Cover story:
Turning solid organic waste into renewable energy

Also inside:
New technology for the blueberry industry
An irrigation scheduling SCADA system
As I write my last column as ASABE President, the spring semester is ending. In my role as head of the Department of Biological Systems Engineering at Virginia Tech, I hear students talking happily about their plans for the summer (and occasionally groaning about a final exam yet to be taken). Others are looking forward to commencement and the next phase of their lives. Faculty are looking forward to a summer of research and working with graduate students (and maybe a little relaxation). I have prepared my letter to our 2016 graduates offering them one-year free ASABE membership as they launch their careers. (If you are a 2016 graduate and haven’t heard about this great offer, contact headquarters at www.asabe.org/contact-us.aspx).

Students (preprofessionals in ASABE lingo) are an important community within ASABE, and I have had the pleasure of interacting with many across the Society this year. It is fun to see them at their own schools or with their ASABE sections as well as gathered together in groups from multiple institutions. The Virginia Tech ASABE Student Branch hosted the 2016 Southeast Region Rally in Blacksburg, Va., the first weekend of April. It was a pleasure to see so many students from across the Southeast get together. I was proud of the leadership that our students demonstrated in planning and hosting the Rally and impressed by those I had the opportunity to talk with during the various events. Young people are excited about the profession and about the great things they are doing now and what they are going to do in the future. By the time you read this, I will also have spent time with students at the 1/4 Scale Tractor Competition in early June. At the University of Nebraska-Lincoln this spring, I had the opportunity to talk with a team member about the tractors that she and her teammates designed for the competition. The work that student teams undertake and accomplish is amazing and highly commendable.

We need to embrace and nurture students’ enthusiasm, their intellect, and their passion for making the world a better place—a passion we all share. We should enhance our partnership with students, as individuals and as a Society. I encourage industrial and government members (and non-members) to provide internships for students. I urge faculty members to provide undergraduate research experiences and to mentor students for careers and skills outside the classroom. I advise students to pursue opportunities and make the most of them. ASABE will continue to provide and expand connections and activities for Society students.

As I have traveled this past year representing ASABE, I have typically entitled my remarks about the Society “ASABE: Members Working Together to Make a Difference.” This is how I see ASABE: a diverse range of people sharing common goals, not always agreeing about everything but always agreeing about our mission—“positively impacting food, water, energy, and the environment” with the overall goal of benefiting people of the world.

It has been an honor and a privilege to serve as president of an organization with passionate, devoted people. I look forward to continuing to work with ASABE members and Society partners as we face global challenges together. Thank you for your support over the past year, and here’s to an even better next year!

Mary Leigh Wolfe
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@ASABEpresident

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**ASABE CONFERENCES AND INTERNATIONAL MEETINGS**

To receive more information about ASABE conferences and meetings, call ASABE at (800) 371-2723 or e-mail mtgs@asabe.org.

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Kent Schescke
Converting Solid Waste into Renewable Energy with Solid-State Anaerobic Digestion

Fuqing Xu, Zhiwu Wang, and Yebo Li

More than 300 million dry tons of waste biomass, including animal manure, food processing waste, and crop residues, are generated every year from agricultural and food processing systems in the U.S. In addition, about 250 million tons of municipal solid waste are discarded each year, about 68% of which is biodegradable. Disposal of this huge volume of waste not only increases the risk of air, water, and soil pollution but also wastes the energy potential in these waste streams.

Anaerobic digestion (AD) is a biological process that converts organic matter into methane-rich biogas as a renewable energy source. In the AD process, organic materials are first hydrolyzed into smaller molecules, including sugars, amino acids, and fatty acids, which are then converted by anaerobic microbes through several fermentation pathways into acetic acid, \( \text{H}_2 \), and \( \text{CO}_2 \). These compounds serve as substrates for methanogenic microbes, which produce methane. The final gaseous product, called biogas, contains about 40% to 70% methane, 30% to 60% \( \text{CO}_2 \), and trace amounts of other gases. Biogas can be used directly for cooking and heating as well as for electricity generation, and it can be purified and upgraded to produce natural gas and transportation fuels. AD also removes a large portion of the carbon from organic waste, and the remaining nutrient-rich residue can be used as a fertilizer or soil amendment. Overall, AD is one of the most cost-effective and mature technologies for treating organic wastes and producing bioenergy.

**Liquid versus solid**

Traditional AD focuses on the treatment of high-strength liquid waste, such as sewage sludge, animal manure, and food processing wastewater. These AD systems usually operate at low total solids contents (<15%) and are referred to as liquid AD (L-AD) systems. Recently, more researchers have started to explore the potential of solid organic wastes and biomass, such as the organic fraction of municipal solid waste (OFMSW) and crop residues. These materials have high total solids contents, so feeding them into an L-AD process would require a large amount of dilution water. Fibrous materials, such as crop residues, are also not suitable for L-AD because the fibers float to the top of the digester and cannot be effectively degraded by anaerobic microbes.

Instead, solid-state anaerobic digestion (SS-AD), which operates at a total solids content greater than 20%, is more suitable for solid organic wastes. The contents of an SS-AD system appear similar to compost and have minimum visible water. Because solid-state digesters contain much less water than liquid digesters, the total volume is 3 to 5 times smaller, and thus the energy required for heating the digester is significantly lower.

Although SS-AD holds promise for energy production from a wide variety of solid feedstocks, SS-AD processes are less understood than L-AD, which has been widely studied and used throughout the world. Recently, research on SS-AD has progressed regarding inoculum, operating parameters, inhibitors, and mass transfer. However, some SS-AD mechanisms, such as the mass transfer of substrates and inhibitors, are still in the hypothesis stage and are difficult to measure with current instruments. Therefore, modeling is a useful method for verifying hypotheses about SS-AD mechanisms, and it provides an important tool for process prediction and optimization.

**Modeling the process**

Different SS-AD models have been developed in the past decade using theoretical, empirical, and statistical approaches. Theoretical models can provide more insight into
the complex system mechanisms but require a series of inputs, including initial conditions, boundary conditions, and kinetic constants, and thus are usually too complicated for general applications. Statistical models are easier to derive but are sometimes considered to be “black boxes” that are hard to interpret. Empirical models are derived from empirical equations, and their complexity is usually between that of theoretical models and statistical models.

The effect of total solids content on methane yield has become a hot topic in recent SS-AD models. Most of the theoretical SS-AD models published before 2005 focused mainly on the effect of the heterogeneous initial distribution of inoculum in the substrate and how methanogenic microbes spread throughout the digester, while more recent SS-AD models have started to focus on total solids content. It has been commonly observed that methane yield and methane production in SS-AD decrease with an increase in total solids content. Our 2014 study (see the “Further Reading” sidebar) found that the maximum methane production rate changed with total solids content, following a bell-shaped curve.

Most recent SS-AD models have tried to interpret this phenomenon by assuming that one or two key kinetic rate constants in SS-AD, such as the hydrolysis rate constant, maximum microbial growth rate, half-saturation coefficient, or diffusion coefficient, are influenced by the total solids content. According to the model results, total solids should affect microbial growth kinetics, mass transfer, and the concentration of inhibitors. Although the phenomena predicted by many of these models have not been observed in experiments, these models have deepened the understanding of SS-AD and provide guidance to researchers for future studies.

To date, diverse models have been proposed for SS-AD based on the different understandings of researchers about this process. Further investigation of SS-AD mechanisms is essential for rational construction of SS-AD models and to provide guidance for the improvement and commercialization of SS-AD systems.

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**Further Reading**


In the past three decades, U.S. blueberry production has increased more than four-fold, accounting for almost 60% of world production. The production area has expanded to more than 25,000 ha (61,000 acres), with a total production of 239 million kg (527 million lb) and a farm gate value close to a billion dollars. This large increase is primarily driven by the well-documented health benefits of blueberries, especially their high concentration of antioxidants. However, most highbush blueberries destined for the fresh market are still hand harvested. This is because as much as 78% of mechanically harvested blueberries develop bruise damage, making them unacceptable for long-term cold storage and fresh consumption. This low-quality fruit can only be sold at half the price of fresh-market fruit, so it’s relegated to blueberry jellies, baked goods, and other processed foods. Therefore, reducing fruit bruising has become a top priority for blueberry growers because product quality is directly related to profitability and to the long-term sustainability of the industry.

As a matter of fact, blueberries invariably interact with various machine parts and surfaces during harvest, postharvest handling, and transport. These interactions cause bruises and reduce fruit quality. During packing, the fruit interacts with several contact points as the blueberries are dumped onto the conveyer and then moved through various transition points between different segments of the conveyer system. In the past, the impacts caused by mechanical handling could only be evaluated by assessing the quality of blueberries after the handling process due to the lack of effective sensing tools.

If a small sensing instrument were available to quantitatively measure the mechanical impacts caused by harvesters, packing lines, and transport vehicles, the resulting information would be quite valuable for blueberry growers, researchers, and equipment manufacturers. However, although the concept of so-called “instrumented spheres” is not new—the earliest instrumented sphere was developed in the early 1990s—most commercially available instrumented spheres are the size of an apple (>50 mm diameter), and none of them can be readily used for small fruits like blueberries.

To address this need, my research assistants Pengcheng Yu and Rui Xu and I have developed two iterations of the Berry Impact Recording Device (BIRD) over the past six years. In essence, the BIRD sensor is an independent wireless data logging sensor with a spherical shape and size, weight, and surface similar to a blueberry. As a result, as it passes through the handling process (e.g., mechanical harvest, packing, and transport), it is subjected to the same stresses as a real blueberry—while quantitatively measuring and recording all the impacts using accelerometers and a microprocessor installed inside the sphere.

The impact data are saved in a memory chip, and a rechargeable battery powers the device. The first-generation BIRD sensor (BIRD I) had a diameter of 25.4 mm and weighed 14 g. The second-generation BIRD sensor (BIRD II) is smaller, with a diameter of 21 mm, and weighs just 6.9 g. In addition to the reduction in size and weight, BIRD II contains other major improvements, such as using the USB interface for both communication and recharging, which eliminates the previous interface box.
**Sensor success**

The sensor has been successfully used to measure the impacts created by mechanical harvesters and packing lines, which has not been done before. For example, the BIRD sensor revealed that the catch plates on a rotary harvester account for more than 30% of all the mechanical impacts imposed on a typical blueberry. Thus, a significant reduction in bruising could be achieved by modification of the catch plates, such as by reducing the fruit falling height or making the catch plates softer.

Overall, the sensor approximates a real blueberry closely enough to allow us to better understand how blueberries interact with different machine parts within the harvester, and which parts create the most impacts. Better understanding of how the harvester interacts with the fruit will lead to better harvester designs and better quality fruit for the fresh market.

The BIRD sensor has also been used to measure mechanical impacts on almost two dozen commercial packing lines in the U.S. and Chile. The data collected by the BIRD sensor revealed that most impacts occurred at transfer points between conveyer belts, and the highest impacts happened when the sensor dropped onto a hard surface, such as stainless steel or hard plastic. Padding the transfer points proved to be effective in reducing the impacts. The impacts measured by the BIRD sensor were correlated to fruit firmness and bruising. Based on this correlation, several large impacts were identified that caused bruise damage to the fruit. Most of the small impacts at the transfer points may not cause bruise damage, but their cumulative effect could cause bruising and significantly increase the bruising rate.

**Present work**

Currently, our group is developing the third-generation BIRD sensor. The sensor will be refined by further reducing its size and weight and by adding several new functions, such as apps for mobile devices so that the BIRD sensor can be configured and the data can be viewed instantaneously in the field on a smartphone.

One unique feature of the BIRD sensor: it is the first device of its kind for studying small fruits. In addition to blueberries, it can be used to study cranberries, cherries, and olives, to name a few. It has drawn great interest from industry, not only in the U.S. but also in South America and Australia.

Our group hopes to develop the sensor technology from a lab prototype to a robust engineering product that can ultimately be commercialized, benefiting more stakeholders.

The first two iterations of the BIRD sensor were funded by a USDA NIFA Specialty Crop Research Initiative (SCRI) grant and a grant from the U.S. Highbush Blueberry Council. The third-generation BIRD is funded by another NIFA SCRI grant and is a large, multifaceted project (http://scri.engr.uga.edu). The overall goal of this NIFA SCRI project is to develop a new semi-mechanical harvest-aid system for efficient fruit harvesting for the fresh market. This system should be affordable to small and medium-size blueberry farms, ergonomically effective for workers, and compliant with all food safety standards.

Meanwhile, other advanced sensor technologies will be developed to help blueberry breeders select blueberry cultivars for mechanical harvestability. I am currently leading a multidisciplinary research team (engineering, plant science, economics, and microbiology) with members from the University of Georgia, USDA-ARS, Michigan State University, University of Florida, Penn State University, Washington State University, North Carolina State University, Oregon State University, and Mississippi State University. Ultimately, our goal is to develop technologies to help make the blueberry industry more profitable and sustainable in the competitive global marketplace.

**ASABE member Changying “Charlie” Li**, Professor, Bio-Sensing and Instrumentation Laboratory, College of Engineering, University of Georgia, Athens, USA, cyl@uga.edu.

*Photos by Rui Xu and Charlie Li.*
While South Dakota may be best known for Mount Rushmore, a short 80-mile trip north will take you to the historic, though progressive, Belle Fourche Irrigation District (BFID). The U.S. Bureau of Reclamation developed the BFID as one of its first projects under the Reclamation Act of 1902. The primary purpose of the project is irrigation; however, secondary benefits include flood control, fish and wildlife conservation, and recreational opportunities. Water for irrigation is diverted from the Belle Fourche River to the Belle Fourche Reservoir, which holds over 185,000 acre-feet of active conservation storage. The BFID delivers irrigation water to over 57,000 acres of farmland through 94 miles of open canals and 450 miles of ditches. The BFID also has several inverted siphons (that is, a pipe for transporting water through a low spot, resembling the P-trap under your kitchen sink) to help transfer water across the natural drainage valleys, which lie perpendicular to the canals.

**Innovation via partnership**

The Belle Fourche Project has a storied past with many lessons; today, it is an example of how innovation through partnership can help solve water quality and quantity issues. In 2004, the BFID, in association with the Belle Fourche River Watershed Partnership, participated with the South Dakota Department of Environment and Natural Resources to complete a water quality study on the amount of total suspended solids (sediment) that enter the adjacent Belle Fourche River. The study determined that reducing the amount of return flow from the irrigation delivery system could eliminate a portion of the sediment entering the river.
The BFID contracted with RESPEC, an engineering and consulting firm, to develop an overall water management system. The components of this management system include automation of the check gates (used to control water levels in the canals), head gates, and flow-measurement structures; software to automate the water order and billing system; and software to calculate the water mass balance that is needed to support water orders and compare recommendations to actual measurements. **ASABE member Jared Oswald**, Manager of the Watershed Management Group at RESPEC, was the team leader for the project. The RESPEC team started the project by meeting with BFID staff to study the current operations.

**To begin with ...**

The first component developed for the water management system was automated control of the check gates and monitoring of the flow-measurement structures throughout the BFID. The automated check gates use pressure transducers and gate actuators in combination with dataloggers with programmable algorithms to maintain a constant upstream water level. The flow-measurement structures (such as weirs and flumes) are monitored by using pressure transducers connected to dataloggers that convert the water depth in the structure to flow. The information from the check gates and flow-measurement structures is relayed to the BFID office via a radio network and then uploaded to a secure remote server so that the system can be monitored and controlled by BFID staff in the office or with a smartphone.

The Vale Ditch provides an example of the efficiencies that can be achieved through automation. In 2006, the Vale Ditch was converted from manual operation to an automated check gate that works in conjunction with a real-time automated flow-measurement structure. The automated system provides a significant improvement in maintaining a constant water level and consistent water delivery, while eliminating significant water losses.

**And secondly ...**

The second component of the water management system was the development of a water order and billing system. Before the water management system was developed, the BFID operated the canals manually and performed all calculations by hand to determine water orders, water billing, and dam releases. This process was extremely labor-intensive, and it led to inefficiencies in transporting water from the dam to farmers’ fields. The new system allows BFID staff to enter the water orders gathered from area farmers into a database. The custom software then calculates the daily total of water to be delivered for each canal section and provides a breakdown per farmer of the amount of water that is currently being delivered, when future amounts will be delivered, and when deliveries will be shut off. The information from the water orders is then automatically entered into the billing records. The billing records are used to track the amount of water that individual farmers use and the amount remaining in each of their accounts.

**Third and last**

The third component of the water management system is the dam-release calculator. The calculator uses aspects of the first two components to produce a comprehensive report and recommend daily releases from Orman Dam, which is the source of the BFID. Included in the report are real-time readings from the automated gates and flow-measurement structures. This summary provides BFID staff with an overview of current conditions throughout the entire irrigation delivery system. The daily recommended dam release is determined by totaling the water orders for each canal section and then estimating the lag time, or the time needed for water to travel from the dam to the delivery point. BFID staff can then compare the recommendation to the real-time data reported by the system and adjust the release to fit current conditions.

The new water management system provides timely information to support daily decision-making, and it allows BFID staff to manage the entire system and compensate for the fluctuations in delivery caused by rainfall, heat, or equipment malfunctions.

The work has been comprehensive, and it has relied on expertise from the farmers, BFID staff, RESPEC, the U.S. Bureau of Reclamation, the South Dakota Department of Environment and Natural Resources, and the USDA-NRCS to deliver irrigation innovation and significant reductions in sediment entering the watershed. **ASABE member Jared Oswald, P.E.,** Manager of the Watershed Management Group, and **ASABE member Russell Persyn, P.E.,** Texas Area Manager, RESPEC, Rapid City, S.D., USA, russell.persyn@respec.com, www.respec.com.
Efficient use of water resources is critical to the Texas High Plains, a region in the Panhandle of Texas that represents only 10% of the state’s land area but almost 28% of the state’s irrigated acreage. The Ogallala Aquifer supplies most of the water for agriculture in this region. Minor aquifers include the Blaine, Dockum, and Whitehorse, which mainly support the surrounding municipalities and industries.

Despite plentiful rainfall in 2015, the average water level in the Ogallala Aquifer continues to decline. Water conservation districts across the state and the Texas Development Water Board are actively promoting strategies for efficient management of water resources to sustain the rural economies and the environment.

The trend toward efficiency

As part of this effort, irrigation methods across Texas continue the trend toward greater efficiency. The percent of irrigated acreage supplied by gravity-fed systems fell from 19% in 2008 to 12% in 2012, while the irrigated acreage with sprinkler and drip systems increased by 4% and 3%, respectively. Center pivots are the mainstream (94%) of sprinkler irrigation systems in Texas. A reduction in water losses that do not contribute directly to crop production has also been demonstrated. The majority of farmers in the Texas High Plains now use in-canopy drops or low-elevation spray application (LESA), and some have adopted low-energy precision application (LEPA) bubblers or LEPA drag socks.

These application methods reduce losses due to evaporation and wind as compared with drops at mid-elevation heights or impact sprinklers mounted on a moving lateral. When using in-canopy drops, planting crops in a circle under a center pivot provides more uniform distribution of the irrigation water. Further reductions in evaporative losses can be achieved using subsurface drip irrigation—as much as 4 to 5 inches less evaporative loss compared to mid-elevation spray irrigation in the windy Panhandle environment.

However, the Texas Water Resources Institute predicts that by 2060, municipal demand for water will increase to 47% of the state’s total water demand due to population growth. This prediction continues to pressure irrigated agriculture to reduce water use by conserving water, growing drought-tolerant crops, improving irrigation scheduling, and adopting advanced irrigation management technologies.

There have been steady advances in the research and development of irrigation management technologies in different parts of the U.S. At the USDA-ARS Conservation and Production Research Laboratory in Bushland, Texas, we are developing a supervisory control and data acquisition (SCADA) system to help farmers manage water more efficiently.
What is SCADA?

In brief, a SCADA system uses various sensors strategically located within the environment to provide optimal control of system processes and early warning of potential failures. Our irrigation scheduling SCADA system (or ISSCADA) supports site-specific irrigation management by integrating: (1) measurements from plant canopy temperature, soil water, and weather sensors with (2) plant stress-based irrigation scheduling methods, and (3) a commercial variable-rate irrigation (VRI) center pivot system.

Wireless infrared thermometers are mounted on the ISSCADA-equipped center pivot system, providing continuous canopy temperature measurements as the system moves across the field. An embedded computer at the center pivot point collects all data streams. A few wireless infrared thermometers are stationary in the field over a well-watered crop to provide a reference temperature curve. This is used to scale the one-time-of-day remote temperature measurements as the ISSCADA system travels across the field.

Soil water sensors provide feedback and redundancy as to how well crop stress is detected by the canopy temperature sensors, and they can be used to provide feedback over areas where the ISSCADA system does not travel during daylight hours. The ISSCADA system can be controlled remotely by means of a client-server program developed by the ARS. This program incorporates a user-friendly graphical user interface (GUI) to aid in configuring and operating the ISSCADA system, and it uses geographic information system (GIS) concepts to facilitate the spatial and temporal analysis of the information collected by the sensors.

The overall goal of the ISSCADA system is to detect crop stress across different areas of a field throughout the irrigation season and provide irrigation recommendations to the farmer. Canopy temperature measurements or calculated crop water stress indices (CWSI) are plotted geographically to create maps that are displayed using the GUI. The maps show the locations and levels of canopy temperature and crop stress for the part of the field that the ISSCADA system traveled over during daylight hours. These maps are a visual guide to the farmer and indicate areas within the field that require attention.

The ISSCADA system also provides prescription maps to aid the farmer in irrigation scheduling by showing which management zones within the field require water and the amount of water required. Irrigation timing is accomplished by establishing thermal stress index thresholds for each management zone. When the threshold is exceeded, an irrigation is triggered. The farmer can remotely access the prescription map, review it, and accept or modify the irrigation recommendations. Uploading the prescription to the center pivot's control panel through the GUI causes the irrigation system to apply the prescribed irrigation depths.

The client-server software provides an integrated environment for communication between the ISSCADA system and the irrigation equipment. Similar to other SCADA systems, the ISSCADA system also allows operation of multiple irrigation systems. In addition, the prescription maps are dynamic, responding to spatially variable crop water needs throughout the irrigation season. After an irrigation season, the farmer can use the GUI to enter historical information for each management zone (e.g., intra-seasonal information, such as average CWSI and soil water content for the zone, and inter-seasonal information, such as yields and total seasonal irrigation amounts).

The information is stored in relational databases that can provide an additional layer of information for the next growing season. The ISSCADA system and its client-server software are ultimately decision support tools. The farmer can view various layers of information pertaining to the field and has the choice to accept the recommendations of the prescription map, or modify the map, before uploading it to the center pivot’s control panel using the GUI.

More to come

As with any new technology, beta testing in different climates and with different crops is needed to determine crop responses to irrigation management using the ISSCADA system. As partners in a cooperative research and development agreement (CRADA), Valmont Industries and ARS scientists at three sub-humid and humid locations, in addition to Bushland, will pursue beta testing of the ISSCADA system to
help facilitate its commercialization. We also acknowledge two other CRADA partners with whom we have worked to develop the sensors used in the ISSCADA system: Dynamax, Inc., with whom we have a CRADA for commercialization of the wireless infrared thermometer network, and Acclima, Inc., who is our CRADA partner in the development of the TDR soil water sensors.

ASA BE member Susan O’Shaughnessy, Research Agricultural Engineer, susan.oshaughnessy@ars.usda.gov; ASA BE member Manuel Andrade, ORISE Post-Doctoral Fellow, alejandro.andrade@ars.usda.gov; ASA BE member Steven Evett, Senior Research Soil Scientist, steve.evett@ars.usda.gov; and ASA BE member Paul Colaizzi, Research Agricultural Engineer, paul.colaizzi@ars.usda.gov, USDA-ARS Conservation and Production Research Laboratory, Bushland, Texas, USA.

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The TREEhouse … Not what it seems!

Kenny Corscadden, P.Eng.

The Department of Engineering at Dalhousie University’s Faculty of Agriculture embarked on an innovative project, which became known as the TREEhouse, for “Technology for the Responsible use of Energy and the Environment.” The project represents an innovative approach to the management of academic infrastructure that combines research, experiential learning, and innovative design in the creation of sustainable graduate student office space.

A 1960s split-level home located on the edge of campus was earmarked for demolition, as it was beyond economical repair. A proposal was pitched to the administration: restore the house for use as graduate office space, which was needed, and in the process provide students with practical experience. This project involved a number of faculty and staff in the planning, supervision, and implementation of the project, with innovative building materials provided by a variety of regional suppliers.

The objective was that the TREEhouse would become a true faculty resource with applications in engineering and applied science (energy efficiency analysis, renewable energy, material performance, wood construction projects) and in plant and environmental science (green roof design, landscape architecture, flood mitigation strategies, and wastewater management).

Due to the scale of the project, we decided to divide it into three phases. Phase one addressed the initial structural renovation or building envelope. It included complete updates of the windows, insulation, drywall, electrical, plumbing, flooring, and exterior siding. Phase two addressed additional building features, such as a pergola, management of waste and gray water (roof runoff and interior wastewater recycling), and landscape design. Phase three addressed the addition of renewable technologies to provide heating, cooling, and electricity to create a completely self-sufficient building.

Further Reading


Phase one
Demolition resulted in the house being completely gutted down to the original studs and wall sheathing.

Green Power Labs of Dartmouth, Nova Scotia, completed a solar efficiency survey, which indicated that installation of five large windows would take advantage of the south-facing orientation and predicted a 20% reduction in annual heating requirements. The redesign resulted in the interior being divided into three zones, and a system was installed to monitor the temperature, humidity, light levels, and energy use in each zone. Each zone used different lighting, wall thickness, and insulation. Insulation obtained from Acadian Drywall in New Glasgow, Nova Scotia, which contained 70% recycled pop bottles and a combination of fillers, was compared to conventional fiberglass batts. The basement was insulated with spray foam. A 100% natural wood siding was chosen, provided by Marwood, a wood products company in Brookfield, Nova Scotia. The roofing shingles, obtained from Enviroshake Ontario, were produced from recycled tires and have a 50-year warranty.

Phase two
In phase two, the pergola was designed, constructed, and installed by two different wood construction classes, providing shade from the summer sun while still allowing passive solar gain in the winter. Landscape architecture classes surveyed and designed the landscaping around the house to minimize the impact of flooding from water runoff.

Phase three
In the final phase, a grid-connected solar PV array was installed, which feeds power back to the grid when consumption in the TREEhouse is below generation levels. A split ground source heat pump was also installed to provide heating and cooling.

And today ...
Although the TREEhouse looks very much like a normal house, the details tell another story. Many faculty, staff, and students participated in the construction process, which provided a unique hands-on learning experience with benefits that are continuing. The TREEhouse is a living laboratory, our graduate students have a newly renovated office building, and the pergola is a great hangout for barbecues in the summer. Several other classes are already looking at ways to integrate programs into the TREEhouse, and strong partnerships have been formed with many local companies. We hope that this project remains an interactive learning experience for years to come.

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The TREEhouse team would like to acknowledge the late Dr. Bernie MacDonald, co-president of the former NSAC (now Faculty of Agriculture), for his receptiveness to the idea; Phil Talbot, former manager of facilities management; Green Power Labs; Marwood; Cape Cod Siding; Enviroshake; Acadian Drywall; Chris Nelson and Scott Read, Senior Instructors, and the many faculty and staff who participated. We had fun, we learned a lot, and we did something different!

For a time-lapse video of the TREEhouse project, visit https://www.youtube.com/watch?v=gtT2bwv8TRo
Unmanned aircraft systems (UAS) are an emerging technology that presents an almost unlimited array of opportunities and applications in agriculture. Let your imagination fly, and bring your passion to this emerging technology. The growth of UAS technology will provide ample space for you to grow as a professional.

The four articles presented in this final installment of the three-part Special Series on Unmanned Aircraft in agriculture convey different stories about the pursuit of opportunities in the emerging area of UAS. The four articles include:

1. “Yield Estimation: A Low-Hanging Fruit for Application of Small UAS”
2. “Small UAS in Agricultural Remote-Sensing Research at Texas A&M”
3. “Why Unmanned Aircraft for Agriculture?”
4. “Aerial Imaging with Manned Aircraft for Precision Agriculture”

These stories represent just a few of the dimensions that can be explored when combining aviation with robotics, big data, and agriculture.

The first article—“Yield Estimation: A Low-Hanging Fruit for Application of Small UAS”—is a story about seizing an opportunity for innovation. In this case, there was a need for a sophisticated sensor pack that could take advantage of the complex crop views that unmanned aircraft can provide. By bringing innovation, ingenuity, and hard work to bear on the challenge, a highly sophisticated sensor pack has been developed. Research and continued refinement of the sensor pack are in progress by teams from the University of Florida and the University of Pennsylvania, leading to greater understanding of key elements of crop production and management.

The second article—“Small UAS in Agricultural Remote-Sensing Research at Texas A&M”—is a different story about seizing an opportunity. This story shows that the Lone Star State has a vision for the potential of unmanned aircraft in agriculture and is pursuing that vision. Texas A&M started its research and development program just one year ago and already has five well positioned teams consisting of over 40 scientists and engineers. That’s impressive, and the lessons they’ve learned so far are instructive for all of us.

The third article—“Why Unmanned Aircraft for Agriculture?”—is a story about entrepreneurship and identifying opportunities for commercialization in the ever-evolving world of unmanned aircraft. Working in partnership with research and development institutions, Black Swift Technologies LLC provides modular navigation and control systems for unmanned aircraft. This successful industry-academia collaboration has resulted in cutting-edge products that retain the “human in the loop” through easy-to-use software interfaces for the control of complex UAS and their payloads.

The fourth article—“Aerial Imaging with Manned Aircraft for Precision Agriculture”—tells a story about connecting opportunities. This contribution from the USDA Agricultural Research Service at College Station, Texas, describes remote sensing of crops with an impressive variety of sensor systems—including color, infrared, multispectral, and hyperspectral imaging—often using combinations of consumer-grade equipment. This research uses manned aircraft as the sensor platform, and the article correctly notes that current aviation rules present challenges for commercial use of unmanned aircraft, while recognizing the great potential for unmanned aircraft in agriculture after the rules are relaxed.

Finally, this three-part series on unmanned aircraft in agriculture wouldn’t be complete without mentioning the opportunities for education about unmanned aircraft in agri-
A new eXtension Learning Network—entitled UAS in Agriculture—has been enabled by USDA Extension and has core leadership from the following Land Grant institutions: University of Nebraska-Lincoln, Purdue University, University of Arkansas, Oregon State University, and Utah State University. Four main objectives have been established for this eXtension Learning Network:

- Build the capacity of Extension to engage in unmanned aircraft through leveraging of numerous research programs focused on agriculture.
- Deliver research-based education programs on unmanned aircraft applications in agriculture to clients at multiple scales, including manufacturers, vendors, and end users.
- Provide guidance to learners that helps them understand the regulations and requirements involved in deploying UAS legally and successfully.
- Engage aviation regulators in the unique challenges of deploying UAS in agriculture.

The eXtension Learning Network is developing as an adaptive learning system in which clients are able to engage according to their preferences and needs, and in which they can learn as well as contribute knowledge. The eXtension Learning Network consists of two main components:

- The UAS in Agriculture Learning Center.
- The UAS in Agriculture Learning Network.

The Learning Center comprises the “people portion” of the Learning Network and includes the core leadership, along with the experts and clients who participate in the network on a regular basis by both pushing and pulling information. The Learning Network consists of the content portion of the eXtension initiative. Additional information on the UAS in Agriculture Learning Network can be found at www.learnUASag.org and on the associated social networking channels. If you would like to join and contribute to this Learning Network, please contact one of the authors for additional information.

Join the journey, follow the flight path

We hope this three-part series on unmanned aircraft in agriculture has given you an opportunity to reflect on how this new technology is taking agriculture to a whole new level. UAS provide exciting new opportunities for sustainability, for precision agriculture, and for helping us meet the grand challenge of feeding a hungry world. However, as with every opportunity, there will be challenges—are you prepared for them? Find out by joining ASABE’s new MS-60 Unmanned Aerial Systems committee, and help shape the future of unmanned aircraft in agriculture.

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Yield Estimation
A low-hanging fruit for application of small UAS

Reza Ehsani, Dvoralai Wulfsohn, Jnaneshwar Das, and Ines Zamora Lagos

Small unmanned aerial systems (sUAS) are powered aerial vehicles that weigh less than 55 lb (25 kg) and can operate autonomously or be operated remotely by a human pilot. A conservative estimate by an aviation economist projected a $13.6 billion impact of this technology in the first three years of approved commercial use, and precision agriculture was projected to comprise as much as 80% of the commercial market. The ability of sUAS to collect high-fidelity spatial, spectral, and temporal aerial data at relatively low cost can provide new opportunities for growers. In fact, sUAS may change the way we collect field data, monitor field equipment, and even operate agricultural machinery. Among the many potential applications of sUAS, crop scouting, inventory management, tree canopy management, and yield estimation will probably be the most highly used applications in commercial fruit and vegetable production.

Software for optimal sampling
Early and accurate yield forecasting is important for many crops, but traditional techniques are time-consuming, labor-intensive, and often inaccurate. As an alternative, sUAS can be used for yield estimation, either by representative sampling or direct count. For sampling, sUAS can be used to get an accurate count of trees and determine the distribution of tree size, health, and other canopy features. This information can then be used to make a near-optimal selection of sample trees for manual fruit counts and measurement of fruit quality and size.

The Pronofrut™ sampling system, developed by Dayenú Limitada, an agriculture technology and consulting firm in San Fernando, Chile, takes this approach and uses sUAS and software algorithms to provide near-optimal tree selection. Manual counts are supported by handheld software for direct sampling in the field, and the within-tree sampling algorithm
can be adapted to many plant structures and architectures. The advantage of manual counting is that systematic errors due to fruit masking and other artifacts in images are avoided, allowing consistent yield estimates from small, statistically representative samples.

Typically, hundreds of fruit counts are distributed spatially over a grove. The handheld software indicates the location of the next sample (row, tree, branch, or branch segment), always moving forward in the orchard, and records the sample location, time stamp, and measurements. The Pronofrut™ system provides yield estimations with a known absolute error range (the goal is typically <10% error) and substantially reduces human resource requirements compared to traditional sampling. The Pronofrut™ sampling methodology has been validated at the commercial scale for fruit, nut, berry, and vegetable crops in Chile, Argentina, the U.S., and Spain, including grapes, sweet cherries, apples, pears, maize, and hybrid cucumber seeds.

**Image-based yield estimates**

Another technique is to use sUAS imagery for counting fruit. In 2015, the USDA funded a project for the University of Pennsylvania and the University of Florida to investigate the use of sUAS for yield estimation of citrus, tomatoes, and blueberries. With a focus on data-driven techniques to improve estimation accuracy, this project will incorporate
direct fruit counts through close-range imaging, followed by a correction based on ground-truth fruit count data.

A specialized sensor suite, called the Intelligent Remote Imaging System (IRIS), was designed and tested at the University of Pennsylvania in collaboration with specialty crop growers to enable high-fidelity multi-spectral and multi-modal data acquisition. Additionally, information on canopy size and health, such as the normalized difference vegetation index (NDVI), acquired by IRIS will allow statistical models to predict yield based on both direct sampling of the fruit count as well as the overall aerial observations.

There are two sources of error with image-based yield estimation that we are addressing. First, image-based fruit counting during daylight hours suffers from shadows and reflections that introduce errors. Second, the camera can only see fruit that are not hidden by leaves, and site-specific calibration with a ground-truth fruit count is needed to ensure an accurate count with the current technique. We are working on new technologies, such as use of controlled illumination, as well as advanced methods such as backscatter x-ray imaging, that can resolve these issues and result in higher accuracy in fruit counts.

With the large amount of research and development currently being conducted by universities and private companies, sUAS will be much more than toys. They will be essential tools for growers in the not-too-distant future.

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The results of an experiment at an orange grove in Booth Ranches, California, where IRIS was used to generate a fruit count for a block of orange trees:

(a) Fruit detection and tracking were carried out simultaneously to generate a running count of the fruit along a row.
(b) Red boxes show fruit detections, and cyan boxes show new fruits that were counted in the frame. The cyan lines show the paths of detected fruits from previous frames to the current frame. The purple boxes show the predicted positions of the fruits detected in previous frames.
(c) A 3-D map of orange trees in a 180 m × 180 m block with the color of the point cloud indicating fruit density. Yellow and red represent higher yields. The total number of oranges for the block was estimated to be 479,395. On average, there were 539 fruit per tree.
As the world population grows rapidly from its current 7 billion and finally plateaus around 12 billion by the year 2100, we must roughly double food production per unit land area. Two major tools at our disposal are optimization of crop production through precision agriculture (PA) and crop improvement through breeding involving high-throughput phenotyping (HTP). Advances in both of these areas rely on the development of rapid, consistent, and reliable sensing technologies.

One of the foremost new sensing technologies for PA and HTP is high-resolution imaging with small unmanned aerial systems (sUAS). Compared to manned aircraft systems, sUAS are much less expensive, are much more flexible in scheduling, enable lower flight altitudes, use lower speeds, and ultimately provide much better spatial resolution in the resulting images. The main disadvantage is that only relatively small areas can be imaged at the lower altitudes and speeds. However, on large farms with contiguous fields, images can be collected with sUAS using sensing technologies that enable high-quality image mosaics to be created with sufficient metadata and ground-control points.

**TAMU and sUAS**

Texas A&M University (TAMU) and its associated agencies, Texas A&M AgriLife Research and the Texas A&M Engineering Experiment Station (TEES), initiated a comprehensive research project in 2015 for agricultural remote sensing with sUAS. The initial objective is to provide geometrically corrected and radiometrically calibrated large-area image mosaics of high-resolution field and plot data to breeders and agronomic researchers within 48 hours of image acquisition. The project has been conducted at AgriLife’s research farm near College Station, Texas, about 10 km from TAMU’s main campus. The farm consists of 568 ha of crop fields and plots where corn, cotton, sorghum, and wheat are the main crops grown for breeding and agronomic research.

The research group is made up of five teams involving over 40 scientists and engineers. The Administration team provides and manages funds, coordinates meetings and initiatives, and assists and encourages faculty members in garnering external funding. The Flight Operations team conducts UAV flights to provide remote-sensing data to the field researchers. The Sensors team manages the sensors used onboard the sUAS and ensures that the imagery received by...
the researchers is of high quality. The Data Management team stores and manages the data and conducts preprocessing to geographically correct images and construct image mosaics. Both the Sensors and Data Management teams work with the field researchers to develop analytic techniques. The Field Research team evaluates the data with respect to ground truth, and develops and uses analytic tools to facilitate breeding and agronomic research.

Three flight team subgroups focus on specific types of aircraft. The principal subgroup focuses on non-commercial and custom fixed-wing sUAS as well as overall data workflow. The second subgroup focuses on rotary-wing aircraft and very high-resolution data. The third subgroup focuses on commercially available fixed-wing sUAS. The sensors carried on these aircraft include numerous multispectral cameras, and other available sensors include hyperspectral cameras, LiDAR sensors, and high-quality thermal-infrared cameras.

Flight operations require obtaining flight authorizations, planning, preparation, and execution. The project team has worked closely with Lone Star Unmanned Aerial Systems (UAS) Center of Excellence, one of six FAA test centers for UAS, in obtaining Certificates of Authorization from the FAA for sUAS flights. During mission planning, the altitude, air speed, camera resolution, and camera exposure time must be balanced to achieve desirable image quality. In addition, to create good mosaics from many images, flight paths must be designed to provide adequate image overlap.

The research farm has been divided into “route packs” — contiguous groups of fields and plots that can be covered efficiently during an individual flight. Route packs are flown by one or more of the flight subgroups at least once per week. Each flight subgroup maintains and installs sensors on its own aircraft. The Sensors team maintains proper operation of the cameras and other sensors and has developed methods to enable radiometric calibration of images. In 2015, the project team accomplished over 100 flights, and work is well underway in 2016.

After images are collected, they are geographically registered and mosaicked together. Geographic registration involves using software to modify pixel positions based on positioning data collected onboard the sUAS during flight as well as ground control points (GCPs) visible in the images. In addition to natural features that can be used as GCPs, the Sensors team installed numerous pairs of 24 in. (61 cm) square tiles throughout the farm so that all mosaicked images of the route packs include at least two of these pairs.

Mosaicking involves using software to geometrically correct individual images and then “stitch them together” to create one large image of each route pack. The positioning and inertial sensors integrated with the camera systems onboard the aircraft, along with the GCPs, provide the metadata that are used in this process.

Finally, radiometric correction involves using software to calibrate pixel values according to objects of known spectral reflectance that appear in the images. The pairs of tiles used as GCPs have been painted to provide upper and lower calibration values for this purpose. In addition to installing and painting the tiles, their precise field positions were measured with RTK GPS, their reflectance values are measured weekly with a handheld spectroradiometer, and they must be cleaned regularly.
Data collection and other issues

Several data collection issues came to light in 2015, the project’s first year. First, image spatial resolution depends on the resolution of the camera detector, the field of view (FOV) provided by the lens, the camera exposure time, and the altitude and ground speed of the aircraft. Camera resolution depends on the number of photosites on the detector and the spatial frequency at which the detector is sampled. While camera resolution, FOV, and altitude determine the theoretical image spatial resolution, the camera exposure time and aircraft ground speed determine the amount of “pixel smear,” which is essentially a reduction in resolution in the direction of travel. To maintain the resolution of the camera at a given altitude, there must be a balance between ground speed and camera exposure time so that the distance traveled during the exposure time is small compared to the spatial resolution.

One issue is that accuracy of the inertial sensors and GPS is essential for precise control of the aircraft and accurate calculation of the camera angle relative to nadir. Accurate optical-angle calculations are critical for accurate mosaicking of images. Accurate mosaicking also requires a high level of overlap among images. Ideally, GCPs are clearly visible in the images in order to line the images up and for geographic registration.

Another issue is airframe stability, particularly for fixed-wing aircraft, which is critical for collection of high-quality images that can be processed into high-quality orthomosaics. Ideally, the camera is positioned so that its viewing angle is on nadir, i.e., directly downward. There are two ways to achieve this. One method is to use an aircraft with controls that can keep it level even when the winds aloft are variable. Another method is to use a gimbaled camera that can maintain an on-nadir angle even when the aircraft is not level. Without either of these methods, many images will be collected when the camera is significantly off nadir, resulting in images and mosaics of poor quality.

Two other issues relate to the radiometric properties of the images. First, some research applications require radiometric correction of images so that pixel values relate directly to reflectance values. In manned aircraft images, this is commonly done by laying out large tarps with known low and high reflectance values, thereby allowing each pixel in the image to be corrected according to a linear model. When UAV images are mosaicked into a larger image of a field or route pack, each individual image is relatively small, so it is impossible to include a calibration reference in every image. As mentioned, painted tiles have been laid out strategically across the route packs, and these tiles are used for radiometric correction (as well as GCPs) after mosaicking. This process requires excellent mosaicking to provide a high level of confidence in the radiometric values.

Moving forward

Texas A&M’s comprehensive project for agricultural remote sensing and high-throughput phenotyping with sUAS had a very successful first year in 2015, with numerous processes developed and refined to help us meet project objectives. We have developed the capability to provide image data of complete fields and plots to researchers in breeding, genetics, and agronomic research at a high resolution, with pixel dimensions commonly less than 50 mm. We are still working on improving the workflow so that we can provide preprocessed data by the next day, but providing data in less than a week is now common. These data include high-quality, geometrically corrected, mosaics of large fields. Current work in 2016 includes the following:

- Development and evaluation of data for decision-making in precision agriculture and high-throughput phenotyping.
- Further refinement of methods to improve the timeliness of data delivery to participating scientists.
- Further development and evaluation of techniques for radiometric calibration.
- Consideration of techniques to account for cloud shadows in images.
- Improvement in aircraft control systems to improve stability.
- Real-time calculation of image area coverage to ensure adequate overlap for mosaicking.
- Testing of new sensors to improve the spatial and spectral resolution of images.

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Manned aviation has been used for agricultural applications for decades, so why all the sudden interest in unmanned aircraft systems (UAS)? There are crop dusters for spray applications, manned aircraft equipped with cameras capable of aerial photography including hyperspectral imaging, and a plethora of satellite measurements to choose from. As you might guess, the answer is not simple.

It may be a surprise, but UAS have been involved in agriculture since the 1990s. One of the earliest examples can be found in spray applications for rice. The typically rugged terrain that is terraced for rice doesn’t lend itself to simple, uniform application of fertilizers and pesticides, so a motorcycle-size unmanned helicopter was developed to navigate the difficult terrain and provide precise delivery of the needed additives. While this technology was successful in accomplishing its primary application, it wasn’t adopted for use in other crops or regions because it was simply too expensive and maintenance-intensive when compared to more traditional application methods.

The consumer electronics revolution helped to bring about the next generation of agricultural UAS. Miniaturization of the sensors necessary for guidance and imaging occurred simultaneously with improved battery energy density. This allowed the creation of vehicles small enough to be simple to operate while still carrying a useful payload and sufficient flight time. With these advances, on-demand data became a reality. Additionally, the continued push for “connectivity” throughout the U.S. allowed collection of crop and management data in near real-time, which is essential for precision agriculture. Finally, the migration to cloud computing meant that an abundance of computing power was available to average citizens. Farmers no longer needed to rely on an outdated home PC to provide the answers they needed; instead, they had access to server farms and online experts.

So really, UAS are only a small part of a vertical technology chain, but they’re a great way to get on-demand data from a unique viewpoint.

Where is all this headed?

Given that precision agriculture is all about the data, why care about UAS? It’s because they’re rapidly becoming the least expensive option for on-demand data. We can now collect NDVI and full visible spectrum maps every hour, instead of only few times a season with manned aviation or up to once a day but at low resolution with satellites. With all this high temporal and spatial resolution data, we’re figuring out better ways to determine plant and animal health. Ultimately, that will lead to more efficient farming and better yields.
Determining plant stress

ASABE member Jose Chavez and his team at Colorado State University (CSU) are working to develop models that use canopy temperature as an indicator of plant stress. They’re hoping that routine temperature observations will be able to determine watering schedules and techniques. Our company, Black Swift Technologies LLC, worked with CSU to develop a custom UAS solution containing an EO camera, multispectral camera, shortwave IR camera, and longwave IR sensor. The IR sensor was used to support the model development, while the other sensors allow the team to validate their assumptions using independent sensors and methods. Experiments are currently in progress, and so far the results have shown an encouraging correlation between canopy temperature and plant stress.

Managing variable-rate irrigation

Black Swift Technologies has also worked with ASABE member Wayne Woldt, director of the NU-AIRE laboratory at the University of Nebraska-Lincoln (UNL), to develop typical approaches to agricultural flight profiles. In addition, Black Swift Technologies worked with the UNL team to integrate a sensor pack for variable-rate irrigation (VRI) into our SwiftPilot autopilot system. Tight integration of the autopilot and payload allows the sensors to be triggered automatically and logged at the appropriate rates. This precision is required for mosaicking of images, creating a data product that provides a complete view of a field for irrigation management purposes. The current focus of the UNL team is to use these images to improve the use of VRI technology. While VRI equipment is available from irrigation manufacturers, the understanding of where, when, and how much irrigation water to apply is still under-developed.

Measuring soil moisture

Both of the above applications use indirect methods and complex models to determine soil moisture. The predominant method in practice today is still direct measurement, using time-intensive soil moisture probes. In collaboration with the Center for Environmental Technology at the University of Colorado under an ongoing NASA grant, Black Swift Technologies is developing UAS technology that will significantly improve the measurement of soil moisture from the air. This new technology is a simple-to-operate system with a highly capable passive L-band microwave radiometer that provides measurements of volumetric soil moisture content over plot-size areas. The technology employed in this small aircraft is based on concepts similar to NASA’s Soil Moisture Active Passive (SMAP) satellite, which was designed to provide global soil moisture maps at a much larger scale. The soil moisture mapping UAS is complementary to this mission and provides local, high-resolution maps of soil moisture.

Black Swift’s expertise enabled tight integration of the sensor with the UAS avionics and airframe to enable precise flight control of low-altitude missions in the range of 15 to 30 m (50 to 100 ft) above ground level. Low-altitude flight is essential for the sensor to accurately map soil moisture down to about 15 to 20 cm (6 to 8 in.) depth at up to 15 m resolu-
A first prototype of the instrument was flown and validated at a NASA instrumented test site in Canton, Oklahoma, in the fall of 2015, yielding encouraging results. The soil moisture maps generated from data provided by this aircraft were shown to correlate well with in situ probes. On-going field campaigns in the summer of 2016 will focus on flying the sensor over different types of crops and soil conditions to characterize and validate the sensor for the large range of conditions it may encounter in agriculture. The team is looking to partner with crop consultants and other agriculture experts to improve water use efficiency with this technology while maintaining or increasing yields. More information on the system can be found at http://SoilMoistureMap.com.

Weather prediction

Additionally, Black Swift Technologies has worked with several national laboratories and the University of Colorado to improve the ability of UAS to perform atmospheric sampling. Through advanced efforts such as the 2010 Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2), the capabilities of UAS have been expanded to sampling areas beyond the reach of conventional radar and weather balloon technology. Improved knowledge of the atmosphere will further improve weather prediction. When combined with better knowledge of soil moisture content, this technology can provide better irrigation schedules as well as warnings about catastrophic events, such as flash floods.

Reliability and cost reduction

Finally, while several off-the-shelf UAS options are now available for collecting visual and multispectral data, the most immediate change in UAS will be continued improvements in autonomy and reliability. Currently, most of these vehicles are still prone to crashing, and they are difficult to operate. We’ve worked extensively to solve many of these issues. Several new techniques—including sensor redundancy, fault recognition and mitigation, the introduction of maintenance schedules, and the use of automatic processes to reduce the burden on the “human in the loop”—have already been incorporated into our aircraft.

Although UAS might seem like little more than toys, the continued advances in their capabilities, combined with the enormous investments that continue to be made in the data infrastructure surrounding them, guarantee that UAS will become a part of the future of agricultural applications. In a business where every cent counts, knowing exactly when, where, and what to do—and what not to do—will make all the difference in profitability.

Jack Elston, Founder and CEO, Black Swift Technologies LLC, Boulder, Colo., USA, elstonj@blackswifttech.com.

Entrepreneur Jack Elston

Jack Elston has over thirteen years of experience working in the UAS field and is the CEO/President and co-founder of Black Swift Technologies (BST). Elston is also the technical lead on all avionics work at BST, including the creation of a low-cost, highly capable autopilot system along with unique networking technologies to enable cooperative control of UAS. Elston received his PhD from the University of Colorado Boulder in 2011, developing a system and algorithms for UAS sampling of tornadic supercell thunderstorms. This work culminated in the design of a UAS used to conduct the first-ever intercept of a tornadic supercell thunderstorm by an unmanned aircraft as part of the NSF and NOAA funded VORTEX2 project. His research demonstrated the utility of integrating payloads into UAS to conduct meaningful scientific research. Elston’s other work at the University of Colorado involved the development of four different unmanned aircraft systems at the Research and Engineering Center for Unmanned Vehicles while conducting over 300 flight experiments. He also co-authored over 70 applications for Certificates of Authorization allowing legal operation of UAS within the national airspace.

BST uniquely couples avionics expertise with consulting services. BST produces its own line of customizable autopilots, ground stations, and supporting avionics that enable customers to fly and coordinate UAS with greater precision and simplicity. Concurrently, BST offers consulting services for customers attempting to navigate the ever-dynamic and often confusing application process for legal access to U.S. airspace, as granted by the Federal Aviation Administration through Certificates of Authorization and Section 333 Exemptions. More information on this service can be found at http://ApprovedFlight.com.
Over the last two decades, numerous commercial and custom-built airborne imaging systems have been developed and deployed for diverse remote sensing applications, including precision agriculture. More recently, unmanned aircraft systems (UAS) have emerged as a versatile and cost-effective platform for airborne remote sensing. These systems fill a gap in spatial resolution in remote sensing between ground-based and manned aircraft-based platforms. However, the safety concerns of commercial pilots and, in particular, aerial applicators and other pilots operating in low-level airspace need to be addressed before the widespread use of UAS for commercial applications. Meanwhile, conventional manned aircraft, including thousands of agricultural aircraft in the U.S., provide a readily available and versatile platform for airborne remote sensing.

Aerial applicators are highly trained pilots who use aircraft to apply crop production and protection materials. If the aircraft are also equipped with imaging systems, they can be used to monitor crop growing conditions, detect crop pests (weeds, diseases, and insect damage), and assess the performance and efficacy of ground and aerial application treatments. This additional imaging capability will increase the usefulness of manned aircraft and help aerial applicators generate additional revenue with remote sensing services.

The commercial availability of high-resolution satellite imaging systems (GeoEye-1, WorldView-2, and WorldView-3) in recent years has provided new opportunities for remote sensing applications in agriculture. Nevertheless, airborne imaging systems still offer advantages over satellite imagery due to their relatively low cost, high spatial resolution, easy deployment, and real-time or near-real-time availability of imagery for visual assessment and processing. More importantly, satellite imagery cannot always be acquired for a desired target area at a specified time due to satellite orbits, weather conditions, and competition with other customers for the same time slot.

Most of today’s airborne imaging systems are designed for use on aircraft equipped with camera ports for research and commercial applications, such as the Cessna 206. These systems typically include multiple scientific-grade cameras equipped with different filters to obtain three or four spectral bands in the blue, green, red, and near-infrared (NIR) regions of the spectrum. True-color images are created with the red, green, and blue bands, while color-infrared (CIR) images are produced with the NIR, red, and green bands. Some imaging systems can capture mid-infrared and far-infrared (thermal) images, while others can capture hyperspectral images from dozens to hundreds of spectral bands in the visible to thermal regions of the spectrum.

Recent advances in imaging technology have made consumer-grade digital cameras an attractive option for remote sensing applications due to their low cost, small size, compact data storage, and ease of use. Consumer-grade cameras are fitted with either a charge-coupled device (CCD) sensor or a complementary metal-oxide-semiconductor (CMOS) sensor. These cameras typically use a Bayer color filter mosaic to obtain true-color RGB images with a single sensor. Consequently, consumer-grade digital cameras have been increasingly used for remote sensing applications.

However, consumer-grade cameras only provide the three broad visible bands.
If NIR images are needed for image analysis or calculation of vegetation indices, such as the normalized difference vegetation index (NDVI), filtering techniques can be used to allow a second RGB camera to capture NIR images or to convert the RGB camera to capture CIR images. With an RGB camera and a converted NIR camera, both RGB and CIR images can be captured simultaneously, but alignment between the two images is necessary.

The Aerial Application Technology Research Unit at the USDA Agricultural Research Service’s Southern Plains Agricultural Research Center in College Station, Texas, has devoted considerable effort to the development and evaluation of airborne imaging systems as part of our research program. Currently, we have a suite of airborne multispectral and hyperspectral imaging systems for monitoring crop conditions, creating prescription maps, and assessing the performance of precision ground and aerial applications.

**Multispectral imaging**

Our multispectral imaging system consists of four high-resolution CCD cameras and a ruggedized PC equipped with a frame grabber and image acquisition software. The cameras are sensitive in the 400 to 1000 nm spectral range and provide 2048 × 2048 active pixels with 12-bit data depth. They are equipped with blue (430-470 nm), green (530-570 nm), red (630-670 nm), and NIR (810-850 nm) bandpass interference filters, respectively, but have the flexibility to change filters for desired wavelengths and bandwidths. The cameras are arranged in a quad configuration and attached to adjustable mounts that facilitate aligning the cameras horizontally, vertically, and rotationally.

The image acquisition software allows the synchronized black-and-white band images from the cameras to be viewed on the computer monitor in three modes: one band image at a time, a normal color composite, or a CIR composite. Images can be captured at altitudes of 305 to 3048 m (1000 to 10,000 ft) above ground level to achieve pixel sizes of 0.1 to 1.0 m. If the flight altitude doubles, the pixel size will double and the ground coverage will quadruple.

This multispectral system has been extensively used for monitoring and mapping of crop diseases and weeds and for assessing the performance and efficacy of site-specific chemical applications. In particular, the system has been used to monitor cotton root rot infection in south and central Texas since 2010, and the imagery has been used to create prescription maps for site-specific fungicide applications. As this disease tends to occur in the same general areas within fields in recurring years, site-specific application of Topguard Terra Fungicide only to the infected areas is more effective and economical than uniform application.

**Hyperspectral imaging**

Our hyperspectral imaging system consists of a Headwall HyperSpec VNIR E-Series imaging spectrometer, an integrated GPS/inertia navigation system, and a hyperspectral data processing unit. The spectrometer can capture 16-bit images with up to 923 spectral bands and a swath of 1600 pixels in the wavelength range of 380 to 1000 nm. At 305 m (1000 ft) above ground level, the hyperspectral camera covers a swath of 220 m (720 ft) with a pixel size of 12 cm. The hyperspectral imaging system has been used to distinguish different plant species with similar spectral signatures. The imagery from the system is compared with imagery from consumer-grade cameras for crop identification and pest detection.

**Thermal camera**

The thermal camera is a FLIR model SC640 thermal imaging camera that is sensitive in the 7.5 to 13 μm spectral range. It captures 14-bit thermal images with a 640 × 480 pixel array. The camera also captures visible RGB images with a 2048 × 1536 pixel array. Temperatures can be measured...
ured from -40°C to 1500°C. At 305 m (1000 ft) above ground level, the thermal camera covers a ground area of 130 × 97 m (426 × 318 ft) with a pixel size of 20 cm, while the RGB images cover a ground area of 280 × 210 m (920 × 690 ft) with a pixel size of 14 cm. Because stressed plants tend to have higher canopy temperatures, the thermal camera has been used to map crop diseases and assess irrigation uniformity.

**Consumer-grade cameras**

More recently, we have assembled two multispectral imaging systems using consumer-grade cameras. One system consists of two Canon EOS D5 Mark III cameras, and the other system includes two Nikon D90 cameras. The Canon cameras have a larger pixel array of 5784 × 3861, compared to the 4288 × 2848 pixel array of the Nikon cameras. In each system, one camera captures normal RGB color images, while the other camera has been modified to obtain NIR images. The RGB camera is also equipped with a GPS receiver to allow the images to be geotagged and a video monitor to view live images.

A remote control is used to trigger both cameras simultaneously. Images are stored in memory cards as 14-bit RAW files and 8-bit JPEG files. Each system can be attached to our Cessna 206 or Air Tractor 402B for capturing images at altitudes of 152 to 3048 m (500 to 10,000 ft). At 305 m (1000 ft) above ground level, the Canon cameras cover a ground area of 550 × 366 m (1800 × 1200 ft) with a pixel size of 10 cm, while the Nikon cameras cover a ground area of approximately 300 × 200 m (1000 × 660 ft) with a pixel size of 7 cm. Flight altitude can be adjusted based on the desired pixel size and ground coverage.

**Image mosaicking**

If a single image cannot cover the area of interest with the required pixel size, then multiple images can be taken along one or more flight lines. For example, to map a 6.4 × 12.8 km (4 × 8 mile) cropping area near College Station, Texas, two Nikon D90 cameras (one RGB and one NIR) were mounted on the Air Tractor 402B. The Nikon cameras were flown at 1524 m (5000 ft) above ground level along 11 flight lines spaced 610 m (2000 ft) apart. With a ground speed of 240 kph (150 mph) and an imaging interval of 6 s, a total of 418 pairs of geotagged RGB and NIR images were acquired with a side overlap of 60% and a forward overlap of 56%. The images were processed using Pix4D software to generate georeferenced RGB and NIR orthomosaics, a 3D surface model, and a NDVI image for the cropping area.

These imaging systems have been used for a variety of research and practical applications in agriculture. For general-purpose applications where broadband multispectral images are needed, two-camera systems can be used for both small fields and large areas. If narrow-band or high spectral resolution images are needed, the four-camera and hyperspectral systems can be selected. The hyperspectral system can identify optimal narrow bands or combinations of bands for a specific application, and the four cameras can then be filtered for the selected bands to optimize data acquisition. The thermal camera can be used in conjunction with any other system when thermal imagery is needed.

As consumer-grade cameras are being increasingly used for remote sensing, more research is needed to evaluate these types of cameras and compare them with more sophisticated multispectral and hyperspectral imaging systems for precision agriculture and other applications. Imagery acquired from different platforms (i.e., UAS, manned aircraft, and satellites) should also be evaluated for its suitability and effectiveness for practical applications.

**ASABE member Chenghai Yang**, Research Agricultural Engineer, USDA Agricultural Research Service, Aerial Application Technology Research Unit, College Station, Texas, USA, chenghai.yang@ars.usda.gov.

*Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA.*
“Partnerships” was a major focus of my presidential year. Partnerships include members working together within ASABE, as well as ASABE partnering with other organizations to achieve common goals and address common challenges. Over the past year, ASABE members and staff have worked together, and with outside partners, to pursue our mission and continue to benefit the people of the world. There is not enough room in this report to mention all of ASABE’s activities and accomplishments during the past year. The sample selected illustrates the broad range of Society activities.

Society outreach

We have been deeply engaged in outreach activities throughout the past year, carefully selecting events and partnerships that provide valuable opportunities to advance Society goals. ASABE was a sponsor of the Smithsonian Institution’s Food History Gala in Washington, D.C. A few months later, ASABE leadership participated in a Congressional Visits Day organized by the Tri-Societies (agronomy, crop science, and soil science) that focused on funding for the USDA Agriculture and Food Research Initiative (AFRI) and featured a presentation by Sonny Ramaswamy, director of the USDA National Institute for Food and Agriculture.

We followed up by participating in the 16th National Conference and Global Forum on Science, Policy, and the Environment, “The Food-Energy-Water Nexus,” also in Washington, D.C., and the Water for Food Global Conference at the University of Nebraska, where we had the honor of attending the premiere of “The Thirsty Land,” a documentary film that ASABE helped sponsor.

We are very excited to be hosting an ASABE Global Initiative Conference in South Africa later this year, “Engineering and Technology Innovation for Global Food Security,” in partnership with Stellenbosch University. We are gratified by the partners and sponsors providing support, and we look forward to a very productive and rewarding conference.

Serving our members

But our gaze is not only outward. We are also keeping a sharp eye on member needs. A committee focusing on student outreach created momentum in 2015 to bring more attention to student activities at the ASABE Annual International Meeting (AIM) and thereby deepen engagement among our younger members. That momentum is continuing into 2016, with scheduling and program changes attuned to the needs and expectations of preprofessional attendees. Competitions and events are being rescheduled to minimize conflicts and facilitate attendance. The first-ever Association of Equipment Manufacturers (AEM) Student Awards and Recognition Breakfast will replace the AEM Student Luncheon and provide a dedicated venue for the recognition of most student scholarship, award, and competition winners.

A two-year collaboration with McKinley Advisors to increase membership and retention ended in July 2015. The second half of our work with McKinley focused on student recruitment, an AIM campaign to drive registration and new
member recruitment (especially of students and young professionals), a proud member campaign, and a volunteer toolkit to aid in industry recruitment.

The efforts were successful. By the end of June 2015, membership among students and professionals had grown, reversing a seven-year trend, and the combined AIM attendance of students and young professionals increased by nearly 20% over 2014. In addition, records were broken in both May and June of 2015 for new full members, and we ended 2015 with total membership growth for the first time since 2008.

On-line resources and website improvements

In preparation for a move to computer-based testing for professional licensure—that is, for the Principles and Practice of Engineering (PE) exam—ASABE volunteers from the EOPD-414 Engineering Licensure committee created an electronic reference resource for the agricultural and biological engineering (ABE) exam. Seven sections have been posted online, and candidates have been invited to use this resource while preparing for the ABE exam. Much of the material was extracted from ASABE textbooks and other publications. ASABE staff have assisted with document preparation and obtaining publishing permissions as needed. The work was supported by Initiative Funds, and additional funds have been awarded to continue work for this vital resource.

As demonstrated by the need for electronic PE exam resources, the demand for digital tools and communications continues to grow, and ASABE is keeping pace. The ASABE website remains the central focus of the Society’s digital efforts. A usability study was undertaken in 2015 with the help of The Understanding Group (TUG), who conducted a site review that examined elements impacting all of the website’s users. Interviews of members and non-members were designed to identify key flows and tasks that would likely be performed by both groups. TUG’s final report resulted in a number of short-term, prioritized quick fixes with little associated cost, and a longer-term roadmap for more complex (and more expensive) changes.

As website technology and user expectations evolve, this exercise will remain valuable in improving the user experience. In fact, it is already proving useful in current follow-on work with TUG that involves a deeper study of the user experience. This work will result in the first major upgrade of the website since the current site launched in 2011.

Digital marketing and publishing

The website is one component, and arguably the core, of ASABE’s digital presence, but in its goal of serving all constituencies, the Society continues to expand utilization of all digital tools—the Technical Library, event registration, social media, and more. One project that will see increased effort in 2016 is a digital marketing strategy that will be implemented in the coming months to better leverage ASABE’s digitally available content.

We’re also keeping pace with digital publication trends. Instructions for manuscripts have been updated so that reference lists will more closely reflect American Psychological Association editorial style guidelines. Consistent application of these guidelines in ASABE journal articles will facilitate use of referencing software.

As a result of a 2013 government mandate, publications reporting research that was supported by U.S. federal funding must soon be made available at no charge to the public within one year of publication. Ordinarily, ASABE does not provide full access to publications except as a benefit of membership or site license, but we are fully complying with the mandate. Our manuscript submission system, ScholarOne, now allows identification of affected papers at the time of submission. Likewise, our manuscript processing software is advancing as well, so that we can make these documents available as required.

ASABE standards activities

We are pleased to share the formal American National Standards Institute (ANSI) announcement of our standards program reaccreditation in January 2016. This closes the
books on our most recent five-year ANSI audit and includes approval of our revised standardization procedures. The new procedures include a number of improvements suggested by ANSI or ASABE members and are expected to improve efficiency.

ASABE continues to seek collaboration with a variety of organizations. The Farm Equipment Manufacturers Association (FEMA), AgGateway, the Canadian Standards Association (CSA), and the American Feed Industry Association (AFIA) are just a few examples of our wide-reaching efforts toward collaboration. FEMA continues its strong standards support by directly contributing and buying ASABE standards for its members.

One of the most significant of ASABE’s projects with AgGateway has been the inclusion of terms and definitions from ASABE standards into AgGateway’s searchable database known as the AgGlossary. To date, more than 3,000 terms and definitions, from 19 ASABE standards and engineering practices, have been entered into the publicly available AgGlossary. This represents about 10% of all terms in the glossary to date.

A current priority of the Standards & Technical Council is to align ASABE agricultural equipment standards with those of CSA. Because CSA routinely endorses or adopts various ASABE and ISO standards, alignment provides opportunities to introduce newly published ASABE standards for consideration. There is great benefit to the North American agricultural equipment industry in having binational alignment regarding design standards.

ASABE’s leadership as U.S. Technical Advisory Group (TAG) administrator for ISO Technical Committee 293, Feed Machinery, has resulted in strengthened ties to AFIA. As a result, ASABE staff and members have been invited to speak at AFIA events and have heavily promoted the development and maintenance of industry standards, attending trade shows to network and draw additional participants and interest to this important work.

Other involvement in ISO work will strengthen ASABE’s ties to the fertilizer and biogas industries. U.S. TAG administration of ISO Technical Committee 134, Fertilizers and Soil Conditioners, was transferred from The Fertilizer Institute to ASABE, which provides ample opportunity to impact this important sector of the agricultural economy. Additionally, the ASABE Board approved 2016 Initiative Funds to allow ASABE involvement in ISO Technical Committee 255, Biogas, an avenue for greater involvement with the renewable energy industry.

This has been a strong year for ASABE

I am thankful to have had the opportunity to be in the midst of the excitement. Members and staff moved ASABE forward and set the stage for continued success in the future. In the next year, I look forward to continuing to build partnerships and to supporting Maynard Herron during his term as president.

Mary Leigh Wolfe
ASABE President, 2015-2016

2015-2016 Officers
Mary Leigh Wolfe, President
Maynard M. Herron, P.E., President-Elect
Terry A. Howell, Jr., P.E., Past President
Sue E. Nokes, P.E., Treasurer
Darrin J. Drollinger, Executive Director

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Candice L. Engler
Dorota Z. Haman
Daren Harmel
Paul H. Heinemann
Kati White Migliaccio
Douglas R. Otto, P.E.
Sylvio Tessier, P.E.
Robert D. (Bob) von Bernuth, P.E.
Gregory D. Williams, P.E., S.E.
### STATEMENT OF FINANCIAL POSITION
**December 31, 2014 and 2015**

<table>
<thead>
<tr>
<th>ASSETS</th>
<th>2014</th>
<th>2015</th>
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<td>Cash</td>
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<td>Book Inventory</td>
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<td>Due from (to) Inter-fund</td>
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<td>(At cost, less accumulated depreciation)</td>
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<td>2014 - $1,056,991</td>
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<tr>
<td>2015 - $1,094,467</td>
<td></td>
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<tr>
<td><strong>Total Assets</strong></td>
<td><strong>$2,092,113</strong></td>
<td><strong>$2,047,365</strong></td>
</tr>
</tbody>
</table>

| LIABILITIES AND FUND BALANCE                |                   |                   |
| Accounts Payable and Accrued Expenses       | $311,557          | $317,504          |
| Unearned Revenue: Dues and Sales            | 1,024,176         | 973,481           |
| Fund Balance                                | 756,380           | 756,380           |
| **Total Liabilities and Fund Balance**      | **$2,092,113**    | **$2,047,365**    |

| RESTRICTED RESERVE BALANCE                  | $2,300,477        | $2,198,027        |
In its nearly 30-year history, the ASABE Foundation has never had a dedicated staff development position. So, when approached by the leadership last year to consider taking this role, I was very interested in how I could leverage my 16-year tenure with ASABE to make a meaningful difference. My history with the Society has taught me a lot about the profession, and more importantly has allowed me to forge lasting relationships with our membership. After careful consideration, I accepted the challenge and became ASABE’s first director of advancement in mid-March. The “advancement” title is common in academia. Now I wear two hats—one for membership, and the other for fundraising. This new position will require realignment of some of my current duties to others on staff, and executive director Darrin Drollinger and I are working closely to ensure a smooth transition.

In my new role, I will strive to advance ASABE in its mission through the integration of membership, marketing and communications, and development programs. I plan to build a culture of philanthropy by raising financial support through the ASABE Foundation and ASABE activities in general. I’ll be responsible for initiating and cultivating relationships with ASABE members and donor prospects that lead to major gift solicitations, as well as annual giving. I’m grateful and excited for this opportunity, and I look forward to better understanding the development priorities as outlined by the ASABE leadership. The newly created E-06 ASABE Foundation Liaison Committee exists for this very reason—to identify needs for Society funding by reaching out to ASABE communities, groups, and units, and then communicating those fundraising needs and priorities to the Foundation.

Since starting my new position, I hit the ground running by immediately joining the Association of Fundraising Professionals and attending their International Fundraising Conference in late March. The timing could not have been better. The conference offered nearly 100 fundraising-related sessions. Was I overwhelmed? Absolutely. But I got a glimpse of what lies before me, and it’s REALLY exciting! I walked away from that event with some great contacts and information that will serve me well as I settle into my new position.

I’ve worked closely with the Foundation Development Committee to begin cultivating a culture of planned giving to meet the long-range goals (5+ years) of the Foundation and the Society. This process takes time if it’s to be done right, and I plan to rely heavily on the collective expertise of those who currently serve or have served on the Foundation Board of Trustees. Thoughtful steps now will establish a solid base for the future.

With the help of the Foundation, you will see new marketing materials, including social media and advertising campaigns, as part of an overall public relations strategy that will help donors understand giving options that might not immediately come to mind, such as legacy giving and stock transfers.

This is an exciting time for ASABE and its Foundation, and the potential to support and grow Society initiatives and activities through fundraising efforts is huge. I’m thrilled to be a part of it! I plan to engage members at each stage of their careers as we work toward our fundraising goals.

I look forward to seeing many of you at the upcoming Orlando AIM and discussing how we can work together to make ASABE stronger.

Mark Crossley, ASABE Director of Advancement, St. Joseph, Mich., USA, crossley@asabe.org.
Images of Agricultural and Biological Engineering

VisualChallenge6

Entry Deadline: October 3, 2016

Engineers have a unique responsibility to communicate technical concepts to a larger audience. Traditionally, that is done with words and numbers. However, communication in images offers intriguing “statements without words.”

Visual imagination combined with technical skill can produce astonishing—and deeply informative—images. We encourage you to participate in our sixth annual challenge!

To celebrate the visual aspects of agricultural and biological engineering, Resource magazine asks you to submit one or more entries in any/all of three categories: photographs/captured images; illustrations/drawings; and informational/explanatory graphics.

VisualChallenge6 is an opportunity to be creative and to show those outside the ABE field: “This is what we do.” Use your entry to convey the beauty and meaning of your work, your research developments, and your Society community.

Submit original work as an e-mail attachment in JPG format (300 dpi or higher) to Sue Mitrovich, Resource managing editor (mitro@asabe.org). Enter VisualChallenge6 in the subject line, and include your full name, professional affiliation, contact information, and a title with a brief description of your entry in your message. If necessary, include a source credit and an assurance that permission has been granted to submit, and possibly reprint, the entry. Multiple entries are welcome.

The winning entries will be selected by Resource staff and published in the January/February 2017 issue.
Your personal or company consultant business card could appear here. For information on rates ($95 and up) visit www.asabe.org/Advertise or contact Sandy Rutter, 269-932-7004, rutter@asabe.org.
As a scientific agricultural organization—supporting a world where decision-making related to agriculture and natural resources is based on credible information developed through reason, science, and consensus building—CAST is committed to helping to feed the 9 billion people estimated to be living on the planet by 2050.

Anyone listening to agricultural experts knows that we are already facing a food security crisis. This problem will grow as the population increases and as the rise in per capita income in developing countries elevates more people into the middle class.

Even worse, the frequency with which we are hearing the question “How will we feed the world of 2050?” can make us numb rather than motivating us to action. There is a risk that both agriculturalists and the public will grow complacent if the discussion remains general and abstract.

The demands on agriculture are huge and increasing. Innovative, integrated solutions are required to sustainably meet these demands to feed a growing world population. Innovations are needed in all segments of agriculture—livestock production, food science, crops, and soils.

The public and decision-makers need to have science-based information to guide them regarding programs, policies, and techniques that will advance global food security in the next several decades. Thus, the Council for Agricultural Science and Technology (CAST) is in the process of creating a 12-part series of issue papers—titled “The Need for Agricultural Innovation to Sustainably Feed the World by 2050”—that looks at specific programs, policies, and techniques that will advance global food security.

CAST is uniquely qualified to assist with this timely initiative, as it has a demonstrated record of producing high-quality publications that are shared with national and global policymakers, producers and commodity groups, the media, and the general public. This series will use CAST’s method of convening task forces composed of scientific experts from a wide variety of specialties to write and peer-review each paper, providing a transdisciplinary, integrated approach to the broad topic. CAST’s goals through this series include the following:

- Look at why more innovation is needed.
- Review megatrends that define the pending agricultural productivity gap.
- Spur interest in research funding and highlight the societal benefits of technologies that can increase agricultural productivity and reduce negative environmental impacts.
- Encourage implementation and use of science-based regulation to support innovation and the advancement of agricultural technology.

Specifically, the series includes an introductory paper; a keynote paper highlighting technologies that exist but are not being used to their potential; three papers each focused on animals, food, and crops; and a summary paper addressing possible barriers to adoption of innovation across the disciplines.

Topics addressed in this series include technologies on the shelf, food animal gene pools, genetic intervention in food production, precision production technologies, plant breeding and genetics, crop protection contributions, precision crop management and irrigation technologies, innovative approaches to zero waste in the food chain, food biofortification, and gene editing. The final paper in the series will address barriers to the development and implementation of innovative technologies that show great potential to close the projected gap in food production over the next 30 to 35 years.

CAST is very proud to have ASABE as one of its long-standing scientific society members. As engineers, you appreciate the importance of using science and technology to solve complex issues. If you are interested in assisting with this series of papers or would like more information on the progress to date of this initiative, please contact me. I would welcome the opportunity to share additional information.

Kent Schescke, Executive Vice-President, The Council for Agricultural Science and Technology (CAST), Ames, Iowa, USA, kschescke@cast-science.org.

Views expressed are solely those of the author and do not necessarily represent the views of ASABE.
ENGINEERING AND TECHNOLOGY INNOVATION
FOR
GLOBAL FOOD SECURITY
An ASABE Global Initiative Conference

Bringing together stakeholders from across the world to address the challenges and opportunities for engineering and technology in producing healthy and safe food in a sustainable manner.

A must-attend event for engineers, scientists, NGO and government administrators, and all who are involved in food production, processing, handling, trading, and marketing.

24-27 October 2016
Spier Wine Estate and Conference Center
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