Farm-to-Table: Global Awareness, Imports, and Safety in Food Production

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ABSTRACT

"The study of *emergence* (author's italics) in all its forms is one of the most important scientific enterprises of our era, and will remain that way for the next century." (Buchanan, *Nexus*, 2002).

General education is essential to significantly and effectively prepare students for collaborative endeavors necessary to deal with emergent characteristics of complex problems. One example is food safety in our current global situation. Despite current industry efforts in control and/or destruction of microbial cells and spores during production, the increase in imports and demands on already strained inspection resources (a plant is inspected once every ten years, whereas the number of imports from 1992-1997 has doubled), has opened the door to enormous public health problems waiting to *emerge* with catastrophic potentials. A critical reality of food production and efforts to mitigate contamination is that in any "farm-to-table" scenario multiple sources, suppliers, and steps along the process chain pose an unintentional, or *intentional*, threat to the safety of the product. Imported food sources compound demands for multiple ways of knowing and accessing expertise (reconnaissance, world news, sensor monitoring, etc.).

This presentation will articulate general education attributes necessary for a multidisciplinary approach to tertiary education as a strategic readying arena for creative thinkers able to meet and foresee the challenges congruent with our current global situation.

INTRODUCTION

The last twenty years or so have seen a turning point in the study of culture away from the **producer** (writer, scientist, city planner) and the **product** (book, discourse, city street) to the **consumer** of knowledge (reader, chemist, pedestrian). While knowledge creation remains critically domain based, the demands of a consumer culture can only be met when knowledge construction becomes largely social. When knowledge is embraced as a social phenomenon, not as a "thing," two important changes are worth noting. One: knowledge becomes less discrete and we see that chunks of knowledge share correspondences by way of increasingly "porous borders" *within* complex global situations. In other words, interdisciplinarity finds its ultimate value in approaching *problems*. And, two: human imagination is cultivated into "tiers of production", or "chunks" as some knowledge production communities have already identified, motivating even the solitary researcher to work with corresponding understandings of the larger picture. Accelerating the idea of knowledge "chunks" for making knowledge productive is not new. With such a perspective, serious global problems – such as safe food production in a global plant – will afford us the opportunity to rediscover the value of human insight as discernment over domain-owned recognition, networked experts of all kinds, and informal debate and dialogue as a powerful complement to expert understanding. While these may seem like, initially, very ordinary characteristics of any team intent on successful outcomes together *these are also general education attributes necessary for readying creative thinkers to tackle the* *emergent characteristics of complex global problems. Yet, these are attributes that are not naturally cultivated in the educational experiences of today.*

One: "POROUS BORDERS"

The following five scenarios describe the effort to secure safe food production in a global plant. Knowledge chunk correspondences share increasingly "porous borders," *with* complex global situations – with *problems*. They show how well intentioned domain-based knowledge developed without the assistance of a multidisciplinary community of experts can address problems only from a limited perspective and create solutions that do not solve the entire problem.

1. In 1997, the Food and Drug Administration (FDA) issued restrictions on animal feed to create a "firewall" against the spread of Bovine Spongiform Encephalopathy (BSE), known commonly as Mad Cow Disease. The 1997 rule prohibits the feeding of ruminant (cattle, sheep, deer, goat) material to other ruminants, but allows the feeding of ruminant material to pigs and chickens, and rendered pig and chicken material to ruminants. The same 1997 rule also permits cattle blood, poultry litter, and salvaged pet food to be fed to cattle and other ruminants. So, in fact, the "firewall" that the FDA has implemented to protect the American public from BSE is full of loopholes, and animal feed remains a route by which the disease could be spread in the United States.

Since BSE is spread through the feeding of rendered animal byproducts back to livestock, the FDA designed the 1997 regulations to address the risk of spreading the disease by clearly labeling animal feed containing rendered cow, sheep, deer and goat protein. But in 2002, the General Accounting Office released a report finding serious flaws in the FDA's inspection and review of animal feed renderers, manufacturers, feed haulers and distributors (U.S. General Accounting Office, 2002). It is simply too easy to let rendered feed from a sick animal slip through the cracks and into the feed supply. Even heavily regulated borders can be porous where "silent carriers," such as pigs and chickens infected with Transmissible Spongiform Encephalopathy (TSE), threaten contamination of the animal food product (Center for Food Safety, 2004). Industry suggests the government should pay for adequate monitoring, while the government claims industry should pay. At the moment, monies garnered for food protection are used for band-aid solutions that are based on the identification of discrete problems and limited by the resources available to the FDA; the real problem—which will demand collaborative efforts amongst government agencies, industries, and consumers from a number of countries—will not be addressed until we are faced with a crisis like that faced by U. K. during the 1980s and /90s which infected 200,000 cows and resulted in the precautionary killing of some 4.5 million more. The outbreak resulted in 150 human deaths and some export markets remain closed to U. K. farmers to this day (Talbot, 2004).

Both meat producers and government regulatory officials have apparently ridden-out the recent alarm associated with the Mad Cow outbreak in the United States and gone back to business as usual with minor modifications, such as no longer allowing dead (or downer) cows into the food system.

2. The FDA cannot act alone on international food issues, and this contributes to the first scenario. Other governmental agencies play major roles in food production in the United States, including the U. S. Departments of Agriculture (USDA), State and Commerce, the Environmental Protection Agency (EPA), and the Office of the U. S. Trade Representative, among others. Further, all Federal activities involving Codex, an international standards setting organization based out of Rome, Italy, are managed within USDA's Food Safety and Inspection Service (FSIS). Complicating an already complex relationship between a number of government agencies are consumer demands for foods produced by other countries, including developing countries. Americans consume beef from Australia, X, and the U. K. Beef from X is not as strictly monitored as it is in the U. K., and yet it was the U. K. that has seen the greatest incidence of BSE. "Food has become a global commodity," says Janice Oliver, deputy director of FDA's Center for Food Safety and Applied Nutrition (CFSAN). "We Americans have changed our eating habits. Today, food is international. It is from Central and South America or Europe or the Asian countries or the islands of the world" (http://www.gmp1st.com/foodimp.htm, 2004). But neither the FDA nor the USDA can inspect every food package brought into the United States. Linda Horton, director of FDA's international agreements, notes in that same article, "We don't have the resources to examine all imported products or to inspect most overseas production facilities. We need to work with those who export food to the United States [to make sure it's safe leaving those countries]." Although related, the example of BSE demonstrates two separate "porous border" phenomena plaguing our food production system: a reticence toward intranational agency collaboration, and international government and economic monitoring discrepencies.

3. Another "porous border" situation impacting safe food production is disease spread between animals and humans. More than a hundred years ago, Rudolf Virchow first proposed the idea of "one medicine," basing his conclusions on work with zoonotic diseases and his observations of the ease with which etiologic agents could move from animals to humans and back again (Brown, 2000). This was long before the notion of a "global village" would call us to apply our respective expertise to design vigilant systems covering a myriad of vulnerable fronts, not mutually exclusive of one another.

For several reasons we are seeing an emergence of pleiotropic effects–on animals, on the environment, and on the health of humans, both directly, through the transfer of zoonotic agents, and also indirectly, through the potential compromise of the food supply (Brown, 2000). Some of these reasons include the overall increase in global human population. Bodily ecosystems are introduced with all their microflora and potential pathogens to new areas and animals when new patterns of animal and human movement increase. With domestic sprawl, habitat destruction and fragmentation, we have seen the aggregation of wild animals (particularly migrating species that can harbor disease) into smaller and isolated patches, increasing the contact rate within species and exposing animals and humans to potentially new pathogens. Avian Influenza epidemics such as the recent one (H7N7) in the Netherlands in 2003 caused 80 confirmed cases of human H7N7 influenza virus infection. Symptoms include acute respiratory distress syndrome (ARDS). Since we also know the most toxic biological threats to the human race are protein toxins produced by bacteria derived from plants and animal protein toxins which target the human respiratory system, it goes without saying we can no longer ignore the emergence of possible zoonotic agents into our environment.

Viruses pathogenic to humans might make excellent agents for bio-crimes or bio-terrorist attacks, but they are poorly adapted for strategic deployment—*with the exception of smallpox and anthrax*—because our environments are unstable (Wilson, 2000). As members of an at-risk global community, we must consider this information from the perspective of identifying the nature of vulnerable "porous borders" and creating "firewalls" to protect against the possible transmission of pathogens through these borders. In this type of scenario, where boundaries are not firm, an equally pressing issue is who will be responsible for the costs associated with the required monitoring?

4. Of great concern is the threat to the world's economic health should the food supply be a target of bio-threat. Conflict between First World prosperity and Third World poverty continues to be a volatile issue. It is projected that by 2050, 8 billion of the world's 9.5 billion people will live in developing countries; they will face the consequent rising social and environmental pressure with little infrastructure or direction (Wilson, 2000). This, along with other factors contributing to their resentment of economic imbalances, point to future wars conducted in a sphere dominated not by military actions but by the targeting of our bio-welfare or other major infrastructures, resulting in crippling economic consequences.

5. A related aspect of this kind of "porous border" (call this a problem emerging as a result of information access) is the relative ease of home manufacture, collection and delivery of lethal biological agents. The World Directory of Collections of Cultures and Microorganisms, for instance, serves 453 worldwide repositories in 67 nations (ABSA/Eagleson, 2002). Fifty-four repositories ship or sell anthrax; 18 ship or sell plague. Etiologic agents can also be acquired through field samples or clinical specimens, commercial biological supply houses, and university or foreign labs. Anthrax, for example, exists in soil as a spore. One hundred thousand whitetail deer die from anthrax annually in the United States. Cattle harboring anthrax appear healthy until a few hours before death. Rabbits can be carriers of *Francisella tularensis* (Tularemia), a highly infectious aerosol agent, and resistant to desiccation and extremes of temperature (a typically reliable decontamination method for many food process designs). Biological toxins such as *Ricinus communis* (Ricin) can be easily constructed from a home recipe including castor oil and beans. Meat, dirt, and wax are simple ingredients needed to create Botulinum. The quantity of *Botulinum Nerotoxins* (Botulism) found in the ink of one period (.) is enough to kill 30 people. One pound will kill the entire human race.

The ability to harvest many agents lethal to humans (anthrax, tularemia, plague) or incapacitating (viral hemorrhagic fevers, or VEE) makes it virtually impossible to eliminate bio-threats. And considering the lack of preparedness of the food industry for bio-terrorist mitigation (as of September 23, 2003, over 70% of food industry professionals surveyed did not know about the FDA Bioterrorism Act or have done nothing to prepare), an enormous public health problem is waiting to emerge with catastrophic potential. Given the unthinkable truth that by infecting its environment an entire population can be put at risk or destroyed, containment issues targeting any farm-to-table (start-to-finish) process suggest the necessity of a fundamental shift in research and education related to other disciplines and to other knowledge bases.

Two: “CHUNKS”

Human imagination cultivated into “tiers of production,” or “chunks,” as designated in the design and production systems characteristic of the car or building industries, are matured and sophisticated systems that span many categories and countries. Unlike disciplinary specializations, significant yields from “chunks” result from understanding correspondences in the morphology of aesthetics, performance engineering, material and labor resources, economy and market. For example, performance engineers intent on designing what is under the hood of the car (from the engine to the carpet) must correspond with the industrial designers’ development of the exterior aesthetics only as they intersect at a few critical points. Beyond that, the expertise and intention of the interior and exterior “chunk” teams of the car may be widely disparate (Kieran, Timberlake, 2004).

In the instance of safe food production in an international arena, “chunk” teams must consider the situation from three correspondences: 1) the relational knowledge between the macro and micro food safety issues possible in order to determine sensor-supported data sources within the food production process (some within the production plant, some through wireless tracking of animals from farm-to-feedlot-to-plant-to-retail); 2) the development of bio-sensor technologies that are robust and redundant under an array of conditions (loss of power, compromise of the sensor); and 3) building upon (2), the design of an information fusion system capable of managing these many heterogeneous data sources in real time. It is important to emphasize that, independently of the current information technology craze, useful information will come from (3) only when (3) gets useful information from (2)—and we are far from having perfect sensors.

This involves a skills-set where, as William Isaacs describes in *Dialogue: And the Art of Thinking Together*, “these things cannot in the end be separated” (Isaacs, 1999). Like the critical correspondences between the interior and the exterior designs of the car, the first step is to determine the “architecture” that will enable the team to come to the point where they can identify the forces at work in a transparent and easily recognizable way. This kind of “architecture” is a conceptualization of something that can only be modeled or simulated, since we cannot stage a real enactment of food compromise. For instance, Hepatitis C infection is the most common reason for needing a liver transplant. Finding a cure for Hepatitis C is difficult since human-cell activity in a Petri dish often does not model what goes on in the human body. Researchers conceptually modeling the liver seek to replicate its structure and mechanics—and by doing so to replicate its functions. External forces applied to the model substitute for the impacts of toxins, drugs, and stress. Conceptualizing the liver as a unique ecosystem impacted by other systems, substances, and biorhythms is a powerfully effective approach to designing drug therapies and to understanding how the liver “system” (read “chunk”) responds to the external forces. This kind of thinking is also at the core of what it means to create “an architecture” for any complex problem (Lindberg, 2003). This yields awareness of the macro and micro influences and allows every discipline to engage at a significant scale of influence. In the end, we learn the primitives of effective “chunk” teams: the rediscovery of human insight as discernment over domain-owned recognition; the valuing of networked experts of all kinds; and the overdue appreciation for informal debate and dialogue as a powerful complement to expert understanding. These are general education attributes necessary for readying creative thinkers to tackle the emergent characteristics of complex global problems.

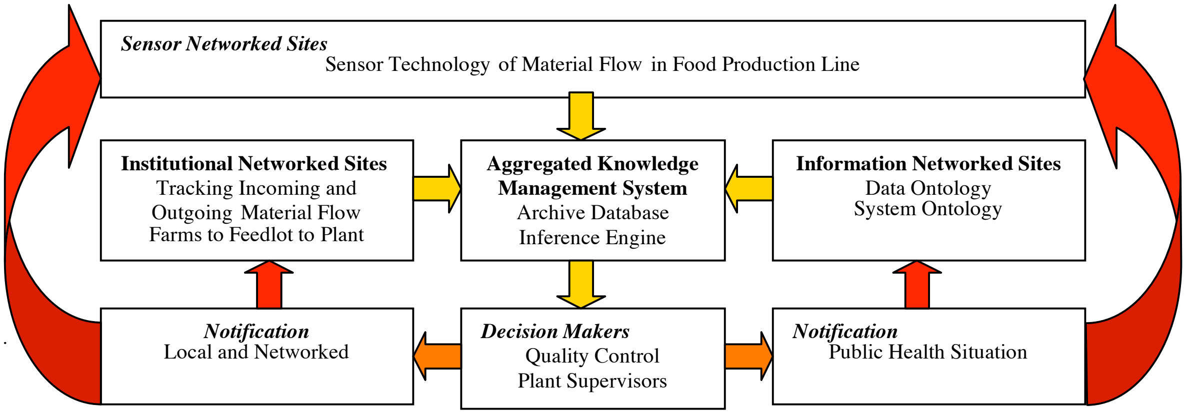

Fig. 1 Architecture of an Aggregated Knowledge Management System Using Sensors, Ontologies, and Inference Technologies. This Farm-to-Table Architecture is critical to "defining a practice that will yield awareness" for a "chunk team" approach to food safety problems.

"The rediscovery of human insight as discernment over domain-owned recognition": This is possibly the most important skills-set to nurture within a "chunk" team approach to knowledge production in that results may challenge an individual researcher's agenda since tiers of influence (the aggregation of creative solutions) ultimately direct production. For example, a significant consequence of managing the "porous borders" of the farm-to-table process is economic. And in any mass production process, a tiny mistake can result in economically devastating consequences. Therefore, critical to the design of a safe production system must be the realization of the most cost effective approach. For instance, an enormous cost-saving measure might be found, in part, by achieving a relatively simple system based on the creation of an opportunity to *rework* (through heat, oxidation, etc.) a product detected with potential contamination; *dispose* (or quarantine) contaminated products; or *notify* appropriate decision-makers of a potential public health situation. Likewise, several steps along the process chain will ask different scales of influence from contributing disciplines (sensor technology, tracking/tracing of the product, secure building envelope). Tiers of production are the result. Data sources for the "architecture" described above include the programmable logic control (PLC) and clean-in-place (CIP) monitoring of the entire plant floor; the human/machine interface (HMI) system monitoring the actual food production (including archived historical processing data); intelligence/reconnaissance search channels (World Health News, CDC, etc.); and pre-harvest product tracking from farm to feedlot to production facility. Therefore, bulk storage, food fabrication, loading and conveying, packaging and warehousing for distribution, can all be sources of data. Hazard Analysis Critical Control Points (HACCP) and Line Inspection Management Systems (LIMS) monitoring and reporting systems provide critical data for each food product fabricated. In addition, data from manufacturers' internal training programs based on the FDA's Good Manufacturing Practices (GMP) provide information to safeguard the environment and the workers. Faced with increasingly complex environmental issues, data from regulatory compliance permitting is also a data source regarding the handling of any discharged or bi-product material such as regular sample outfalls, in-plant waste stream surveys, and spill/emissions reports. Wastewater and storm water collection, transport, and treatment data sources can also be included. Additionally, hazardous material management and storage (above and underground storage tanks), industrial hygiene, and waste minimization and pollution prevention, all require critical information streams to assure a safe and healthy interface between workers, the product and the environment. The clean environment's envelope also provides information to secure the food production environment from bio-threat incidents through sensor data monitoring air intake and distribution, worker and product movement, drop-offs and deliveries. *These heterogeneous data sources are a few of those considered when cultivating "tiers of production" in food safety. Particular knowledge of a food fabrication process, the corresponding sensors used, and the goal for the fusion system, are primitives necessary in order to design an appropriate knowledge chunk.*

"Valuing networked experts of all kinds":

While government officials considering public health and food safety issues appear to want a Star Trek "Tricorder", i.e. a magical wand that tells all, the reality is much different. There is no magic all-useful sensor that costs nothing. Tiers of production can also be tiers of advocacy convincing research and regulatory agencies to fund critical missing parts. The food chain, being premised on a bulk commodity, dictates that, whatever sensors are used to ensure food safety, they be relatively inexpensive. Hence, relatively sensitive sensors, which are generally costly, may not be cost effective in the real world. This needs to be addressed at multiple levels in order to achieve success in the production plant. Furthermore, there is often an institutional bias against testing techniques. This is apparent in the American versus European means of testing for Mad Cow. The European method is not only significantly faster, but also cheaper and more accurate than the American model. Sensors generally do not appear miraculously on the market place, but rather require extensive research and development. The government can help ensure future food safety efforts by making a critical evaluation of the ultimate cost and practicality of a sensor platform by funding parts of the development of the evaluation process. While it is always difficult to predict the ultimate technology winner in any field, we make note that the trends of government funding on new technologies is not always for the best. For example, premising the word "sensor" with "nano" has resulted in few breakthroughs in the sensor field. The fundamental detection problems are still with us, *particularly in the context of robust and redundant production environment conditions and food design protocols where sensor cost, accuracy, potential for false readings (positive, negative), and sensor lifetimes are the issues that commonly dictate use in actual practice*. Productive research needs to be done to place useful sensors in place, with a transduction signal that can be readily converted to a microprocessor with compatible voltage, the modern era's signal processing coin-of-the-realm, so that data streams can be reliable and ubiquitous and then shared and interpreted quickly and accurately.

From there what can be done with the information is unlimited. Obvious examples for the processing and handling of the analyzed and compensated data are automatic alerts, and World Wide Web postings of the information so users across all borders can track and ensure food quality. <u>The goal is situation awareness of the food chain—farm-to-table—ensuring food safety.</u>

"Informal debate and dialogue as a powerful complement to expert understanding":

In the end, readying creative thinkers to tackle the emergent characteristics of complex global problems contributes solutions that apply not only to the problem of food safety but also to the development of situation awareness technology that enables real time vigilance for potentially <u>any</u> start-to-finish scenario (water, communications, distribution trucking, transportation). The collaborative research inspiring this paper presented the goal of creating an information fusion system capable of managing large data bases and resolving the heterogeneity of the myriad of data sources described in the situation of global food production by dynamically generating common "ontologies" – domain-specific semantic structures – rendering a meaningful representation of the world of the situation (Wang, et.al, 2003, Matheus, et.al, 2003, Kokar, Wang, 2002). Using the JDL Data Fusion Model (terminology of data fusion standardized by the Joint Directors of Laboratories), information fusion can be designed to sufficiently represent and capture information about a situation in real time (Matheus, et. al, 2003). Granted, this is a conclusion to the situation that favors software engineering and computer science technology over Architecture as a traditional discipline, and one that lumps food safety into the same category as any start-to-finish scenario needing real time monitoring and awareness. But all disciplines are informed and benefit enormously from the initial yield. Architects contribute as designers of "architectures" for collaborative integration systems–in and of itself a breakthrough for the professional services traditionally offered by an architect. Linking data from the outside of the production plant to the inside (recall the interior/exterior car "chunk teams"), through an inference engine (a "best conclusion" smart search), utilizes the information from reconnaissance intelligence, public health news, and the tracking of animals from their pre-harvest environment of farm-to-feedlot. This joins the data of the interior production plant, where highly developed sensor monitoring designed for every food fabricated, can only be enhanced by robust and redundant bio-sensor development on the production floor. Understanding how these kinds of networked situations work, as much as anything, is as important to our national security as smart bombs and stealth bombers, and worthy of considerable government attention today, ***not after the next outbreak of food poisoning***. Altogether, the relational impact of research and design ideas called up by the "porous borders" situations, requires dialogic reasoning across disciplines and knowledge bases, and collaborative thinkers capable of discerning scales of influence a research endeavor or idea can have in any given dilemma.

SUMMARY

The problems emerging as a result of international situations of population, resource management, technology, knowledge production, conflict, economic integration, and governance, will inevitably impact research and education for the future. The serious situation of international food production, along with plant and animal disease threats to the food supply presented here, is one example. When we approach the "chunk" of nutrition as intrinsically linked to the other "chunks" of world peace and global prosperity, we will begin to appreciate the potential of approaching world food safety issues from the perspective of "porous borders." General education attributes are necessary for readying creative thinkers to tackle these complex global problems. There is the rediscovery of human insight as discernment over domain-owned recognition, the valuing of networked experts of all kinds, and the overdue appreciation for informal debate and dialogue as a powerful complement to expert understanding. Mark Buchanan in *Nexus* argues that the very aim of the science of complexity is to discover patterns in complex networks of all kinds, and to learn how we might use this understanding to better our selves and our world. Central to this task is the notion of emergence, the idea that meaningful order can emerge all on its own in complex systems made of many interacting parts. The study of emergence in all its forms is one of the most important scientific enterprises of our era and will remain that way for the next century. As one eminent physicist puts it, "the central task of theoretical physics in our time is no longer to write down the ultimate equations but rather to catalogue and understand emergent behavior in its many guises, including potentially, life itself" (Buchanan, 2002)

REFERENCES

American Biological Safety Association/Eagleson Institute Spring Seminar Series. 2002. *Bioterrorism and Biosecurity.*

Brown, C. 2000. *Emerging Infectious Diseases of Animals: an Overview*. ASM Press. Washington, DC. 1. 10-11.

Brown, J. S., Duguid, P. 2002. *The Social Life of Information.* Harvard Business School Press. Boston, MA. xvii.

Buchanan, M. 2002. *Nexus: Small Worlds and the Groundbreaking Science of Networks.* W. W. Norton & Co. New York, NY. 207.

Center for Food Safety. 2004. *Mad Cow Disease: Closing the Loopholes in FDA's Feed Regulation.* U.S. General Accounting Office, "Mad Cow Disease: Improvements in the Animal Feed Ban and Other Regulatory Areas Would Strengthen U. S. Prevention Efforts," GAO-02-183. January 2002.

Cohn, J. 2004. *The International Flow of Food: FDA Takes on Growing Responsibilities for Imported Food Safety.* http://www.gmp1st.com/foodimp.htm.

De Certeau, M. 1988. Chapter IV. Foucault and Bourdieu. *The Practice of Everyday Life*. University of California Press, Berkeley, CA. 57.

Isaacs, W. 1999. *Dialogue: and the Art of Thinking Together*. Doubleday, New York, NY. 292 300.

Kieran, S., Timberlake, J. 2004. *Refabricating Architecture: How Manufacturing Methodologies Are Poised to Transform Building Construction.* McGraw-Hill, New York, NY. 21-45.

Kokar, M. M., and Wang, J. 2002. Using ontologies for recognition: An Example. In *Proceedings of the 5th International Conference on Information Fusion*. 1324-1343.

Lindberg, D. V., "Modeling Emergenc(i)es." *Research Penn State* (May, 2003). 47.

Matheus, C. J., Baclawski, K. P., and Kokar, M. M. 2003. Derivation of ontolological relations using formal methods in a situation awareness scenario. In *Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications*. 298-309. SPIE, 2003.

Wang, J., Baclawski, K., Brady, D., Kokar, M. M., Lechowicz, L. 2003. The use of ontologies for the self-awareness of communication nodes. In *Proceedings of the Software Defined Radio Technical Conference*.

Wilson, T. M., Logan-Henfrey, L., Weller, R. and Kellman, B. 2000. Agroterrorism, biological crimes, biological warfare targeting agriculture. *Emerging Animal Diseases* (Brown, C., & Bolin, C., eds.). ASM Press, Washington, DC. 23-58.