Advancement of a whole-chain, stakeholder driven traceability system for agricultural commodities: beef cattle pilot demonstration

PROJECT NARRATIVE

JUSTIFICATION:

This proposal directly addresses the following Request to Applications priority area:

> *(111.F) Strengthening national traceback systems; promoting an outbreak response system that shortens the time between outbreak detection, resolution, and recovery; and improving methods for communicating with consumers about traceback and foodborne illness outbreaks*

Magnitude of Food Safety Issues to be Addressed

Traceability is a key component in developing a safe food supply, as evidenced by the recent outbreak of foodborne illnesses attributed to spinach, peppers, and tomatoes in the United States and the ongoing e-coli outbreak in Europe with 27 deaths reported to date. The European Union has agreed to pay over $300 million to farmers who suffered losses due to the outbreak. The Centers for Disease Control reported that salmonella infection rates are on the rise with one million people sickened by food-borne pathogens each year (Food Safety Monitor, 2011). Unfortunately, the current approach to product traceability is one-up, one-back information sharing at the GTIN (global trade item number) lot level. This type of traceability system has many disadvantages, including lack of privacy, and fails to maximize system benefits such as efficiency and more complete or "whole-chain" information sharing. This approach is fraught with inherent delays, limiting consumers' and regulators' ability to identify the contaminant source and limiting mitigation efforts in the event of outbreaks or bioterrorism. This lack of critical information can cause significant economic losses to multiple industries resulting from public uncertainty on the potential for human hazard. This uncertainty can and will affect industries ultimately found to not be related to outbreaks. Conversely, research suggests that whole-chain traceability can substantially limit the economic loss of food safety events (Resende-Filho and Buhr, 2010).

Long-Term Vision

The long-term goal of this project is to develop and implement an internet-based stakeholder-driven traceability and marketing system for food products that is not punitive or profit-limiting but that adds value to the process while providing a method to limit and remedy food safety outbreaks and biosecurity breaches. This system will include data input by producers, vendors, and consumers. This data not only provides information to facilitate mitigation but also marketing information, value-added details, cultural and sociological features about the production or handling of the produce, quality standards criteria, and a feedback opportunity for consumers to rate or improve product quality. Data will be controlled within the context of a multi-tenant social media system. In the proposed system, stakeholders, particularly producers, will maintain granular privacy control over access to data. This is critical, since the ability to trace food through a supply chain depends on private firms sharing product information with competitors as well as collaborators. If they are not assured of privacy control over information, they may refuse to participate in the system.

The resulting field-tested system will be built using GS1 GTIN identification. This system will interface with internationally recognized and active traceability and marketing systems. It will interface with social networking internet opportunities and consumer information technologies. This system incorporates both traceability functions for food safety and biosecurity and data marketing functions. The data marketing functions will provide producers and processors an opportunity to develop new revenue streams by deploying new and innovative marketing strategies that make use of cell phone technologies and GIS graphic mapping web applications. This system will reduce the mitigation time related to food safety emergencies. Producers will feel confident in their data security within the system because they control who has the ability to access their data access. Consumers will feel secure in the information they access because of the stakeholder-driven input built into the system. One of the benefits of a stakeholder system (producers, processors, consumers, and regulators) is bringing people on both ends of the spectrum closer together by sharing data, enhancing the "farm-to-fork" relationship.

This proposal is unique. All other systems offered to date have been proprietary "silos," rather than open source. These proprietary "silos" have presented economic disadvantages to small growers and have created trust issues with all growers concerning data ownership. Companies such as Microsoft have not addressed these issues and have been unsuccessful in accommodating the needs of industry and government mitigation agencies. The proposed system will protect confidential data, except that in case of a food safety event it could be used quickly and efficiently by regulators to resolve the issue. A stakeholder-driven and trusted system allows forward-thinking industries a means of rapidly communicating with regulatory agencies and consumers. From a traceability standpoint, the goal is to provide the necessary information needed to prove a company's or industry's products are safe in a rapid manner that will ultimately save market share and maintain consumer confidence in these products.

Why this Research Team Is Especially Well Suited for this Work

Oklahoma State University is the lead institution in an informal "Whole Chain Traceability Consortium" (WCTC) composed of OSU, Michigan State University (MSU), North Dakota State University (NDSU), and the University of Arkansas (UA) (Figure 1). This group has been working on traceability issues for the past two years. The consortium has a unique blend of researchers and extension specialists with expertise in food science, animal science, computer science, engineering, food process technology, sensing technology (including use of nano-sensing devices), risk management, supply chain management, economics, communications, and sociology. A goal of this consortium is to establish a Center for Food Safety and Whole Chain Traceability, which will be the first such center in the United States dedicated to food safety by tracing the whole supply chain.

The subset of the consortium participating in this proposal represents key areas for advancing the backbone traceability and marketing software system. Once this backbone has been advanced to the point of completing a successful pilot demonstration, the entire consortium will work to secure funding to incorporate additional commodities into the system and increase/enhance the system add-ons. The system add-on would include various types of real-time sensors that provide data directly into the traceability system. The research team submitting this proposal to advance the backbone traceability and marketing system is multi-disciplinary and multi-institutional. The team utilizes personnel from land grant universities, research foundations, and industry. The team is composed of both research and extension personnel with expertise in computer science, animal science, food science, food processing technology, engineering and

economics. Most importantly the team has a strong background in working with stakeholders to design and implement stakeholder driven systems.
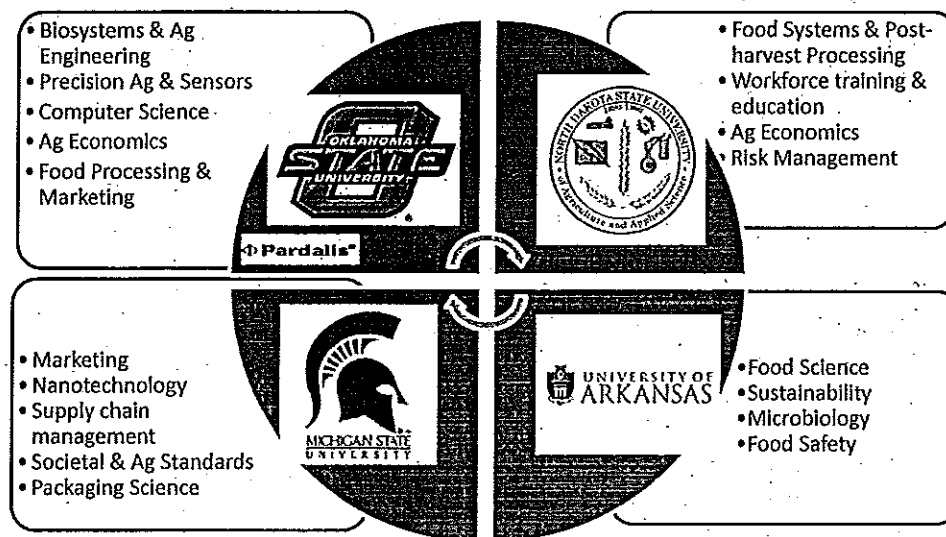

Figure 1. Whole Chain Traceability Consortium

OSU computer scientist Dr. Blayne Mayfield specializes in object-oriented and Web-based software development. Dr. Johnson Thomas has expertise in network protocols and network security. He also teaches graduate classes in database systems. Together, they will update the patented technology provided by Pardalis and adapt it for use in each of the pilot applications proposed here, in a format that is easily adaptable to other products and supply chains.

Dr. Timothy Bowser (OSU Biosystems and Agricultural Engineering/FAPC) is a food process engineer with more than 25 years of experience including sensor development and meat processing technologies. He will propose and test ways to integrate sensing devices and the developed software into the meat production process. He has a dual appointment in the Biosystems and Agricultural Engineering Department and the OSU Robert M. Kerr Food & Agricultural Products Center and has access to the considerable expertise and resources of that center and department (see Facilities section). Dr. Bowser has a 35% research and 65% extension appointment.

Dr. Steven Ricke is Director of the Center for Food Safety at U. of Arkansas. In that position he has special interest in effects on consumers of food safety events. His research specializes in the microbiology of food safety. He focuses on the pathogenesis and control of foodborne pathogens in food production as well as development and implementation of rapid methods for their detection. Dr. Philip Crandall is Professor of Food Science at U. of Arkansas, specializing in food safety. They will work directly with retailers and beef processors, using their working relationships in the retail and processing industries to identify appropriate stakeholders, and then gathering information and sharing the traceability system information and structure with these entities. Dr. Ricke has a 60% research, 20% education, and 20% extension appointment. Dr. Crandall has a 26% research, 64% education, and 10% outreach appointment.

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Dr. John Blanton (Animal Scientist, Sam Robert Noble Foundation) manages the Agricultural Research Team of the Noble Foundation's Agricultural Division. This team conducts research across five primary disciplines: agricultural economics, horticulture, livestock, soils and crops, and wildlife. In addition to managing the team, Dr. Blanton manages the 12,000 acres operated by the Noble Foundation, including a 5,000 acre fully operational cattle ranch near Marietta, OK. Dr. Blanton conducts research in the areas of animal growth and health management with the goal of increasing animal performance, carcass merit and meat quality.

Pardalis, Inc. (represented by Steve Holcombe, CEO) will provide patented traceability technology and assistance in updating/adapting the technology for the proposal's applications. A description of the technology is provided in the Pardalis letter of collaboration. Pardalis, Inc. is a software company providing technology for web-connected, user-centric sharing and traceability of data granularly identified at the 'atomic level'. Pardalis focuses on why granular 'data ownership' matters to complex, segmented supply chains. One of Pardalis' strengths is the building of virtual communities that facilitate profit growth and industry safety through communication and trust. Mr. Holcombe will provide technology, co-consultation with an enterprise class software engineer (interfacing with the OSU Computer Science and the OSU College of Agriculture), intellectual property reconciliation in systems development from existing source code, and will develop and manage an informational website for the group and its stakeholders.

Top 10 Produce, LLC has an excellent history of helping small producers in California implement GS1 traceability systems and is highly active in the development of the Produce Traceability Initiative (PTI) and the use of Global Trade Identification numbers (GTIN). Top 10 Produce was the world's first 100% transparent produce brand, and it has a nationwide network of participating growers that produce everything from grass fed beef to cactus. Top 10 connects consumers and growers by identifying the source farm and grower at the point of sale using mobile media and social media. Top 10 has specialized in transparent traceability; however, Top 10 would like the complementary capability of sharing some, but not all, information in the supply chain, and being able to select which parties share which information.

Top 10 will provide the use of its GS1 GTIN (14-digit) databars to interface with the proposed whole chain system, including its ability to link with consumers through mobile and social media. Top 10's brand provides a GTIN that is unique to the grower. That means when the databar barcode on the produce item is scanned, that information is specific to that grower. Other brands commonly use the same GTINs for all of their growers' items so there may be 500 producers using the same GTIN for their produce. Integrating the proposed whole chain system with the Top 10 brand and its current technology matrix is intended to provide a dynamic for the real-time sharing of food safety and marketing information between supply chains and their consumers.

Top 10 will also provide connections to growers and other service providers who participate in its traceability services under the "Locale" brand. One of the growers using Top 10's "Locale" brand is Stoner Family Farms, represented by Dick Stoner. Stoner Family Farms is a progressive farm interested in using traceability technology to provide more accurate and efficient data management using the "Locale" brand as "Chesapeake Locale." Stoner Family Farm will provide its herd for use in demonstrating the traceability technology, using RFID tags provided by Hana Micron America.

Hana Micron America (DBA Hana Innosys) is a system integrator that has expertise in auto ID processing, including RFID animal traceability systems. Hana Innosys has an interest in helping to develop and implement an internet-based, systemized, stakeholder-driven traceability and marketing system for agricultural commodities, not only for food safety but also for disease outbreak prevention in animal herds. They will provide all RFID equipment and associated support for tracing cattle through the supply chain using the proposed software technology.

Dr. Michael Buser (OSU Biosystems and Agricultural Engineering) and Dr. Brian Adam (OSU Agricultural Economics) will be coordinating and directing the project. Dr. Buser will serve as the primary interface between the extension and research components; a seamless working relationship between the extension and research components is critical to the success of the project. He has expertise in technology development and adoption, and has an extensive background in project management and working with stakeholder groups; including producers and associations in the cattle industry and governmental agencies. Dr. Buser's extension work will focus on facilitating continuous input from producers and other stakeholder in the supply chain in development, deployment, and continued development of the traceback system. This will also facilitate strong stakeholder involvement with the project. Dr. Buser will coordinate the application of the systems add-on hardware, such as RFID tags, scanners, and stakeholder specific systems. Dr. Buser has a 50% research and 50% extension appointment.

Dr. Adam's research and teaching focuses on marketing of agricultural products, including market supply chain and market system efficiency. His expertise is in analyzing costs and benefits of alternative technologies in the food marketing system. He and a multidisciplinary team recently receive funding from the Andersons Group and from Dept. of Defense (via OSU's Dept. of Management Science and Information Systems) to develop RFID and traceability technology for food safety, supply chain efficiency, and biosecurity in grain handling systems. He will direct the evaluation of benefits and costs of implementing and using the system. Dr. Adam has a 70% research and 30% education appointment.

By partnering with the private sector companies, Top 10 Produce, Pardalis, Hana Innosys, and Stoner Family Farms, the proposed research and extension effort will provide creative and original answers to three problems inherent to real-time traceability and marketing within agricultural supply chains: (1) cost effectiveness of developing an efficient data collection system, food supply chain, that originates from producers, (2) producers' privacy concerns, and (3) lack of data sharing between the proprietary data supply chain silos. Stoner Family Farms and Noble Foundation, using technology provided by Hana Innosys, will provide cost-effective, efficient, GS1 GTIN item-level data at the beginning of livestock supply chains to input into our proposed traceability system. Top 10 Produce will provide technology to interface between the traceability system and the retail/consumer level.

Pardalis and OSU will integrate their software development activities to help assuage producers' privacy concerns with greater technological data sharing control than that provided by conventional social media systems. Pardalis will open up both its software source code and global intellectual properties to help foster a highly motivated national (and, perhaps, international) community of software developers dedicated to increasing the flow of information through food supply chains. This cross-disciplinary team represents a powerful assemblage of engineering, economics, virtual community development, software expertise, legal expertise, and livestock knowledge.

OBJECTIVES:

1. **Develop** a working, scalable stakeholder-driven "whole chain" agricultural commodity traceability system.

2. **Develop** consumer information links to the traceability system using mobile and social media.

3. **Deploy** the traceability system as a pilot beef cattle demonstration.

4. **Evaluate** the benefits and costs of using the system.

5. **Transfer** lessons learned about benefits and costs of using the system to producers, industry professionals, retailers, and other stakeholders, with the goal of extending the technology to other commodities and products.

Specific Aims

- **Stakeholder engagement**. This approach insures current and cutting edge industry, governmental, and consumer information needs are incorporated into the system. This approach seeks to develop and grow stakeholder "buy-in" to avoid the negative response commonly found in systems that are forced on industry without industry input.

- **Develop a server-based, data repository traceability and marketing system** using Pardalis' IP. Housed originally at OSU, this multi-tenant central server will provide tenant-controlled data that will position both grower and consumer data for real-time, item-level traceability viewed through commodity specific interfaces. The proposed system will allow all stakeholders including government, consumers, and growers to obtain information at the item level when needed.

- **Deploy the data repository traceability and marketing system** in a demonstration project. Cutting edge technology will allow immediate access to location data so that government and health resource units can mitigate outbreaks or attacks on food supplies without economically and socially devastating the industry and interrupting the food supply chain throughout the US unnecessarily. Producer selected real-time marketing data will be accessible by connected consumers.

- **Demonstrate** the integration of end software and equipment add-ins to help producers, processors, and consumers. Show stakeholders the full potential of stakeholder-driven, "whole-chain" data repository traceability and marketing system.

- **Initiate, deploy and manage a working web-model of a "whole chain" product traceability system** that is provided under open source licensing backed by secured intellectual properties for low cost and rapid adoption by the domestic (and potentially international) agricultural and food supply chains.

Broader Impacts

Through the availability of real time item level product information, consumers will see value added commodities thus providing a sustainable profit edge for producers and a safe food supply to consumers. Data will be in place to **quickly mitigate food safety outbreaks or agroterrorism**, thus providing safety for consumers and economic security for agricultural industries. Use of GS1 and GTIN's will allow easy interface with international markets that already use the GTIN system. This provides additional safety for imported and exported products.

METHODS:

Objective 1. Develop a working, scalable stakeholder-driven "whole chain" agricultural commodity traceability system.

Description:

A useful explanation of the "whole-chain" product traceability system can be made with critical traceability identifiers (CTIDs), critical tracking events (CTEs) and nodes (IFT/FDA 2009) (Figure 2). CTEs are events, or transactions, that must be recorded to allow for effective traceability of products in the supply chain. A node refers to a point in the supply chain when an item is produced, processed, shipped or sold. While important and relevant data may exist at any phase of a CTE transaction, the entire collection of data for that transaction may be uniquely identified and referenced by a code referred to as a CTID. With the emergence of biosensor development for the real-time detection of food borne contamination, one may also envision adding associated real-time environmental sampling data from each node.
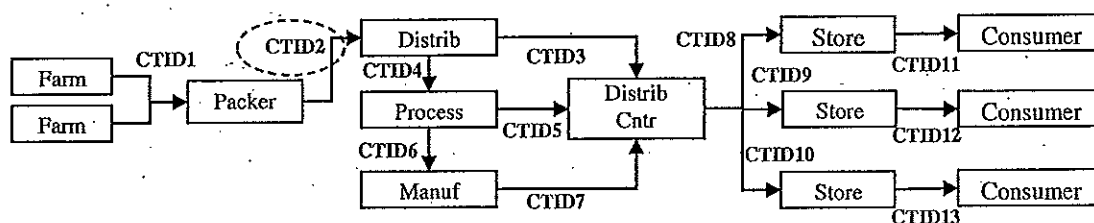
Figure 2. Critical tracking events within the supply chain.

The challenge is that even top-of-the-line "one up/one down" product traceability systems (compare CTID2 in Fig. 1 with CTID2 in Fig. 3), notwithstanding the use of a single CTID, are inherently limiting in the data sharing options provided to both stakeholders and government regulators. With the proposed stakeholder-driven "Whole Chain" product traceability system, in which CTID2 is essentially assigned to the data entry level (see CTID2A, etc. in Fig. 3), transactional and environmental sampling data may, in real-time, be communicated to supply chain partners and food safety regulators.

The goal is to develop and deploy a web-based "whole chain" product traceability system. Real-time environmental data will be deposited into the system from biosensors, and real-time data synchronization will occur with FoodSHIELD (2011) for real-time access to data in a food recall situation. Note: sensors beyond RFID tags is beyond the scope of this proposal and will be the focus of future work. Results will be evidenced by increased access to real-time data concerning food borne contamination data and analyses by one or more FoodSHIELD workgroups via the "whole chain" product traceability system. The real-time access to food safety data will assist foodborne-outbreak investigators when conducting traceback and traceforward epidemiological investigations.

Procedures:

The software development for a working, scalable stakeholder-driven "whole chain" agricultural commodity traceability system is broken down into four categories: 1) system architecture, 2) system software, 3) content-centric networking and 4) stakeholder feedback.
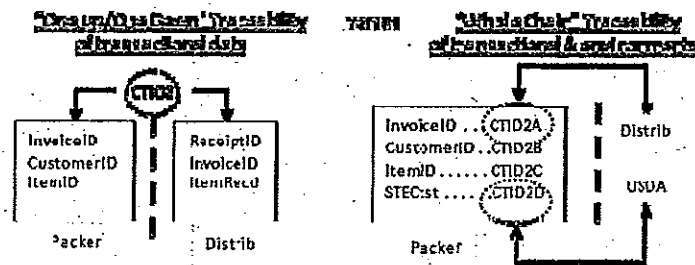
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Figure 3. "One up/One down" Traceability versus "Whole Chain" Traceability.

System Architecture

The proposed Whole Chain Traceability System (WCTS) system will allow users to access data whenever and wherever it is needed. This is achieved by WCTS having at its core a distributed database management system. Through distribution of data across a network of physical servers, as well as replication of data across that network, the WCTS system will be made more reliable and less susceptible to network latency problems.

Mobile and social media applications developed in this project will enable different stakeholders to link to the WCTS system and thereby access content in the supply chain. Hence, a consumer at the point of sale can be linked to the producer and other stakeholders along the chain. We propose to use the Android free open source software to implement applications that permit stakeholders to access and update appropriate information along the supply chain, taking privacy and security constraints into consideration.

We propose to implement the distributed system using a content-centric networking (CCN) data framework such as the CCNx framework currently under development by Xerox PARC (Palo Alto Research Center). The primary benefit of CCN lies in its ability to retrieve data objects based on *what* the user wants, instead of *where* the data is located.

The current system uses a thin-client/server framework. The new WCTS system architecture instead will use a Web-based approach. A primary advantage of this approach is the ability to access the server and its data from any computer with a compliant Web browser installed, without the need of installing a thin client on that computer. This project will promote open source development across three complimentary communities, Project CCNx, Android and the current proposed research with the aim of providing the different stakeholders a robust, ubiquitous pervasive, secure and efficient traceability and marketing system.

System Software

The proposed WCTS system will extend the existing supply chain software of Pardalis, Inc. to which the PIs will have access (see attached supporting letter). The existing centralized system allows the creation of an information authoring and distribution system for generating information objects related to food traceability; for example, health record objects of an animal. Each of these objects contains a set of immutable data. The system authenticates users and is also able to authenticate these information objects to ensure correct and secure data. The proposed work aims to design and implement a distributed system for food traceability. Security mechanisms that are tailored for food traceability such as access control to the objects in the chain and third party certification to data owned by supply chain participants will be developed. As multiple stakeholders

may be generating and accessing shared data, we will develop algorithms for data synchronization, data reconciliation and certification of shared data. The system must also manifest reports such as supply chain traceability reports, that is, the complete trail of an animal. A browser-based version of the user interface will be designed and implemented. Microsoft products available through the OSU Microsoft Developer Network Academic Alliance, such as SQL Server for realizing a distributed database system, the C# programming language, and the .NET framework, will be used for system implementation. A critical subset of these requirement to be identified during the early stages of the research will be implemented as applications in mobile Android based smart phones.

Content-Centric Networking for Food Traceability

We propose to implement a distributed whole chain food commodity traceability system within a content-centric networking data framework. The main approaches for content centric networking are outlined in Jacobson et al. (2009), Fotiou et al. (2010), Johnsson (2011) and Kopponen et al. (2007). Our implementation will build on Xerox PARC's CCNx scheme (Jacobson et al. (2009), and the free open source code for CCNx is available at Project CCNx (2011).

Initially, CCNx will be applied for commodity traceability to determine system performance characteristics such as bandwidth, caching requirements, delays, throughput, etc. CCNx's performance will be compared to the Internet Protocol. The security of CCNx for commodity traceability will be analyzed. In the second phase we will seek to alleviate the bottlenecks and weaknesses identified in the first phase, particularly the security vulnerabilities and trust implementation in the whole chain. We will first identify the security goals for a whole chain commodity traceability system to define security policies. These policies, which will include access rights, for example, will be enforced by credentials.

Second, we will analyze the different levels of protection and privacy required by the different types of content. Third, we will implement trust in the whole supply chain within the CCNx framework by integrating credentials (Blaze et. al. 1996) with reputation-based trust management (Zacharia 2000) and policy-based trust management. A Bayesian (Neapolitan 2004) dynamic trust scheme that evolves with changing credentials and reputations is proposed. We propose to create and discover by content the distributed credentials, reputations, users and data and thereby create a trust chain that is content-centric. Sanitation algorithms (Dilys 2007)) to filter content will be explored with a view to incorporating them within CCNx to ensure privacy.

Stakeholder Feedback

Advisory groups will be developed for four primary groups: producers, processors, governmental entities, and vendors/end consumers. Goals for the number of group members include: 10 to 20 for agricultural producers, 2 to 5 for food processors, 1 to 5 for governmental agencies (allows for multiple individuals from the same agency), and 5 to 10 vendors/end users. These group sizes are targets and not limits; investigators welcome all participants.

Surveys will be developed by assessment specialists at Oklahoma State University, distributed, collected, and analyzed for each advisory group. It is anticipated that at least one survey per year will be conducted. Survey results will be distributed to all advisory group members and posted on the projects official website. The results will be used to access the perceived advantages and disadvantages with traceability in general and the current version of the investigators traceability and marketing system. The surveys will also be used in preliminarily

evaluating potential future changes to the system thus providing an industry and consumer driven emphasis for the system's design.

Informational meetings/workshops will be developed and scheduled. These meetings will be held in OK, TX, and AR with some participates joining via conference call. The purposes of these meetings are for investigators and advisory group members to exchange ideas. Oklahoma State University investigators will share the concepts for the proposed system and/or demonstrate the current traceability and marketing system, discuss survey results, and provide an overview of the current advisory group opinions. Members attending the workshops would be asked to evaluate the current system and provide specific feedback. Stakeholder (advisory group member) ownership ("buy-in") is a primary objective of these meetings.

Data analysis, interpretation, and dissemination:
Survey results will be distributed to all advisory group members and posted on the projects official website. The results will be used to access the perceived advantages and disadvantages with traceability in general and the current version of the investigators traceability system. The surveys will also be used in preliminarily evaluating potential future changes to the traceability system thus providing an industry and consumer driven emphasis for the system's design.

All stakeholder comments will be complied in a living document. For example stakeholders will most likely be asked exactly the same question on a yearly basis throughout the life of the project. These repetitive questions will be used to gauge how stakeholder opinions change over time and with improved knowledge of the system.

Expected outcomes:
We expect to develop and deploy a working model for a web-model of a "whole chain" product traceability system that is open sourced under a CDDL for low cost and rapid adoption by the domestic and international beef sector supply chains. It is expected that our highly active advisory groups who are engaged and enthusiastically share their opinions on the development of the traceability and marketing system, current status of this projects data repository system and future system versions will be developed, maintained, and expanded. Stakeholder buy-in is critical to the success of a stakeholder driven traceability and marketing system for agricultural commodities. The system vision is not punitive or profit limiting but adds value to the process as well as providing a method to limit and remedy food safety outbreaks and biosecurity breaches.

Potential pitfalls and limitations:
This system is designed for large enterprises and therefore scalable beyond the projected working model. Speed performance issues are common with enterprise-class systems though solvable with time and resources. The limitations will not be technological but primarily the sociological or anthropological issues that have long sustained the "data silos" that prevent real-time sharing of data.

All identified pitfalls correspond to the level of stakeholder involvement. High stakeholder involvement could correspond to massive and contradicting comments from the same stakeholder pool (e.g. producers). These situations will require the investigators to be sensitive to the stakeholder opinions that may not be incorporated into the system. Stakeholder involvement and buy-in throughout the life of the project are essential..

Objective 2. Develop consumer information links to the traceability system using mobile and social media.

Description:

In general, it is anticipated that add-ins will be requested by the stakeholders, outside software companies looking to tap into alternative markets, and/or suggested research team. Prioritized lists of requested add-ins will be developed throughout the life of the project. Integration of these recommended features will only occur when the entire research team has approved the new feature and adequate time and funds are available to complete the integration. The software add-ins that will be developed as part of this project are described in the following procedures section.

Procedures:

The traceability software developed in Objective 1 will be interfaced with software that links the information to consumers and to retailers through mobile and social media adapted from that used by Top Produce. Top 10 Produce LLC is a marketing brand providing 100-percent traceability to the item level and exceeds the case-level traceability recommended by the Produce Traceability Initiative (PTI). The brand makes items sold under the label traceable by assigning each produce item with a unique 14-digit GS1 GTIN databar or an equivalent data matrix or QR barcode (GS1 a, b; Vans and Simske, 2011). When that produce item goes in a case, that case is also assigned a databar. The brand currently provides an "open mic" (i.e., transparent) traceability system in that it shares the data associated with the databars in a "one up/one down" manner with all of the grower's competitive trading partners. GS1 set a global sunrise date of January 1, 2010 for all scanning systems to achieve the capability to read DataBar codes on any trade item (GS1 Canada). Figure 3 shows a QR barcode label (a substitute for the aforementioned databar), and the front page of information that a consumer can instantly access.

Top 10's brand extends all the way to consumers in its application of ShopSavvy, a comparison shopping application found on smart phones employing the successful Android operating system developed by Google (ShopSavvy is also available or the iPhone, although that platform is proprietary.) You can find items by either typing them on a phone keyboard or using the camera to scan the bar code. Yet because of the limitations of "one-up/one-down" information sharing, ShopSavvy – and therefore the Top 10 Produce brand – does not include information about intermediate transactions along the supply chain. This is simply because the information is not available online. A key objective of this research is to overcome "one-up/one-down" information deficiencies by providing all parties in supply chains with more granular control over how their information is shared. This may also include recall notices, or other data that a party desires to share only with a trading partner and not another competitor. Similarly to the manner in which Google has developed a community of "open source" development of the Android smartphone operating system, the proposed project will also initiate and manage "open source" server-based development for supply chains that is complimentary to Android smartphones.

Data analysis, interpretation, and dissemination:

The software and equipment add-ins integrated into the system will be released to the advisory group members through the avenues defined in objectives one. The functionality of these add-ins will be evaluated in the same manner in which the primary system is evaluated, as described in objective one.

Expected outcomes:

The potential benefits of the system go far beyond product traceability – it also aims to help the local grower build social networks to support local economies centered around food production. Social networks can have a "groundswell" effect on regional agricultural communities - "a spontaneous movement of people using online tools to connect, take charge of their own experience, and get what they need--information, support, ideas, products, and bargaining power-- from each other." One of the "groundswell" effects of our system can be seen in the ability of consumers to leave real-time feedback.

Figure 3. Top 10 Produce/ShopSavvy Technology for Consumers to Trace Food Back to Producer

Potential pitfalls and limitations:

The purpose of including software and equipment add-in integration into this project is to provide the stakeholders a taste of the possibilities that exist with current and developing technologies. The pitfall is the potential to lose track of the primary objective of this project which is to develop and deploy a real-time, item-level, stakeholder driven traceability system. Numerous add-in technologies are being developed on a daily basis that could provide the data repository traceability system added value. However, the number of "bells and whistles" added to the system will be limited due to time and funding limitations.

Objective 3. Deploy the traceability system as a pilot beef cattle demonstration.

Description:

Deployment of the whole-chain traceability and marketing system will give consumers an unprecedented level of information about producers in their local area. Locally grown commodities are often harvested and consumed in just a few days, meaning that consumers must receive local feedback about their local growers in "real-time" in order for the information to be meaningful. Stakeholder "buy-in" is critical to the system's success and a direct and interactive means of demonstrating the systems capabilities and soliciting stakeholder feedback is deploying the system as a pilot demonstration. This team has an outstanding professional network in the cattle industry and deploying a pilot demonstration in the beef cattle industry is a good fit for the team and the project.

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Procedures:

The traceability and marketing system will be deployed on two different livestock production-to-processor systems. The team will begin by researching the processes, available data, and data flow of the existing systems. The team working with the stakeholders will identify and determine the significance of data, how the data is presently recorded (or could be obtained and recorded) and then resolve how to capture useful data in traceability and marketing system. Hana Innosys will provide the RFID animal traceability system equipment for use at the two sites. This equipment will include UHF handheld readers, UHF cow ear tags, UHF fixed readers, and UHF fixed antennae (see "equipment.pdf" document). Error analysis will be an important feature of the study to determine how and where data recording and transfer errors might occur and how to avoid them.

Both Stoner Family Farms and the Samuel Roberts Noble Foundation will serve as testing sites for the technology. These are small-scale operations that will help the team focus on key technology components as the pilot demonstration evolves over time, without having to overcome the many complicating factors of a larger system. The UHF ear tags will be administered to animals in each location. Both Stoner Family Farms and the Noble Foundation have simple supply chains to facilitate tests of tracing the product through the system, and tracing it from the processor to the processing and consumption sites.

Data analysis, interpretation, and dissemination:

During this entire process, the system will be assessed for market profitability by Agricultural Economists at Oklahoma State University. Peer-reviewed contributions will be written that identify economic and potential for food safety issues, as well as key technical and policy challenges. Measurements of time required for data recording and analysis, as well as error evaluation will be conducted on this data. These data will be used in objective 4 (Evaluate the costs and benefits of the system). Non-technical papers are intended to summarize the findings of the workshop for agricultural producers and technology developers. These publications will provide one outlet for this work.

Expected outcomes:

We expect to develop and deploy a working model of the "whole chain" product traceability and marketing system that is open sourced for low cost and rapid adoption by the domestic and international beef sector supply chains.

Potential pitfalls and limitations:

A significant challenge to the success of the long-term vision might be producers' reluctance to share information, and thus to participate in the system. Therefore, to test the pilot system we are using producers (Stoner Family Farms and Noble Foundation) that are committed to the project goals. By identifying potential problems and resolving them, and documenting the costs and benefits of using the system, we can help address producers' concerns.

A limitation of the proposed research is that as food commodities are processed they may be separated into many individual components, so that from a food safety and traceability standpoint the food is inherently less traceable. However, individual firms likely have their own means of tracking internal operations such as blending and processing, and our proposed system is intended to interface with information provided by those firms: it can track inputs to firms, as well as outputs from those firms.

Objective 4. Evaluate the benefits and costs of using the system.

Description:

The traceability and marketing system will be assessed for market profitability.

Procedures; Data analysis and interpretation:

The evaluation the costs and benefits of the proposed technology will require a combination of economic engineering, partial budgeting, and simulation analysis. Economic engineering and partial budgeting methods permit comparisons between alternative technologies while holding other factors constant. Statistical techniques such as econometrics would permit such a comparison if sufficient data existed, but since it is a new technology no data exist.

Costs of the alternative technologies can be expressed as fixed costs and variable costs, with costs of fixed investments amortized over their useful lives. A partial budgeting approach can be used for these costs. Some costs, though, are not easily quantified, such as changes in supply chain configuration and associated adjustments or even disruptions in the process. These costs will be estimated using economic engineering analysis, explicitly considering changes in each cost component of the supply chain, including estimating opportunity cost of differences in process time for each technology. This analysis will follow methods outlined by Rulon et al. (1999) and Adam et al. (2010a, b). These articles addressed situations in which a cost estimate of a new technology was needed, but few, if any, applications of the technology were in operation, so no cost data existed from working configurations. The economic engineering approach they used generated cost estimates that did not apply to any specific firm, but that could be used to estimate costs of a firm under a range of possible conditions by adjusting parameters used in the analysis within reasonable limits.

Ingalls (1998) summarizes the benefits of simulation analysis for evaluating robustness and efficiency of supply chains under alternative scenarios. Simple simulation analysis will be combined with the economic engineering and partial budgeting analysis to predict the effect of alternative assumptions about market and physical parameters on the costs and benefits of using the traceback system.

Dissemination:

The results of this analysis will be shared with stakeholders in ways described below in the discussion of Objective 5, presented in an integral way with explanations of the traceability technology developed under Objectives 1 and 2. For supply chain participants to willingly adopt traceability technology it is critical that they know clearly the costs and benefits of the investment, and also to be confident in the integrity and accuracy of the cost/benefit estimates.

Expected outcomes:

Once the baseline economic engineering estimates are completed, effects of changing economic factors will be assessed by varying individual parameters of the model. Thus, this approach provides estimates of costs that "typical" firms would face under a range of "typical" scenarios, rather than costs particular firms might have experienced under unique situations.

Potential pitfalls and limitations:

Labor and management costs and cost of disruptions to current operations are often underestimated or ignored when considering alternative technologies. Conversely, gains from

adopting a new technology may also be underestimated because of failure to consider gains in efficiency and supply chain management, as well as the potential for enhanced marketability of the product. Although economic engineering methods along with simulation will help overcome these issues, it will be important to focus especially on this issue in consultations with stakeholders to be sure the economic engineering estimates reasonably approximate reality.

The scope of the project – a pilot demonstration – will not permit a full-scale analysis of the economics of using the system to mitigate risk in a food safety event, but the work proposed here will provide a foundation for such analyses as the technology is extended to other commodities and products.

Objective 5. Transfer lessons learned about benefits and costs of using the system to producers, industry professionals, retailers, and other stakeholders, with the goal of extending the technology to other commodities and products.

Description:
The knowledge learned in the pilot demonstration will be extended to other commodity supply chains. In Arkansas, for example, such a traceability system would be extremely useful for not only large poultry operations but also the small flock owners who cater to local small organic and pasture-raised retail and restaurant markets.

Procedures:
The following established means of educating stakeholders will be used:

- OSU Food & Agricultural Processing Center (FAPC) Flash news article that is e-mailed to the regional food processing industry.
- FAPC/OSU fact sheets on the topic that can be downloaded by anyone with internet access.
- Presentation on the topic at international meetings of professional societies (e.g. American Society of Agricultural and Biological Engineers, Institute of Food Technologists, etc.)
- Workshops for producers, processors, and consumer groups

An internet social networking site to foster broad support from an international development community will be created and managed by Pardalis' CEO, Steve Holcombe, in LinkedIn, possibly as a sub-group to Holcombe's already existing 500+ member Data Ownership in the Cloud networking group (see http://www.linkedin.com/e/vgh/1891037/ or http://tinyurl.com/datacloud). Furthermore, a separate outreach website for open source outreach will be provided and maintained for management of active participants in the development community much as is provided by MIT"s open source SourceMap visualization project found at http://www.sourcemap.org/. And this focus on Pardalis' brand will serve as a model for other market driven brands held by other technology companies providing crop traceability software solutions, all for the purpose of helping to break the continuing cycle of food safety traceability crises.

Data analysis, interpretation, and dissemination:
The primary measurement of success will directly correspond to the number of stakeholders actively participating in the data repository traceability and marketing system. All social networking sites and the projects official web site will track the number of hits. Evaluation forms

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will be developed and distributed at each workshop. Similar evaluation forms will be distributed electronically to all stakeholders annually.

Expected outcomes:

Develop and implement a stakeholder-driven traceability system that is not punitive or profit limiting and that adds value to the process. The system will provide a method to limit and remedy food safety outbreaks and biosecurity breaches. The traceability system will include data input by the producer, vendor, consumer, regulator, and online, real-time detection systems. This data provides not only information to facilitate mitigation but also marketing information, value-added details, cultural and sociological features about the production or handling of beef products, quality standards criteria, and a feedback opportunity for consumers to rate or improve product quality. The primary expected outcome is that by sharing the lessons learned from the beef cattle pilot demonstration project with other commodity producers and processors will generate the support needed to expend the traceability and marketing system into multiple commodity sectors.

Potential pitfalls and limitations:

No pitfalls or limitations were identified for objective 5.

HAZARDS STATEMENT: There are NO foreseen materials, procedures, situations, or activities related to any phase of this project that may be hazardous to personnel.

LITERATURE REVIEW:

Consumers are increasingly concerned about the safety and wholesomeness of the food they eat. Recent well-publicized salmonella outbreaks have heightened that concern. At the same time, public health officials and advocates concerned about American dietary habits are emphasizing the need for plentiful and affordable fresh produce supplies for all consumers. Traceability technology promises to aid in resolving these apparently conflicting goals (USDA 2009).

Several authors (see, for example, Kennett et al.; Thakur and Hurburgh; Golan et al.) have persuasively argued that tracking commodities in the early food marketing system stages can provide benefits similar to those achieved through improved supply chain management for industrial and consumer products. Golan et al. suggest that firms have three primary purposes in using traceability systems:

- improved supply management
- improve food safety and quality through traceback capability, and
- differentiate and market foods with varying quality attributes

Although the focus here is on food safety, food supply chain security is closely related, and is a strong motivator for designing and implementing traceability systems. Much research and several state initiatives have focused on the development of these traceability systems. The US Public Health Security and Bioterrorism Preparedness and Response Act of 2002 requires that all companies involved with the food and feed industry self-register with the Food and Drug Administration and maintain records that provide a measure of traceability (US Food and Drug Administration, 2002). The ISO 22005 Food Traceability Standard requires that each company record their immediate supplier and to whom the product is being sent (International Organization for Standardization, 2007).

Food safety is directly affected by the quality of information utilized in the food supply chain. Information integrity is paramount to optimal decision making: incorrect information can, for

example, result in poor choice of insect control methods, including pesticides, or sale of unsafe food products. Homeland Security Presidential Directive HSPD-7 for Critical Infrastructure Identification, Prioritization, and Protection (2003) – hereafter referred to as Critical Infrastructure Protection (CIP) – identifies agriculture and food as one of the eleven sectors requiring attention. Providing accurate data free from manipulation is critical to our nation's food supply.

While RFID has been proven to be successful in other critical sectors (i.e. utilities, transportation, etc.) and other parts of the food industry such as retail inventory management, there has been little employment of the technology in earlier stages of food processing. Just as in other CIP sectors, data integrity is of significant importance, and is a central tenet of information security. This not only includes the deterrence of outside threats (i.e. hackers, etc) and outside dangers, but also includes preserving integrity from mechanical and human error in austere environments. RFID offers a capability to rapidly collect critical data in real time, but the technology must be tested in the field to ensure it is operationally feasible and the data collected can be protected from a myriad of threats

Economic Evaluation of Traceability

A few studies have addressed the economics of traceability, finding that traceability is an important issue in the food industry. Using auction models, Dickinson and Bailey (2002) showed that U.S. consumers were willing to pay a premium for traceability-assured meat products. Dickinson and Bailey (2005) also used experimental auctions to estimate WTP for red meat traceability and found a significant premium for traceability in the U.S., Canada, the U.K., and Japan. The experimental results showed even higher premiums when traceability was provided with additional food safety and humane animal treatment guarantees. Hooker et al. (1999) surveyed U.S. and Australian food processors on the feasibility of traceability at the processor level and found overall positive response from the processors.

More recently, Pouliot and Sumner (2008) found that exogenous increases in food traceability created incentives for farms and marketing firms to supply safer food by increasing liability costs. The study also showed, though, that food safety declined with higher number of farms and marketers, and imperfect traceability from consumers to marketers dampened liability incentives to supply safer food by farms. Past economic studies on traceability have focused primarily on evaluating its value to consumers, particularly concentrating on red meat products. These studies have been based on limited samples using experimental auction models. Also, few studies have evaluated the economic costs of implementing traceability.

While few studies have evaluated costs of traceability systems, studies by Rulon et al. (1999) and Adam et al. 2010a and 2010b have successfully evaluated the costs and benefits of proposed alternative technologies using economic engineering and partial budgeting methods. While these studies focused on technologies to manage stored products, the approaches they used can be applied with minor adaptation to other technologies.

CURRENT WORK:

OSU – Grain Traceability - Work in progress on a traceability "proof-of-concept" project funded by Andersons Grain Company through NC-213 Grain Quality Consortium is demonstrating that RFID technology can be interfaced with traceability software to track grain from a producer's farm through a grain elevator.

EQUIPMENT AND FACILITIES:

The team pulled together for this proposal has extensive facilities, equipment, and other resources which are too numerous to list in the project narrative. Please refer for the "FacilitiesOtherResources.pdf" document for a complete summary of the team's facilities and other resources and the "equipment.pdf" document for a complete summary of the team's equipment that will be made available for this project. Some of the key equipment and facility resources include:

- The Pardalis, Inc. intellectual properties
- Use of the Top 10 Produce, LLC locale brand and corresponding GS1 GTIN databars
- Use of Hana Micron America (DBA Hana Innosys) RFID equipment
- Use of Stoner Family Farms, LLC in Washington County, MD for a pilot demonstration
- Use of the Noble Foundation's Oswalt Ranch for a pilot demonstration
- The OSU Computer Science Department facilities and equipment
- The OSO Biosystems and Agricultural Engineering facilities
- The UA Food and Animal Science Departments facilities

PROJECT TIMETABLE:

Objective	Task	Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Evaluation of Current Thin Client Software												
1	Metadata Access Control												
1	Develop Third Party Certification												
1	Devolop Data Synchronization Algorithms												
1	Develop Data Reconciliation and Certification Algorithms												
1	Develop Algorithms for Report Generation												
1	Integration and Assessment of CCNx												
1	CCNx to Internet Protocol Evaluation												
1	Evaluation of CCNx Security, Trust, and Privacy												
1	Develop Trust Management Protocol on top of CCNx												
1	Test the Integrated System												
1	Web Based Interface Development												
1	Gather Stakeholder Initial Concept Feedback												
1	Stakeholder System Evaluation												
1	System Upgrades Based on Stakeholder Feedback												
1	Develop of Web Information Presence												
1	Development of Open Source Management												
2	Integration of Mobile Media Using GS1 GTIN databars												
2	Integration of Social Media												
2	Integration of the Top 10 and New System												
2	System Feedback from Current Top 10 Clients												
3	Integration of RFID into the System												
3	Deployment of a Pilot System at the Noble Foundation												
3	Deployment of a Pilot System at the Stoner Family Farms												
3	Evaluation of Pilot Systems												
3	Bring Local Stakeholders in to Evaluate Pilot Systems												
3	Development of a Demonstration Video												
4	Cost Benefit Analyses												
4	Robustness and Efficiency Simulations												
5	Outreach - Internet Social Networking												
5	Outreach - Fact Sheet Development												
5	Outreach - International Professional Meetings												
5	Outreach - Stakeholder Workshops												