work that includes geomicrobiological, hydrological, and

thermographic sampling since 2002 and leverages existing relationships in the region.

E^{N}COMPASS will function as a central hub and virtual place for researchers and practitioners to interact and a portal for visitors to learn about energy-water resource systems. The platform will set the stage for multi-disciplinary collaboration by geologists, hydrogeologists, geophysicists, geomicrobiologists, computer scientists, applied mathematicians, economists, and social scientists in a format that can be shared and replicated at other sites in Latin America.

Background Rationale – Societal need and previous work

Often labeled the Yellowstone of South America, ETGF is a beautiful geyser basin and a rare natural resource that attracts Chilean and international tourists. The extreme isolation of ETGF creates intrinsic scientific value that can be studied by analyzing the unique chemistry and microbiological community of arsenic and UV tolerant organisms that exist in the geothermal springs. While the unique setting generates heavy visitation that provides an important economic resource for the local towns and indigenous peoples, the geothermal resource also has potential for energy generation capable of increasing energy security and stability for industries in the region, such as mining. These tensions create conditions for intense conflict over use and management of the area.

Research for the pilot case initially grew out of the rapid response needed to immediately assess the impact of a release event in September 2009 (Correa et al, 2010; Pierce, 2009). A geothermal developer was testing a set of exploratory wells dating from the 1970's when an accident occurred, damaging a wellhead and producing a 60m artificial geyser that took over a month to control. The wellhead release created localized impacts to the environment, perceived health risks due to arsenic precipitates, and concerns regarding the relative impacts to basin fluxes due to depressurization of the geothermal complex.

I led an interdisciplinary research team from The Jackson School of Geosciences to collect Forward Looking Infared (FLIR), or thermographic data, along with geochemical, hydrological, and stakeholder interview data (Pierce, 2009). This dataset forms the base on which the pilot case study is built. Results demonstrate that social perceptions for most stakeholders groups (government representatives, tour operators, hotel services, environmentalists, and tourists) are anchored in the belief that long-term environmental impacts have occurred. However, observed scientific data do not substantiate that interpretation. Early indications from the geoscientific data imply that temporary shifts in the geochemical, hydrological, and thermal fluxes of the basin occurred and quickly rebounded. However due to the massive public outcry over the event, geothermal development was swiftly reined in by the Chilean Senate and the most advanced Chilean geothermal exploration project in 30 years was shut down.

The results of early research at ETGF highlight the challenge faced by many industries dependent on earth resources—that perception can outweigh measurements when it comes to decision-making. It also shows that top down management by government agencies, or a Planned Management paradigm (Wagner, 2006; Shani and Mitki, 1996), is not enough to assure the advance of approved projects when community resistance is firm.

Recent events, such as the Gulf of Mexico Oil Spill, have shown that social concerns are

mounting with regard to the tradeoffs related to energy generation and environmental impacts. In the next decade demand for energy is expected to double in Chile if the economic rate of growth in the country is to be maintained (Figueroa, 2010). Events have shown that government directives alone cannot assure resource development – in that case can technological advances provide the solution?

Professional Preparation and Substantive Role of the Fulbright Nexus

In answer to the question of technological innovation as a solution, or Technological Determinism (Shani and Mitki, 1996), I will share my personal experiences. I created my first Decision Support System (DSS) while working in Chile. At the time I was the Environmental Manager for the El Abra Copper Mine, the seventh largest copper mine in the world and a flagship property for environmental performance, with funding from the International Monetary Fund. The DSS collected data related to the preservation of a critical wetland inside a playa lake basin, the Salar de Ascotan, where the El Abra mine site extracted water resources (Pierce, 2008).

The system was cutting edge by the standards of the 90's, with telemetry and trigger alarms for flow levels reported directly to the Operation Control Room of the mine site and clearly defined mitigation and response actions for anticipated conditions. The experience was inspirational, I considered it a crowning success from my time as Environmental Manager, and I decided to return to graduate studies to learn more about incorporating scientific data into computational systems for decision support.

In 2002, just one year into my doctoral studies I revisited the Salar de Ascotan expecting to find a healthy wetland system. Instead, I found a system suffering the effects of water extraction to the point of ecosystem collapse. It was a painful and very personal moment that reframed my research direction and brought home with full force the inadequacy of Technological Determinism. In that moment I realized technology and automation cannot solve resource management issues – social and behavioral aspects of human organization must be considered as well.

The result has been a shift in my research to incorporate social aspects of decision problems (Pierce, 2008). My doctoral research engaged community stakeholders and five research disciplines to develop a transdisciplinary methodology that resulted in the construction of both web and desktop versions of a Decision Support System to aid dynamic dialogue for groundwater resource management decisions.

Nexus Project Scope and Methods – Science and Society

As humans our perceptions are based on how we understand and make sense of what has occurred in relation to an event, Karl Weik identified this process as *sensemaking* (Boland, 2008; Weik, 1995). While sensemaking is situated with an eye to evaluating past events, decision making is the process by which we evaluate possibilities for the future through carefully weighing comparative alternatives and expectations of outcomes (Boland, 2008).

In the case of energy and earth resource problems, which often fall into the category of common pool resources (Steins et al., 2001), policy determinations are most effective when they are based on both public values (sensemaking) and facts (science supported decision making) (Dietz and

Stern, 2008). Research that spans these aspects is identified by the National Research Council (Dietz and Stern, 2008). To address each aspect, the E^{N}COMPASS pilot-case will use a blend of socio-technical and informatics approaches to inquiry. The socio-technical perspective is an approach from organizational behavior that is tightly coupled with concepts from sensemaking. Informatics on the other hand, is closely aligned with methods and philosophies of decision analysis techniques. Research during the Fulbright Nexus year will evaluate the following sub-questions as they relate to ETGF:

1) *Socio-technical Context: What is the data with the greatest value and relevance for decision support and engagement?* A socio-technical approach starts with problem framing from an organizational or planning paradigm (Dietz and Stern, 2008). Building on my prior field work, this aspect of the project will evaluate the perception and value of scientific information in the context of multi-stakeholder interests for the ETGF. Data collection will continue under an existing approval from the Internal Review Board for studies involving human participants (Pierce, 2009). Baseline concerns and community knowledge about ETGF will be collected using field elicitation and willingness to pay surveys. Results will provide a rich qualitative data set from community participants regarding their sensemaking and concern about ETGF management options (Weik, 1995). These data will in turn inform translation of concerns into metrics using a value-focused thinking approach (Keeney,1992; Pierce, 2006) to convert observed data into decision relevant metrics, or measures of performance.
2) *Informatics: How can collection of key data be streamlined, automated, and what components can involve citizen scientists?* Informatics is an emerging field of inquiry that uses analytical techniques to mine, visualize, and communicate information so that it can be transformed into knowledge or new insight (Neopolitan, 2007). Value-focused thinking outcomes will feed directly into implementation of the informatics components for the pilot case. Metrics will be developed for priority parameters and potential trigger levels of the physical system that are relevant to stakeholders. Data will be collected in the field using digital systems for capturing qualitative and quantitative data quickly through a LIFT- Innovation and Technology Grant (Pierce and Rich, 2010).
3) *Computation: How can information be converted into accessible knowledge with datasets for use by scientists, decision makers analysts, and interested citizens?* Recent debate among CI researchers has argued that the true benefits of CI can only be achieved with incorporation of social and organizational considerations (Ure et al., 2009). Simultaneously CI with disciplinary foci, such as Geosciences, are growing rapidly (Baur et al., 2009; Nativi et al, 2009). The E^{N}COMPASS pilot case begins with sociotechnical considerations in mind. The preliminary CI platform is expected to provide access via a simple web-served, service-oriented architecture (SOA) that will feature data upload using both hand-held devices and in-situ sensors. The virtual architecture will use WaterBase, a recently unveiled data management and storage system that can enable sharing of cross-theme and cross-sector research products, the system used by the Department for Water in Australia (Nicholson, B., 2010). Implementation of a cyberinfrastructure poses a novel approach to data management

and data sharing to ensure cross-theme and cross-sector use of research products, as well as creating a portal for interacting with interested citizens from around the world.

Synergies, Challenges, and Communication

Implementation at the Tatio Geothermal site leverages existing relationships and funding for development of a CI. Work during the Fulbright Nexus year will:

- Extend multi-disciplinary research efforts underway since 2002 (Correa et al, 2010; Dunckel et al., 2009; Landrum et al., 2009; Phoenix, 2006),
- Strengthen efforts for a newly formed Memorandum of Understanding between Universidad Catolica del Norte, Universidad de Chile, and The University of Texas at Austin (signed August 27, 2010),
- Leverage recent funding for innovation and technology (Pierce and Rich, 2010),
- Operate under an existing human studies approval (Pierce, 2009),
- Benefit from in-kind software applications, such as WaterBase (Nicholson, 2010) and
- Link with existing interests of the Latin American Forum to develop applications that transfer knowledge and can be shared.

The virtual observatory portal provides direct access for communicating outcomes of research with data, applications, analysis, and educational tools. Advances will be published in peer reviewed journals and presented at technical or professional conferences, such as the annual Latin American Forum convened by leaders in Energy and Environment from around the region. An International Seminar on Managing Energy and Water Resources for Regional Development co-hosted by the E^{N}COMPASS university partners will be planned during the Fulbright Nexus year. At this event we expect to host an open house with the general public in the II Region of Chile to share research results, progress, and understanding about the regional resources.

Additionally, tasks associated with LIFT aim to directly interact with local stakeholders including community NGO's, government agencies, and schools and universities. These stakeholders are crucial in the implementation of the virtual observatory program for ETGF. Graduate students will be actively involved in ETGF research with co-supervision between university partners through the MOU anticipated.

As E^{N}COMPASS gains momentum, information from the ongoing research will be used to develop informal education and regional science tours which in turn, have potential for encouraging micro-entrepreneurism via science docents or tour guides in the geothermal basin.

Expected Results – Scientific and societal benefits from this research

The practical aim of E^{N}COMPASS is to establish a cyberinfrastructure that can be replicated in developing countries. Methods explore the role of context, quantification, and computation as they pertain to proactive resource management and policy making. Scientific knowledge cannot be incorporated into policy and decision making unless the information is available and people understand the implications. E^{N}COMPASS is a step towards improving engagement with communities and providing an avenue for communication between citizens and scientists, so that science can be part of community dialog and improve access to relevant information.