Robert Blair is pioneering use of Unmanned Aerial Vehicles in agriculture. The aerial view provides detailed crop data to guide management decisions. All photos by Alex Garland.

UAVs provide a high-level crop management perspective

Agricultural revolutions usually happen on the ground. Robert Blair is leading a revolution from the air.

Blair is pioneering the use of Unmanned Aerial Vehicles (UAVs) in agriculture. He was one of the first farmers, the first to his knowledge, to operate a UAV commercially. That was 2006. His first full growing season employing UAV imagery to make management decisions was 2007. Today, people from all over the world visit his Idaho Palouse farm to see how the aerial perspective offered by UAVs is changing how agriculture is done.

"UAVs are going to play a bigger and bigger role over time," Blair predicts. "I equate them to John Deere's plow, McCormick's reaper and Eli Whitney's cotton gin. These were transformative technologies in agriculture. UAVs are a transformative technology for the information revolution in agriculture."

"UAVs are a transformative technology for the information revolution in agriculture."

The key value proposition of UAVs for agriculture is crop visibility at a high level of detail. Seeing fields from above literally provides a new dimension.

"Scouting a field from the ground, you can see around 10 feet from each side of your four-wheeler, around five percent of the field," Blair says. "I can see 100 percent into the canopy from the air. What you see from the ground is not the true story of what you can see from the air."

"Farmers are visual. We're looking and seeing what's happening. UAVs give us another view."

Using aerial data in crop management

Pulling up mapped images of his fields on a laptop at his kitchen table, Blair illustrates the value of the aerial perspective. He rotates the image to reveal a three-dimensional picture of field slopes and crop conditions. A winter wheat crop image reveals where population density is falling short of potentials. "What this map tells me is that I would increase the seed rate 10 percent on one part of the field, and 20 percent on the ridge top."

On another image he points to white spots that "bugged the heck out of me for weeks. I finally figured out that's where the peas bunched up on the header" during harvesting. That left a gap in resi-

Blair demonstrates how he launches an Unmanned Aerial Vehicle.

due on the fields, the white spots. Another picture reveals a weed problem that "you wouldn't be able to see from the outside."

Indicators such as plant height can tell a lot about nutrient levels. "You can't see inside the ground. But the maps point to where to look. They point to trouble spots."

A flight over irrigated land can uncover areas that are overwatered and underwatered. It can reveal where center pivot irrigation nozzles are clogged, or worn out, and show where moisture retention is varying between sandy and clay soils.

"Changes at the field ground level are subtle, but you can see them from the air. That's why remote sensing is so important to farmers. It tells the whole story."

Blair still does ground scouting informed by anomalies detected from the air. "We can go out and do directed scouting. Now I'm scouting with a purpose."

UAVs fly over the Blair place for whole seasons and for multiple crops.

"If you can catch a problem early enough, you can go in and replant," Blair says. "Am I always going to go out and make a change during the growing season? No. But it gives me a better chance of doing right. It allows me to make better management decisions. The value proposition is for the long-term management strategy, increasing long-term productivity."

UAVs still face "skepticism within ag itself," he acknowledges. "The farmer has to see the value in the product, the information. That will come."

To help farmers understand the value of UAVs their operation, Blair has created a Drone Flight Calculator: http://www.measure.aero/drone-value-calculator/ It tells the basic cost of flights per acre, and how flight data from flights can make fertilizer and irrigation application more effective, and improve management decisions. Blair also writes about UAVs in agriculture at his blog, The Unmanned Farmer, http://theunmannedfarmer.blogspot.com.

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"The missing puzzle piece for precision ag"

Blair's exploration of UAVs goes back to an earlier venture into precision agriculture. He began the practice in 2003 using a personal digital assistant and GPS to do simple field mapping. In 2004 he purchased his first combine yield monitor, and used the information to begin varying the rates of nitrogen application. From early test strips to whole fields, he converted his entire spread to precision applications by 2008. Variable applications optimize use of costly inputs such as nitrogen fertilizer, chemicals and seed.

In 2004 Blair's precision ag mentor took him on a flight above his fields.

"When I got up in the air and could see the variability in my fields, it was boom! That's the missing puzzle piece for precision ag, high resolution real-time monitoring."

That is exactly what he has found in his UAV experience, which goes back to 2006 when he saw an ad for a UAV in an ag publication. "Love at first sight," is the way Blair describes the experience. He soon was flying one of his own. Next year he began applying UAV data to crop management. Now, Blair says, "UAVs are taking us from precision agriculture to surgical agriculture and surgical scouting."

A combination of visibility and intense granularity of data elevates precision to a new level. Precision ag relies heavily on combine yield monitors, available since the early 1990s. They typically assemble datapoints in 400-square-foot blocks, which tell what has happened to the crop after the fact. Farmers can only react in the next crop management plan. UAVs can generate datapoints down to three square centimeters, and sometimes even less, during the course of crop growth. That gives producers the opportunity to make adjustments during the season.

Blair uses UAVs that capture a full light spectrum with four lenses:

- RGB, Red-Green-Blue, what humans can see
- Near infrared, to record the thermal profile
- Red Edge, a 700-800 nanometer range not visible to the human eye, where chlorophyll levels and plant cellular structure are revealed
- Incident light sensor, recording sunlight levels, correcting for atmospheric conditions, and removing shadows from images.

The combination of spectra "allows us to do a quantitative image analysis. It lets us put a number to rank the best to the worst places in a field," Blair says

Computer algorithms "make sense of the picture," revealing factors such as canopy chlorophyll levels and the vegetation index, a measure of the live vegetation on a particular piece of ground. With multispectral imaging, problems become visible before they would show to the human eyes. Sometimes the visible light image alone is enough. "Just in a color image I can see issues between rows."

Quantified data from the images is used to generate maps of zone prescriptions for precision applications of chemicals, fertilizer and seeds. They are fed directly into guidance systems on equipment such as tractors or sprayers. "You have to get data from the air and apply it directly on the ground."

Blair's farm is broken up into 48 test plots to ground truth aerial data. The combine yield monitor provides another source to validate image data. Soil test and nutrient management information is also incorporated into the picture.

Blair uses the senseFly eBee, a 38-inch wingspan craft made of carbon fibers and foam. His UAVs are officially registered in Idaho, much as any general aviation or commercial aircraft. At 1.7 pounds they are the lightest ever planes on the registry. Blair smiles when he notes the registration fee was 57 cents.

UAV data translates into field mapping that reveals conditions ranging from crop growth to weed problems.

A flight begins with the operator hurling the craft into the air, where it will run passes at around 24mph. Battery life is 45 minutes. A typical flight lasts 20 minutes. The machine is operated by a computer with a transmitter. The aim is to fly as high as possible and build an overlapping pattern of imagery. Once in the air, the UAV will fly a pre-programmed pattern unless the operator intervenes. For the most part the only time that happens is to dodge a bird or to upload another flight pattern. Indeed, a scrape with a bird is evidenced on one of the eBees.

Pioneering agricultural UAV adoption

The aviation era was only arriving when the Blair farm was started by Blair's great-great-great uncle in 1903, the year the Wright brothers made their first flight at Kitty Hawk. Today the Blairs farm a 1,300-acre spread in the fertile hills on the edge of the Palouse Region near Kendrick, Idaho, around 20 miles southeast of Moscow as the crow flies. The farm is minimum till with three rotations – winter wheat, a spring grain, and then a legume – peas, lentils and garbanzos. With 20-22 inches annual rainfall, the Blairs raise winter and spring wheat varieties – soft white and hard red depending on market conditions. The operation also grows barley and alfalfa. In addition, the Blairs raise cows, as well as calves for their own herd.

Blair's resume underscores his role as a farm leader and advance agricultural pioneer – past chair of the National Association of Wheat Growers Research & Technology Committee, past president of the Idaho Grain Producers Association, past president of the Nez Perce County Farm Bureau, 2009 Precision Agriculture Institute Farmer of the Year, Eisenhower Fellow in 2011 for his work on UAVs, McCloy Fellow for Agriculture in 2012, Idaho governor's award for excellence in agriculture and technology in 2012.

Blair built on his own experience to become co-founder of the first company to gain approval for commercial use of UAVs in agriculture, Empire Unmanned. Today Blair is the Vice President of Agriculture for Measure, another UAV company entering the agricultural field.

It took an explorer's determination and grit to navigate the bumpy flight path where he is today. UAVs have operated in a "wild, wild west," or something like the first days of automobiles before stoplights, Blair says. "That was a change. We're in the same historic cycle."

"In the beginning you felt like you were banging your head against a wall. You had no support. Today you can't open a farming publication without seeing an article on UAVs."

"UAVs are taking us from precision agriculture to surgical agriculture and surgical scouting."

"We've come a long way, baby. There have definitely been growing pains."

A lot of those pains came in obtaining clearance from the Federal Aviation Administration (FAA). The status of UAVs for commercial uses such as farming remained ambiguous for years, a situation that has only recently cleared up. Farmers must have an FAA Section 333 exemption to fly their own UAVs and legally use information gathered from flights to make management decisions. In 2008 Blair applied for an FAA exemption to allow commercial use. It was not given until 2014. Empire received an FAA exemption in January 2015, only the eighth company in the US to receive an exemption, and the first in agriculture. There are now several for firms serving agriculture including Measure. Most exemptions have been granted for film and photography companies.

"Not even one percent of farmers are using UAVs. We are not even seeing the tip of the iceberg. We haven't even scratched the surface of what we can do."

A Certificate of Authorization (COA) issued in March 2015 provided Blair's first company an area to fly legally. Covering flights up to 400 feet above the Idaho Palouse region, it was the first agricultural COA in the U.S. That March the FAA also provided a blanket COA for Section 333 operators across the U.S. up to 200 feet. A year later the agency elevated that to 400 feet, with the exception of restricted airspace and over urban areas.

Blair has been working hard "to get FAA responsive to the needs of farmers. We have pushed the knowledge base on how FAA needs to operate. The FAA needs to open up and bring ag to the table. Ag still doesn't have a seat."

"I'm trying to promote this industry and get it right," Blair says, recalling earlier instances where technologies were not properly introduced. Technology was "one of the downfalls of precision technology in the early days."

Lack of support from technology companies and trained mechanics made adoption difficult. Landsat remote sensing data was available even in the 1970s, but it was not marketed properly and did not work well for farmers, Blair says. Even today, Blair estimates that only 5-10% of producers are fully using precision ag. He sees similar problems popping up with UAVs. Some companies are overselling what are basically toys with a television camera, he says. Unscrupulous vendors are misinforming customers that they can legally fly commercially without an FAA exemption.

Agriculture's aviation future

Blair has flown a number of UAVs, "too many to count." He keeps many in the "boneyard," a side room of his barn. On the shelves are everything from a primitive Styrofoam model to a helicopter-style craft.

"If you own UAVs, you're going to crash one," he quips.

UAVs can cost as little as $1,500 or range well over $100,000. The higher end is "overkill," Blair says, adding that systems in the $20,000-$40,000 range work well.

For farmers considering running their own UAVs, Blair advises, "It's a time drain. It's another job you have to do. You have to get all the images and put them in a useful format. It will save you time in the long run." Farmers must evaluate what they want technology to do and have expertise at the table. They must also understand the liability risks and FAA certification framework. Some farmers will opt to go through the process. Others will hire companies such as Blair's.

Privacy is also a concern. "We can't fly over anyone's property without permission. And we won't."

The new capacities for real-time situational awareness will demonstrate increasing value for farmers, Blair says.

"Agriculture has a tremendous responsibility to feed nine billion people by 2050. We're going to have to open up to other sectors to meet that challenge. We're getting into aviation," he comments. "There are very few times you can affect an industry you love. This gives me a chance."

At 46, "my game plan is to use this stuff to give my kids a head start." One of his sons is preparing to go into the business, taking an agricultural engineering degree at University of Idaho. "He's fascinated with technology, especially UAVs. Embracing this technology will make it easier for my kids moving forward." Using UAVs "will be an everyday occurrence."

As of now, "not even one percent of farmers are using UAVs. We are not even seeing the tip of the iceberg. We haven't even scratched the surface of what we can do." ■

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