BIG DATA AND AGRICULTURE: INNOVATION IN THE AIR

HEARING

BEFORE THE

SUBCOMMITTEE ON
GENERAL FARM COMMODITIES
AND RISK MANAGEMENT

OF THE

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BIG DATA AND AGRICULTURE: INNOVATION IN THE AIR

THURSDAY, JUNE 23, 2016

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON GENERAL FARM COMMODITIES AND RISK MANAGEMENT,
COMMITTEE ON AGRICULTURE,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:01 a.m., in Room 1300 of the Longworth House Office Building, Hon. Frank D. Lucas presiding.

Members present: Representatives Lucas, Neugebauer, Rogers, Gibbs, Austin Scott of Georgia, LaMalfa, Allen, Bost, Abraham, Bustos, and Graham.

Staff present: Bart Fischer, Callie McAdams, Haley Graves, Matt Schertz, Skylar Sowder, Stephanie Addison, John Konya, Anne Simmons, Liz Friedlander, Mike Stranz, Nicole Scott, and Carly Reedholm.

OPENING STATEMENT OF HON. FRANK D. LUCAS, A REPRESENTATIVE IN CONGRESS FROM OKLAHOMA

Mr. LUCAS. Thank you all for being here this morning for this hearing exploring big data and agriculture: innovation in the air. This is our second hearing in a series to educate Members about different facets of the new frontier in agriculture.

Production agriculture from 100 years ago is markedly different than it is today. While our farmers still produce many of the same crops, a plow once pulled by mules is now pulled by a tractor with a satellite guiding it through the field. When formerly the only option a farmer had to control weeds was tilling the field with major losses to water and wind erosion, pinpoint chemical and fertilizer application now enable the use of no-till farming technologies.

While these are just two simple examples, an important piece underpinning much of the innovation in agriculture, and specifically in precision agriculture, is the development of imaging and mapping technology. As we all know, maps of farmland and cropland are not new, but the means of capturing and utilizing the imagery is constantly changing.

We will have an opportunity to hear about three technologies used to capture images: manned airplanes, satellites, and Unmanned Aerial Systems or drones. Each of these technologies serve a specific purpose for providing information based on imagery for farmers and improving their stewardship of natural resources and the sustainability of their farming operations.

While we are only scratching the surface on the innovation that satellites and Unmanned Aerial Systems will bring to agriculture, manned airplanes also continue to play a vital role. Aerial imagery from manned airplanes is the foundation of the administration of Farm Service Agency programs, such as ARC and PLC, and we will hear more today about how FSA's National Agricultural Imagery Program, NAIP, is useful to farmers and to a broad spectrum of other users, which in the past has included companies such as Google.

This hearing is timely since the FAA finalized the Small Unmanned Aircraft Rule, known as Part 107, which governs commercial use of drones, just this week. Commercial drone use will now be possible without the need to acquire a special exemption, which under the old regulations could take up to 6 months to be approved. We will be engaging with industry to gather their views on the impacts of this new rule on the use of drones in agriculture.

And before I turn to my colleague, I would like to note that the hearing on the Committee of Agriculture, *Big Data and Agriculture: Innovation in the Air,* has come to order, and before I recognize my ranking colleague in my role as a substitute, she too is ably manning this position, I think it would be worth noting that our good friend and the Ranking Member of this Subcommittee, Mr. Walz, is not at the hearing this morning. As many of you know, his brother, Craig, was killed in a tragic accident this past weekend, and Craig's son, Jacob, was seriously injured. It is an incredibly difficult time for the Walz family, and of course, I and you together will keep them in our thoughts and prayers over the coming days and weeks ahead.

[The prepared statement of Mr. Crawford follows:]

PREPARED STATEMENT OF HON. ERIC A. "RICK" CRAWFORD, A REPRESENTATIVE IN CONGRESS FROM ARKANSAS

Thank you all for being here for this hearing exploring big data and agriculture: innovation in the air. This is our second hearing in a series to educate Members about the different facets of this new frontier in agriculture.

Production agriculture from 100 years ago is markedly different than it is today. While our farmers are still producing many of the same crops, a plow once pulled by a team of mules is now pulled by a tractor that satellites guide through the field. When formerly the only option a farmer had to control weeds was tilling the field with major losses to water and wind erosion, pinpoint chemical and fertilizer application now enables the use of no-till farming techniques.

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We will have an opportunity to hear about three technologies used to capture images—manned airplanes, satellites, and Unmanned Aerial Systems or drones. Each of these technologies can serve a specific purpose for providing information based on imagery for farmers and improving their stewardship of natural resources and the sustainability of their farming operations.

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Before I conclude and before we carry on with today's hearing, I want to briefly change the subject. You can all see that the Ranking Member and my good friend Mr. Walz is not at the hearing this morning. As some of you may know, his brother Craig was killed in a tragic accident this past weekend and Craig's son Jacob was seriously injured. This is an incredibly difficult time for the Walz family, and I'd ask that you keep them all in your thoughts and prayers over the days and weeks ahead.

Ms. Graham has graciously agreed to fill in for him today, and I now recognize her for her opening statement.

Mr. LUCAS. Ms. Graham has graciously agreed to fill in for him today, and at this point I would like to recognize her for any opening statement that she would have.

OPENING STATEMENT OF HON. GWEN GRAHAM, A REPRESENTATIVE IN CONGRESS FROM FLORIDA

Ms. GRAHAM. Thank you, Mr. Chairman, and I echo your thoughts regarding Mr. Walz, and I ask that we all continue to keep him and his family in our prayers.

It has been a tough time to be a farmer in America today. The farm economy is struggling, and farmers are being forced to do more with less. As Members of this Subcommittee, our role is to protect our existing agriculture infrastructure, while exploring new ways to make it work more effectively and efficiently.

Aerial imaging is at the forefront of innovation in agriculture. This technology has already proven to be an important tool for agriculture agencies, and it has great potential to make farming operations more streamlined and efficient. I look forward to hearing today how we can safely harness this technology to benefit individual farmers and farm programs like crop insurance and others.

Thank you very much for being here today. You all represent the different sectors of the aerial data collection industry, and your testimony will shed light on applications for this technology in the realm of agriculture. I look forward to hearing from each of you, and Mr. Chairman, I yield back.

Mr. LUCAS. I thank the Ranking Member for her insightful opening statement. The chair would request that other Members submit their opening statement for the record so that the witnesses may begin their testimony, and to ensure that there is ample time for questions.

I would like to welcome to the table our witnesses. Mr. Lanny Faleide, President of Satshot, Incorporated, Fargo, North Dakota. Mr. Craig Molander, Senior Vice President, Business Development, Surdex Corporation, Chesterville, Missouri, was unable to be with us today due to flight complications, and every Member of this Committee understands the joys of flights in this day and time. In his place, we have Mr. Tim Crago, Vice President of North West Geomatics Limited, Calgary, Alberta, will be giving his testimony, and also, Mr. Robert Blair, Farmer/Vice President, Measure Drones as a Service, Kendrick, Idaho.

And with that, Mr. Faleide, you may begin whenever you are ready, sir.

STATEMENT OF RODNEY "LANNY" FALEIDE, FOUNDER AND PRESIDENT, SATSHOT INC., FARGO, ND

Mr. FALEIDE. Thank you, Mr. Chairman, and thank you for inviting me to your hearing here today, and the Members of the Committee as well. I appreciate the opportunity to discuss a little bit about our experience and how imaging technologies and big data comes together. I have my written testimony, as has been submitted, and I will provide an overview of that. There are many details in there that I won't go into.

Let me give you a little history of why I am in this business and how it all happened. I farmed for about 18+ years with my father in central North Dakota, starting around 1978. I received my pilot's license before that, and I was actually taking pictures of my fields with new infrared photography back in about 1977. I thought it was pretty cool looking at the fields, and I remember one time or many times, actually, my father would say to me, "Gee, Lanny, the fields don't look very good. Your new ideas are maybe not proper ones." And of course, I would say, "Dad, why are you looking at the fields at noon? Why don't you look at them at 8:00 a.m. in the morning when you are up and I might still be in bed, or at night at 8:00 p.m. when the sunlight reflects off the leaves and shines the quality of the crop?" Well, that was always a discussion point that we had.

But I learned from my father's history and how he grew up in an open cab tractor how the soils worked, how the fields looked, how the vegetation changed. I saw the variability in the fields back then as a young farmer. I went through the 1980s. As many of you know, that farm situation was very difficult. Actually, I looked into some satellite stuff in 1987 when some of the first private satellites went up, European satellites and government satellites in the United States. But in 1992, we decided to go back to school and change our careers, because farming was very difficult. That lasted for about a year, and I started a company, and so we went and say well, I like to do imaging technologies with satellites. That turned into a discussion with American Crystal Sugar Beets, a company up in Fargo Morehead, and a colleague of mine now that works for me was part of that. I said let's go look at all the sugarbeet fields. Let's see if we can monitor nitrogen off of these sugarbeet leaves and come up with a more environmental, economically sound practice to develop variable rate solutions to manage nitrogen. Because they were paying on high quality sugar content. So back 20+ years ago, we were already looking at that.

In 1996, we did the first *actionable*—that is the word, actionable variable rate application of nitrogen with a satellite image: 1996. That is 20 years ago. The technology was put into a tractor with an ag leader monitor, GPS, variable rating with a Raven Industries nitrogen controller, a company out of Sioux Falls, South Dakota.

The technology that we are talking about, bringing imaging in to help precision agriculture, which started at about the same time officially was available then. We have been doing this for 20 years. The difficulties to get that technology out into a form that allows the farmers to understand it and to see it easily with one, two, three button approach, it has been a struggle. We were using mobile devices in the early 2000s, around the 2000 timeframe, but it wasn't on the phone. Because of the iPhone, android phone, mobile devices, the ability to stream that into the farmers' hands, right into the tractors, is now completely available today.

The question is, is how do we get that technology to scale up? All the interpretation of imagery, whether it is from a satellite, an airplane—and we did aerial imaging in 1998 as well—and drones now, or UAVs, let's bring the proper terminology to that, is now using technologies that have been developed by the scientific community and from NASA and others, and now we are just embracing that. Now with the mobile technologies going and bringing that into the hands of everybody just in the last 4 or 5 years has become commonplace, and with the stringing of fiberoptics across many parts of the rural areas, which I am very happy in North Dakota, where I am from, we are maybe about 80, 90 percent fiberoptic-based. And that actually helped our company partner with a new Silicon Valley company to put two $1 million satellite receiving stations in the middle of North Dakota on my prairie farmland.

What I am trying to get at is the technology is moving fast. Education really needs to be done more, but the economics of the current farm situation is now starting to open up eyes to a number of farmers and ag companies, and that scaling up of availability of data to help control costs is becoming a very, very possible situation.

This morning I just had a brand new customer clamoring for imagery from us, and I said, "Look, we just got an image 2 days ago that covered all of Iowa. Here you go. Let's do variable rate nitrogen."

So in closing, I will be open to any questions here, more details, but the big data situation is taking care of a lot of things. Our big data today is tomorrow's small data. The industries are adapting to that, but there is a great future in precision agriculture and how imaging is going to be used to help farmers to economically farm in the future. Thank you.

[The prepared statement of Mr. Faleide follows:]

PREPARED STATEMENT OF RODNEY "LANNY" FALEIDE, FOUNDER AND PRESIDENT, SATSHOT INC., FARGO, ND

Hon. ERIC A. "RICK" CRAWFORD,
Chairman,
Subcommittee on General Farm Commodities and Risk Management,
House Committee on Agriculture,
Washington, D.C.

Subject: Big Data in Agriculture—Innovations in the Air

I am the founder and President of Satshot. I have been deeply engaged in developing remote sensing technologies for agriculture since the early 1990's. My accomplishments include creating the first variable rate applications map back in 1996, based on imagery and assisting in the development of agronomic remote sensing methods. My current responsibilities at Satshot include driving strategic vision, overseeing operations, and marketing the Company's products to high-value strategic accounts.

Satshot began analyzing satellite imagery for agriculture in 1994. In 1998, the Company released their first web-based GIS mapping software, becoming the first commercial user of MapServer, a NASA funded open-source software that serves as a geographic data rendering engine. In 2003, Satshot migrated its mapping database to open cloud based technology, allowing more user customization and seamless integration with more data sources.

Satshot is focused on producing and marketing satellite data products for sale to agribusiness, such as production cooperatives, ag suppliers, crop consultants and also crop Insurance companies as well as to individual producers. Satshot is currently marketing the Satshot system across 400 million acres across North America and expanding around the world in countries like Brazil, Argentina, Russia, Ukraine and Australia.

Our Satshot system is also being integrated into Precision Ag systems softwares to access satellite imagery directly through their processes. Our history, current business and leading capabilities position us for exponential growth in Agriculture Sales & Marketing, Precision Agriculture, Ag Intelligence, Crop Identification, Crop Acreage Estimation, Yield Evaluation and Environmental Monitoring.

Satshot is one of precision agriculture's longest operating and most interconnected data providers, uniquely offering advanced analytics through automated processing and distribution of imagery. Satshot's cutting edge push notification system enables global delivery of updated field-specific imagery the moment it becomes available. Satshot is sensor agnostic and has the ability to bundle the entire imagery distribution chain, delivering from all sources. Image sensors have the same specifications and conform to NASA standards, thus the supply of imagery data sold by Satshot is based on the same structures of multi-spectral bands. As a result, Satshot's core code can enter any imagery server, including drones, and distinctively pull out imagery field by field.

The remote sensing imagery for agriculture has its official beginning back in the early 1970s when the first satellite Landsat was launched for largely to monitor agriculture. Since then technology has rapidly increased with resolution coverage and technical enhancements. The concept of using imagery to define field crop conditions is nothing new. Even in the previous decade, near infrared photography was used to define vegetation bias with photographic film, For example, all SSURGO soils maps created were based off of high resolution grayscale images taken in the 1950s, 1960s and 1970s

I got my start taking aerial NIR images of my fields in 1977 of my farm in central North Dakota. The advancements in technology has now allowed me to look at any field anywhere on the earth right from my desk or through a mobile devices in the tractor and use that image to define crop production patterns while adjusting them on the fly to manage crop inputs more efficiently for more profit gain. You can also look at crop damage to assess crop insurance loss across a field and define more accurately production and quality of the growing crop.

These real-time observations and advancements are the core future of how agriculture will be managed to gain the best profitability to manage our food production system for our food security needs.

There are many way to provide image crop production data to the user. My company Satshot, specializes in satellites because of their ability to cover large area of the [E]arth. We also use aerial and UAV imagery if desired by the customer. There are many consideration of logistics to get the proper data to the farmer cost effectively and timely. Each of these platforms whether Satellite, Aerial and UAV have their advantages and disadvantages.

Satellite imagery has a relative advantage over other types of other agronomic data layers given its comprehensive geographical coverage, lack of privacy issues, and rapidly increasing analytical capabilities. The scalability of satellite imaging also makes it the most cost effective form of coverage. Ongoing development in the private commercial satellite industry provides detailed spatial and spectral resolution imagery that allows for increasingly accurate in-season yield variability measurements, soil and water content monitoring, and harvest yield estimates. I believe that at this time that accessing any field on the earth anytime is an extremely valuable tool, that is why we focus on the satellite source as first option.

Satellite Imagery Market

New satellite launches will make consistent weekly access to in-season imagery possible, providing growers real-time crop conditions. Scheduled satellite launches will provide daily curated imagery for future growing seasons. Advancements in on board remote sensing analytic capabilities from satellites coupled with increasing adoption rates for precision ag services in general are projected to drive considerable demand for imagery based crop health analytical products.

Recent estimates show the size of the precision agriculture market in the U.S. is between $1.5 and $2.0 billion. It is estimated over the next 5 years to grow at greater than 13% per annum to reach $3.0 to $3.5 billion. Outside the U.S., including developing countries where the need to improve productivity is even greater, the growth rate is expected to be over 25% per year. Satellite imagery offers the compelling benefit of being the fastest growing area of the precision agriculture market, while also having the highest ceiling.

The recent CropLife/Purdue Precision Agriculture Survey project that this year that over 46% of the growers are using satellite imagery, up from 33.3% in 2013. Next generation imaging promises further intensification of demand with improved remote sensing technology and increasing downstream market potential.

Satellite Imagery Data Agriculture Uses

Satellite imagery has important applications to other aspects of farm management which also include: year-to-year comparisons on a micro-area or macro basis; early detection of crop stress (weeds, disease); accurate mapping of damage (hail, floods, *etc.*) for insurance purposes; yield estimation of crop and acreage and others.

Satellite Imagery allows Agribusiness the visibility to precisely target their products and solutions to the right prospect at the right time and with the right offer. In addition to serving the Agribusiness sector, we provide solutions for the growers. Imagery analysis involves quantitative evaluation of satellite images for crop health vegetative growth patterns across fields.

Satellites can deliver broadscale field resolution imagery, information and analysis to the farmer/grower to use in their precision farming systems. Crops and vegetation appear differently in each spectral band, and these differences can vary due to plant vigor, soil type, available moisture, and a host of other factors.

Results of this analysis are used to supply information for precision farming operations, in assisting crop production decisions, and in making yield and quality estimates on a detailed level. Growers can draw in their field and analyze each field by acres, and build maps to scout or variable rate their field. Maps can be exported directly to variable rate controllers into their tractors or application equipment.

GIS mapped farm boundaries associated with landowner contact information and related vendors for substantially all farmland in the United States can also drive field-level distribution. Back-end tracking of notification interest and imagery distribution allows the user to build multi-layer relationship trees that identify valuable interactions within the big geospatial data systems hierarchy user ecosystem. As a companies user base grows, these relationship networks become increasingly valuable.

Imagery analytical tools allow the grower to analyze a farm field for vegetation variability, which relates to different productivity of soils within the field. Tying this information with agronomic knowledge and farming techniques, one can efficiently apply chemicals and fertilizers where needed for improved productive capabilities. Vegetation field variability is determined by analyzing near Infrared wavelengths obtained from the satellite sensors.

By providing soil type, precipitation and the history on farm field production down to 5 $meter^2$ resolutions or better, the grower can efficiently maximize farm production by applying the right quantity and type of seed variety, the optimal amount of water and fertilizer, *etc.* To the dealer it provides the farm field level intelligence to recommend the optimal seed variety to the farmers or appropriate type and quantity of fertilizer.

Satellite Imagery can be available within as early as 24–48 hrs. from the time the satellite takes an image. Once available, web-based GIS systems allow the user to quickly submit field information over a website, which can be turned into management information for ag companies. In return farmer/growers can have access to incentives for crop information submitted.

Although many precision ag platforms still use the free low resolution imagery from Landsat, it has significant limitations in deciphering the sub-field variance necessary to make accurate agronomic decisions. Detailed image accuracy allows for more precise field management. Different satellites provide comprehensive offerings of high quality imagery data sources with resolutions ranging from 30 meters to 25 centimeters:

Insight into crop variability using various graphical indicators, known as vegetation indices are created by the coordination of various satellite sensor readings for electromagnetic reflectance. During the photosynthetic process, the chlorophyll in plants captures electromagnetic energy, but does so at varying levels for waves of different lengths. Vegetation indices use the variation in specific wavelength channel reflections to analyze chlorophyll content and extrapolate a field's vegetation biomass.

These analytics are accomplished by sensor reflectance readings for near-infrared, red-edge, red, green, and blue electromagnetic waves. Healthy leaves with high chlorophyll levels reflect wavelengths that distinctively fall in the near-infrared band, whereas distressed leaves absorb waves. High near-infrared reflectance corresponds with crop health. Similarly, chlorophyll strongly absorbs red wavelengths and reflects green. As such, low red reflectance and high green reflectance are both indicators of healthy pants. The different vegetation indices utilize different wavelength channel reflectance to provide a variety of field information

Imagery is increasingly viable for determining real-time intra-field yield variability, an essential component to precision ag practices. Near-infrared wavelengths show the most detailed field variability analysis of a field.

Precision Agriculture Growth

Powerful technological trends are developing within precision agriculture. These trends include increasing hardware and software adoption, cloud connectivity, and growing data standards for platform integrations. Rapid growth in the agricultural data science market is fostering companies to move quickly to penetrate the market. Many companies are developing large user geospatial bases by empowering local agronomists and dealers to make informed, graphical decisions for their clients.

Rapid growth in the agricultural data science market is fostering unprecedented levels of growth opportunities to penetrate the market. Precision Ag Data companies are building large client user bases over years by empowering local agronomists and dealers to make informed, graphical decisions for their clients.

Field Management focused on fulfilling orders for curated imagery in real-time and providing clear analytics that intentionally do not provide direct recommendations, will serve as highly effective tools for informing or validating agronomic decisions. Enhanced remote sensed imagery from different multi-spectral channels with multi-temporal capabilities during the growing season are coveted to quantify, project and manage vegetation changes of crops throughout the year.

The driving force behind the growth of precision farming is that patterns of productivity are highly variable within a given farm field, and that farm management provided to this micro-level of variation can significantly reduce costs, while also increasing yield. However, this does require some investment in new equipment. In addition to variable rate applicators (fertilizer, chemicals, seed, and Water) and in-field navigation equipment (*i.e.,* GPS), a digital data map is provided from a geo-referenced vegetation biomass Image dataset that tells the computer-controlled applicator how much to apply based on vegetation productivity. The data in this digital map can also be based on a number of sources, such as soil tests and historical yield (from harvester monitors). Patterns detected from satellite imagery can significantly enhance, and in some cases supplant, these other sources of information.

New Satellite Technology shift

Next generation satellites improve the frequency of in-season shots, allowing real-time monitoring of crop conditions. Leading partners developing high frequency satellite imaging will soon 1–3 years operate powerful micro satellites capable of shooting more reliable, inexpensive imagery on a weekly and eventually daily basis. The increasing availability of imagery allows the ag industry to fully leverage its notification capabilities by providing actionable crop condition updates.

Tremendous disruption is underway for the satellite imaging industry, and the most notable breakthrough is the ambition of several well-funded entities to supply global satellite coverage with high-resolution daily imaging through small low-cost satellites that form constellations of "birds" of Microsats or CubeSats. The CubeSat low-orbit standard format is revolutionizing how satellites are used by providing much of the performance of a conventional satellite for a fraction of the cost by using many off-the-shelf micro technologies.

The low cost of these micro satellites enable increased launches and therefore high frequency data. This creates a radical new data set, which makes clear a need for advanced processing and distribution technologies. The paradigm shift in the satellite imaging industry is that a current lack of image availability will quickly swing towards overcapacity over the next 10 years.

The first private companies to build CubeSats already have a significant amount of traction and are entering their latter financing rounds with strong proof of concept. Critical design is complete and the focus has shifted to large-scale manufacturing and deployment. Many companies are planning to launch extensive constellations, several of which will cost in excess of $1 billion.

At the same time, traditional satellite cost is also declining and many planned launches for relatively smaller and infinitely more powerful structures exist as well. Upcoming generations of satellites will also use new technologies like short-wave infrared, which is capable of seeing through smoke, clouds, fog and other particulates. The most recent or identified upcoming Satellite launches (traditional and CubeSat) will provide consistent global coverage and a nice scale to meet agricultural needs.

Satellite imagery has a relative advantage over other imaging aerial platforms given its comprehensive geographical coverage, lack of permission issues, cost effectiveness, and rapidly increasing analytical capabilities. A single satellite image can cover millions of acres, enabling cost effective coverage.

New satellite launches will make consistent weekly access to in-season imagery possible, providing growers real-time crop conditions. Scheduled satellite launches, will provide daily curated imagery for users. Advancements in remote sensing analytic capabilities from satellites coupled with increasing adoption rates for Precision Ag services in general, are projected to drive considerable demand for the industry. This increased availability of imagery will allow farmers to fully leverage image notification capabilities by using actionable crop condition updates.

Most satellite imagery is used as a crop health vegetation analyses overlaid on a precisely bound, recent satellite image of a grower's field. These images and analyses provide valuable insight for pre- and in-season crop conditions. Field image analysis employs a variety of data correction techniques on orthorectified satellite imagery and then applies a set of index algorithms which interpret channel wavelength data.

Precision Ag software systems display this data as an image, enabling growers to easily view several measures of crop variability such as biomass diversity. Primary crop health indices include NIR, NIR Red Edge, NDVIR, NDVIG, and NDVI Red Edge. These graphical indicators enable users to easily build variable rate application maps or identify precise in-field zones to scout. Currently, Satellite processed spatial resolution of 5 meters provides the ideal mix of analytic capabilities, image cost, and geographical coverage.

Many precision agriculture platforms employing imagery rely on low resolution imagery for cost savings, delivery now of 5⁄10 meter resolution imagery provide a drastic improvement over the industry standard Landsat images, which are often only available 2–4 times per season. While irregularities can begin to be seen with 30 meter imagery, the reduced resolution also makes these images a less effective tool for precision applications. Distinct advantages of a high resolution quality data layer is essential for the level of accuracy for performing agronomic cross-analysis activities including definition and adjustment of management zones for variable rate applications.

For super high resolution imagery from 1 MM to 6″ resolution, The market for unmanned aerial vehicles (UAVs) commonly known as drones will be available upon approval by the FAA, which infant drone technologies seek to fill the white space left by satellites. UAV's have a place along the modern agriculture imaging chain, and the marketplace will eventually grow once standardized, processing and delivery drone imagery will be little different than that of aerial imaging or satellites.

Despite its limitations regarding logistical processing and scalability, the commercial unmanned aircraft systems market is projected to experience growth as a result of the integration of UAVs into the National Airspace System. UAV data will be more available following clarity on legal permission issues, standardization of imagery, and decreased bandwidth utilization.

UAV's do present problems associated with managing the data load because of the massive amount of pixel data, and the stumbling logistical points of platform execution. UAV's do not currently provide scale and coverage, and are akin to fine dining for imaging. Big geospatial data systems are being developed to capitalize on this opportunity by easily incorporating UAV data into its existing data storage and analytical framework, This will require bigger servers and more bandwidth, but future core architectures will handle any data load to scale across the agriculture sector.

A strong platform for imaging will ultimately fuse the use of UAV, satellite and aerial imaging, and capture the benefits of each source. With scalable infrastructure, these big geospatial data systems will have the ability to expand data curation, analysis, and delivery capabilities to include diverse geospatial data in raster and vector formats, from micro-weather sources, and soil sensors, among others.

Satellites, Airplanes and UAV's will solve the problem of imagery access in the near term, and successful systems will deliver these images in a useful format to the common grower. However, capabilities in a decision support system within the cab will make the biggest impact in terms of decision-making on the farm. Distribution of real-time data streams, coupled with unbiased education regarding how to leverage this information is really the Holy Grail of platform execution. Simplifying the massive data to meet the daily needs of the common grower through decision support modules will change the farming paradigm!

Big Data—Cloud Structure—Todays Big Data Is Tomorrows Small Data!

Cloud systems are becoming logical steps towards building a larger platforms for data storage, analysis, and mosaic processing, enabling distribution and management of mass amounts of satellite, aerial, and UAV data.

Service providers, resellers and operators concur that the Internet is a key enabler in disseminating (EO) Earth observation data and services. Web-based platforms are becoming common for storing and distributing data sets and products, and will continue to provide innovative delivery platforms from which users can obtain data and services.

A pillar of wide-ranging user ecosystems that include leading agronomic data providers, growers, cooperatives, crop consultants, crop insurance companies, dealers, crop input retailers, equipment manufacturers, and independent dashboards will become more available. Internet platforms and distribution is expected to be the important tool for attracting enterprise and private users in the effort to bring EO data to the masses.

With these systems, Big data is now transforming modern agricultural practices by ingesting real-time field information into geospatial mapping systems. These systems along with big data allow farmers to get more out of their arable land in order to meet rising commercial agriculture production needs. There are few big data platforms which have proven to be scalable globally, particularly in areas of the world where there is limited access to historical yield, weather, water, topography and soil data to develop decision algorithms and support optimization of various agronomic models.

In more advanced agricultural markets like the United States, data platforms struggle with logistical issues like quality of data acquisition and privacy. For reasons like these, the market is becoming increasingly reliant on satellite imagery technologies to collect real-time field crop data to inform GIS models for pixel-level applications.

A focus on data cloud imagery infrastructure enables image providers to develop a range of applications that previously required complicated contracts with data providers or the maintenance of a separate geospatial database. Robust open platform user ecosystems continue to grow through an increasingly diverse group of agribusiness related entities, as third party developer momentum proliferates.

Cloud infrastructures for back-end distribution for digital imagery curation and distribution capabilities are needed to highly scale to the ag sector. Once an image is delivered, users can measure, or project growth characteristics such as early season crop vigor, biomass, or yield variations through agronomic modeling. These models may determine economic return variability, define effective management zones, or inform timing of planting, treating, and harvesting the crop.

Through the culmination of years of software development, leveraging cloud-driven distribution capabilities in a manner that provides more timely and frequent field management insights, companies like us are providing synergistic benefits and allow users to also leverage the clouds data infrastructure for easy storage, management, and sharing of their agronomic data. Cloud data systems must permit users to import other geospatial data layers such as UAV imagery, aerial imagery, and soil sensor data. For imagery, analysis tools must be broadly applied.

Cloud Data delivery and notification infrastructures are also extending into third party software through API's (Application Programming Interface). Core API structures must be enterprise ready and provide retrieval and batch processing of multiple value-added images from a single imagery hub. Also platform partners must be able to redistribute image products to a growing number of connected applications and users.

Push to Grower Technology

Data notification platforms are massively becoming deployable through relatively frictionless distribution. To accelerate scale, companies can intentionally omit direct recommendations, in favor of offering the most impactful set of applications and data for the use of their grower/advisor clients as support for individual judgments. The ability to link geospatial data and imagery with precision to areas within the individual farm field gives a distinct grower touch and results in the ability to deliver unique and highly relevant data. Data image hubs can effectively reach the edges of a mass user base at a fraction of the overall cost.

Distributing predominantly high-resolution imagery, directly to the cab will help ease the case for precision management and machine empowerment through automation. Solutions must be scalable for rapid integrations into large agribusinesses. Enterprises must be able to quickly set up and link users to fields through extensively attributed databases and allow tools for the creation of a hierarchy of users, which enables clients to track interactions for active field management and big data analytics which will offer unique opportunities to immediately acquire a scalable, robust, and vertically focused imaging platform for agriculture.

Platforms that are successful will tactically and strategically use cloud core code to enable a broad range of solutions for tracking user activity for social or ecosystem benefits while leveraging the cloud notification systems backbone to generate real-time, relevant dialogue with the grower. This allows scalable big data analysis through a network of APIs and advanced database-level algorithms, which users can access a system that is limitless in data-depiction and manipulation.

Mobile Apps

Mobile Image analytics software apps are now mostly cloud-driven, and used for in-field decision support solutions. These mobile applications offer analytical tools specifically focused on in-field analysis which enable users to define management zones for variable rate applications as well as track in-field crop condition events.

Scouting tools within the app also provide tracking capabilities for users to record all the harvesting, soil-testing, and scouting events that take place throughout the season. Events are linked directly to field boundaries, allowing the information to be included in any related analysis. Additionally, "Photos" tabs give users the ability to shoot in-field images of problem areas from their mobile devices. These photos are precisely geo-tagged with the geographic coordinates of where they were taken.

These mobile apps not only provide satellite and aerial imagery based analytics, but also seamlessly incorporates UAV imagery into the apps platform. When users conduct in-field biomass analyses based on satellite imagery, they are directed to specific zones of concern within the field. This streamlined process allows for targeted high resolution UAV imagery to detail leaf-level crop conditions. This synergistic use of satellites and UAV's provides the optimal mix of data storage and detail for large scale management. Mobile in the field platforms show the consultant to the variations in the field. The consultant has the option to take a picture of the affected area and beam that right to the management team back at the office for immediate management techniques.

Next-Generation Notification Capability: Automatic notification of field observations is fundamental to next generation customer acquisition and user interaction. Using multiple imaging sources to increase frequency and quality, normalizing all images, and introduce change detection algorithms in the near term and will be scalable globally, likely driving adoption of the notification center and the platform in general.

Crop Insurance Claim & Compliance Analysis

Satellite imagery has also been used extensively for 10 years or more for Crop Insurance and field loss claims.

The USDA/RMA and the crop insurance industry uses satellite imagery to evaluate crop damage and assess a more accurate loss analysis of the crop loss event. Imagery is taken from satellite archives before the damage event and another image is tasked of the area after the event. An analysis of vegetation conditions are provided by acreage and percentage of vegetative change to the adjustor in the field, resulting in a more accurate loss determination. Imagery is also used in fraud claims to evaluate losses from previous year to determine accuracy of the adjustment.

For crop loss determination, users can track crop loss claims and reports while at the same time analyzing vegetation loss through satellite imagery analysis. Features include claim tracking, map creation of field location, with GPS coordinates plus acreage of analysis using a satellite image taken 10 days of the loss. Map report generation of the vegetation zone characteristics by acre and percentage. Loss maps are printed and emailed to the loss adjuster in the field.

Imagery is also used for creation of Crop Insurance map booklets tied to historical insurance yield information. For crop loss determination, imagery is used to evaluate crop damage and assess a more accurate loss analysis of the crop loss event.

AG Intelligence

Agricultural uses of satellite imagery to date, have historically focused on broad macro-based evaluations, such as regional, national, and international estimates of acreage and yield. However, agribusiness's demand for satellite data is shifting to a more micro-based (local area, individual farm, and in-field) focus. The primary driver in this shift is the increasing adoption of precision farming techniques for increased crop input and yield maximization efficiency.

Individual field vegetation analysis of satellite data provides users access to enhanced tools to process and analyze satellite imagery of comparable fields or groups of fields. Imagery analysis involves quantitative evaluation of satellite images for patterns and trends. Crops and vegetation, can be compared by farm to farm or county by county by a host of agronomic vegetative factors.

Software platforms will continue to be developed further to provide more advanced crop monitoring tools automatically for the Agribusiness community and provide detailed reports of crop acreage conditions. This allows grain buyers/traders to quantitatively assess the impact of drought conditions. Similarly, users can use tools and datasets to evaluate crop growing conditions.

The need for future food security for evaluating crop levels will allow stability of the food supply for Worlds needs. In the past few years, volatility in crop prices has been caused by a lack of real-time information on crop conditions and their levels of productivity. For example, in the 2010 season the agriculture grain trading industry was affected by the inadequate crop information sources of the Russian wheat crop, resulting in a 50% increase of prices within weeks.

Also these past years, inaccurate USDA crops report have resulted in an increase in crop prices that has affected the stability of commodity stocks , like corn and soybeans. The ability to track crop information down to the field level and its infield variability tied to grower operator information will result in new tools to allow the food security situation to be addressed.

The ability to have real-time information of crops is invaluable for the proper pricing of commodities. Satellite imagery provides real-time crop information across the country and the world throughout.

Crop Identification, Crop Acreage Estimation and Yield Evaluation

Many new satellites have just been available in the past years. These new satellites have changed the logistics in accessing real-time growing information like never seen before. New satellites system can access ten times more information real-time than current and previous satellites. World coverage of satellite images and data linked with field boundary data allows multiple satellite sources in varying resolution and footprints to remotely:

- Identify crops, current vegetation and crop density.
- Evaluate and track crop growth trends against other regions, other years.
- Assist crop insurers to estimate risk based on vegetation patterns and confirm loss claims.
- Assist Farm lenders to evaluate current and potential crop income.
- Provide grain buyers visibility to available grain production acres.
- Early detection of crop stress (weeds, disease).
- Accurate mapping of damage (hail, floods, *etc.*) for insurance purposes.
- Estimated current vegetation using biomass information which has been calibrated with verifiable crop data.
- Precipitation and weather data.
- Previous crop rotation (*i.e.,* is their current vegetative state the product of a good crop year or crop rotation).
- 3D topographic elevation of each farm field.
- Biomass Index that allows to estimate current level of vegetation in regular (*e.g.,* every 3–4 days) intervals.
- Weather reports tied to Grower degree days and crop stages relating to Vegetation Image maps.

Other developments in the market include environmental monitoring, for carbon management and food security. Technologies allow regulators or the market to accurately define the level of total biomass carbon sequestration on agricultural land and its acreage. Identifying and monitoring actual carbon sources and carbon sinks within a given region or farm, with comparisons of net carbon dioxide emission sources amongst individual crop fields, can improve annual reporting of carbon sequestration levels per agricultural grower.

Hyperspectral Imaging

Applied research for high spectral resolution imagery in agriculture is increasing due to availability of new image sensors. This technology is expected to gain high levels of adoption in the future once new spectral libraries are created, improving efficiency and market awareness of detailed crop conditions.

The benefits of hyperspectral imagery lie in its ability to attribute a complete wavelength spectrum to each individual pixel. This creates hundreds more spectral bands than multi-spectral imagery, enabling precise measurements that support a variety of agronomic activities. This includes added accuracy for yield predictions, vegetative stress detection, seed stock differentiation, and crop tillage methodology assessments. Advancements in hyper spectral remote sensing and applied research will provide users added precision for better yield projections, vegetative stress detection, and crop quality differentiation.

Future Agricultural Imaging Trends

Curated imagery provides a powerful data layer along with robust suites of analytical tools to support long-term agronomic decision making processes. High volume satellite image distribution platforms have ben available for agriculture for a number of years, and as the commercial space industry releases next generation satellites capable of more frequent in-season monitoring, scalable, high utility components for agronomic platforms must be available for the agricultural information market

Big data will be an ever increasing concern because of the massive amounts of information we gather for defining our fields needs for more efficient production. The tech industry has the infrastructure to handle this growth. The main issues are data privacy and security concerns which need to be addressed, and the proper rules applied for secure access to agricultural data. These issues can be resolved by looking at other industries data policies, and to allow open data standards to continue to develop. Transparency of data will be key to the growth of the agriculture information industry to allow new technology to proliferate and create a robust food industry for our future growth as a society.

Sincerely,

RODNEY "LANNY" FALEIDE,
President,
Satshot Inc.

Mr. LUCAS. Thank you, Mr. Faleide.

Mr. Crago, you are recognized for 5 minutes. Pushing that button is always important, yes.

STATEMENT OF TIM CRAGO, VICE PRESIDENT, NORTH WEST GEOMATICS LTD., CALGARY, AB, CAN; ON BEHALF OF CRAIG MOLANDER, SENIOR VICE PRESIDENT, BUSINESS DEVELOPMENT, SURDEX CORPORATION, CHESTERFIELD, MO

Mr. CRAGO. It is only one button. You think I could figure that out.

Mr. Chairman and other Members of the Subcommittee, thank you very much for the opportunity. I appreciate it very much. What I would like to provide is a bit of a discussion on the innovation in the air, and specifically as it relates to the NAIP Program, which is the National Agricultural Imagery Program. This is a longstanding aerial imagery program that was initiated and is currently maintained by the Aerial Photography Field Office out of FSA in Salt Lake City. The program has been running since 2002, and from its beginning and what it is today is a program that collects high resolution aerial imagery of the entire lower 48 states, currently, on a 2 year refresh cycle. There are three prime contractors that are awarded 5 year contracts with annual task orders issued, and these companies work in collaboration with the APFO in Salt Lake City and with each other in ensuring that the entire lower 48 states are covered on a 2 year cycle.

The program is interesting in the way that it came about, and as it has evolved over the years. What I would like to do is find my presentation and put some examples of the imagery up for you to view. There we go. Thank you.

So this program is undertaken with aircraft, and as it has evolved over the years, it has taken advantage of technological advances in the sensor technology. What you see on the screen here are two images taken last year in Wyoming, one standard color RGB, the one on the right is color infrared. These two renditions are part of the visible spectrum that are acquired simultaneously by a single sensor. Another example of it from Craighead County in Arkansas, again taken in 2015.

This evolution of the technology that has occurred has really been a result of driving from the USDA from FSA, and manufacturers of these sensors in trying to accommodate the requirements of the USDA and undertaking its role in providing this type of data to the USDA and to the farmers themselves.

Here is another example of the ability to take this imagery and provide a 3D version of it, simply from a single flight.

One of the innovations that has occurred, and you can appreciate that this data is acquired, the value of the data is getting the data into the hands of those folks within FSA that have requirements with respect to management of various programs, including RMA programs and other programs within the USDA.

The urgency of getting this data and the currency of this data is of utmost importance. One of the innovations that has been driven by FSA has been the requirement now to provide this data within 5 days of a flight, so you can appreciate that at the beginning of the program, delivery times were something in the order of months, and today we are delivering the imagery to Salt Lake City within 5 days of acquisition. It is made available through a web service, and it is available to all participants within the FSA and their requirements for compliance and monitoring.

To give you an idea of what we are talking about here, to cover ½ of the lower 48 in a single acquisition season—and remember, an acquisition season is during peak crop growing times—the three contractors that undertake this work have, at any one time, up to 25 aircraft with sensors in the aircraft. Some of the parameters for the acquisition are 35,000′ altitude, speeds of up to 200 knots.

In summary, what I want to communicate to you is some of the improvements that have occurred and the importance of this program in the sense that the original program was partial state coverage. This is now full state coverage. It is ½ of the 48 states. Resolution has gone from a 2 meter acquisition now to some states being done at a ½ meter resolution. Originally the program was all film. It is now all digital. It is all multiband. Accuracy is an extremely important part of this when you consider the comparison and use of CLUs and other land units in relationship to the imagery. Delivery, as I said, has gone from several months down to 5 days. And finally, what we have is a program now that is being undertaken for approximately ½ of the cost that it was being undertaken with as recently as 5 years ago.

This funding issue is probably one of the most significant ones in the sense that the program is not authorized specifically for the NAIP program, and you can see in this chart the fluctuations in the funding. The desire of the USDA and FSA and the APFO in Salt Lake City is complete 48 state coverage within 1 year. That would require an authorization of approximately $30 million per year. The last couple of years, we have been able to secure funding for about ½, and this is a consideration we would like to put to the Subcommittee is consideration of an authorization for full 48 state acquisition annually at an annual cost of $30 million per year.

And with that, I will thank you for your time, and I would welcome any questions later. Thank you.

[The prepared statement of Mr. Molander follows:]

PREPARED STATEMENT OF CRAIG MOLANDER, SENIOR VICE PRESIDENT, BUSINESS DEVELOPMENT, SURDEX CORPORATION, CHESTERFIELD, MO

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to testify at this morning's hearing on "Big Data and Agriculture: Innovation in the Air." I am Craig Molander, Senior Vice President of Surdex Corporation, one of the three prime contractors working with the USDA's Farm Service Agency (FSA) to implement the National Agricultural Imagery Program or NAIP. With me is Tim Crago, Vice President of North West Geomatics Ltd., representing another of the three NAIP contractors. Surdex and North West have each been involved with NAIP for 15 years.

Agriculture, because of its tie to the land, has been a leader in mapping since the 1930s when USDA first began collecting aerial photography of farmland on a small scale basis, then consolidated its efforts with the Aerial Photography Field Office in Salt Lake City (APFO) in 1977. NAIP was initiated in 2002 to coordinate the collection of imagery in support of the administration of FSA farm programs. Today, NAIP imagery covers the entire lower 48 states and has achieved a 2 year refresh cycle. It is safe to say that this is the largest continuous imagery mapping program in U.S. history.

So useful has NAIP imagery become that a 2014 National Earth Portfolio Assessment by the White House Office of Science and Technology Policy ranked NAIP as the fifth most important of 149 existing [E]arth observation systems in terms of assisting Federal agencies and providing societal benefits. Much of the imagery in consumer products, from automobile GPS systems to web services companies, that consumers assume originate with satellites, actually come from NAIP and other aerial sources.

Imagery from satellites and drones also play vital roles, and we appreciate that this hearing has been structured to explore the importance of each of these technologies in a complementary fashion. NAIP, however, has demonstrated that aerial imagery acquisition is uniquely capable of providing widespread coverage that meets the demanding seasonal windows aligned with peak crop growing seasons and weather and cloud constraints.

Within USDA, NAIP imagery is a key geospatial data layer for FSA, the Risk Management Agency (RMA), the Natural Resources Conservation Service (NRCS), the U.S. Forest Service (USFS), and the Animal and Plant Health Inspection Service (APHIS), which use it for a variety of farmer services and program compliance functions. But NAIP imagery is used far beyond USDA itself. It is made available both government-wide and to the public for digital download, purchase at nominal cost—literally the cost of a thumb drive—or web imagery services hosted by the APFO. Within the Federal Government, other users include the Department of [the] Interior and its U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, Homeland Security, the Census Bureau, and the National Geospatial-Intelligence Agency. State and local governments use NAIP imagery to support functions from law enforcement to fire and emergency services to crisis management to transportation to urban planning to natural resources management and monitoring. In the private sector, NAIP imagery has become an essential tool for companies involved in mining and energy, urban planning, engineering, and environmental analysis. *Attachment A* shows the range of entities using NAIP imagery from the USDA NRCS portal.

Finally, individual farmers and their supporting services use NAIP for a host of farm management functions. They are a foundation for FSA's Common Land Units, crucial to acreage reporting for crop insurance and farm programs, and are integrated into precision farming, agronomic analysis, and irrigation systems. *Attachment B* is a list of typical NAIP farmer uses. In order to assure consistency and avoid duplication, the NAIP program, and particularly its technical specifications, are coordinated though the government-wide Federal Geographic Data Committee created in 1990 by OMB Circular A–16 and co-chaired by the Secretary of [the] Interior and the Deputy Director of OMB, as well as its National Digital Orthoimagery Program (NDOP) subcommittee.

The collection and processing of NAIP imagery each year is a substantial undertaking that has required continual investment by contractors in equipment, software, and process refinement. Imagery is acquired under "leaf-on" conditions during the growing season in order to reflect crop status. This is in marked contrast to nearly all other Federal, state, and local government "leaf-off" projects at higher resolution for traditional mapping. The aircraft used in NAIP, approximately twenty-five of them in 2015, represent an investment of $2.5 to $3.5 million each. These aircraft operate at up to 35,000′ using multi-spectral sensors yielding color and color-infrared imagery. Standard NAIP products include Compressed County Mosaics (CCMs) and Digital Orthophoto Quarter-Quadrangle (DOQQ) imagery. In recent years, the contractors have implemented Early Access Web Services (EAWS) to provide initial imagery within 5 days of acquisition, allowing USDA and its Federal partners to begin analysis earlier and meet demanding reporting timelines.

NAIP imagery fits seamlessly into modern Geospatial Information Systems as a "base layer" that is combined with other layers such as farm program data, information on structures and underground pipelines, political boundaries, financial and [C]ensus information, land agronomics, elevation data, soil qualities, addresses, so on. Often, these systems also incorporate imagery from drones and satellites to address special needs, creating powerful systems for business, government, and science.

Over the years, we have witnessed numerous improvements in NAIP:

- *Cost:* The program cost has fallen sharply from an estimated $55 million per year to cover the entire lower forty-eight states a few years ago to now just below $30 million, a result both of improved technology and excellent program management by FSA's APFO. APFO has reduced the program to three prime contractors (down from as many as ten early in the program) to streamline management and coordination.
- *Quality:* NAIP imagery is now entirely captured with digital sensors rather than film cameras, and has improved in clarity to as fine as ½ meter resolution, thus meeting established map accuracy standards at the highest level. The multi-spectral data can be exploited using automated classification for investigation of plant health, spread of infestations such as bark beetles and the like. The success of the program has resulted in its standards and guidelines being adopted by many other Federal, state, and local projects.
- *Speed and currency:* Initial imagery is now available within 5 days of acquisition and final products within 30 days. With resolution of the funding issue discussed below, it is possible to provide coverage of the entire lower 48 states on an annual basis, which would provide substantial benefits to program users. User surveys conducted by the USDA and organizations such as the National States Geographic Information Council (NSGIC) highlight the need for annual coverage. Surveys by the USDA have shown a consistently very high level of satisfaction among NAIP users.

The result of these improvements has been an extremely high return on taxpayer dollars, a high value for funding partners, and more widespread use both by public- and private-sectors.

The single greatest concern regarding NAIP is its funding structure that has resulted in instability. Since NAIP originally was created as an internal oversight/service initiative within the FSA, it has been funded primarily out of FSA's own "salaries and expenses" appropriation—despite the program's wide use both by government and the public—and without a separate statutory authorization from Congress. FSA's support for NAIP has been strong and unwavering, a principal reason that NAIP has survived several years of budget constraints. FSA annually provides about ⅔ of the annual cost of NAIP, with its partners, notably USGS, NRCS, and USFS, funding the remaining portion along with occasional investments by state partners. As mentioned earlier, public users of NAIP and noncontributing government agencies obtain imagery essentially for free.

This situation has placed FSA in a difficult position with regard to NAIP, and the result has been unpredictable program funding. (*Attachment C* contains a chart showing the annual NAIP funding from 2003 through 2016.) In years when FSA faces severe internal funding needs—be it staff training, implementation of farm bills or other major legislation, computer upgrades or maintaining field offices—these create direct competition for funding NAIP. In some years, FSA has been forced to turn to the Commodity Credit Corporation to fill the gap. In other years, contracts were finalized too late for much of the growing season.

For this reason, we have long advocated that Congress adopt a statutory line-item authorization and appropriations for NAIP as a basis for long-term funding stability. We hope you will consider this idea in upcoming legislation.

From our collective experience in contracting with Federal, state, and local government, we at Surdex and North West Geomatics have found NAIP an exemplary illustration of a true government-private partnership that has improved products and services and exploited technology to lower costs, resulting in expanded coverage. Our annual contractor meetings with APFO at the end of each year to review lessons learned and explore improvements features open discussions benefitting both sides and, most importantly, improve the quality, accuracy, and timeliness of our imagery for the end-users.

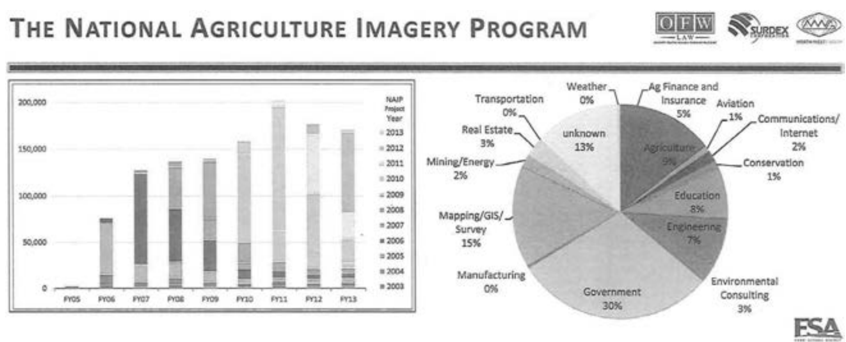
Thank you again for the opportunity to appear at today's hearing. We would be glad to answer any questions you might have.

ATTACHMENT A

Data Distribution by the USDA

Downloads of CCMs from the USDA Geospatial Gateway

Downloads by Usage



Note: *APFO CSS more than offset the drop-off in 2012–2013.*

Graphics courtesy of Farm Service Agency.

>30% are from some level of government.

ATTACHMENT B

How Farmers Benefit from NAIP Imagery

Managing their Farms:

- Keep current, effective farm records.
- Oversee operations and plan new projects.
- Find best locations for grain bin and other farm structure locations for loans.
- Identify urban encroachment, sites for new buildings, gas and oil well development.
- Review topography changes around waterways after flooding or other extreme weather.
- Identify and plan irrigation changes.
- Assist with crop reporting.
- Support program appeals.
- See surrounding lands and fields for comparison and planning.

Receiving benefits from USDA agencies:

- Respond to inquiries on USDA programs.
- Self-check for program compliance.
- Verify crop history and planting patterns.
- Apply for and receiving disaster response/assessments.
- Manage food plots on CRP fields and CRP-managed haying and grazing acreage.
- Assess, monitor, and address crop and animal disease outbreaks with APHIS.
- Assist U.S. Forest Service in managing forest lands.
- Work with NRCS on resource assessments & inventory management.

- Benefit from NASS, ERS, and University statistics and ag. Research in USDA program; management and development.

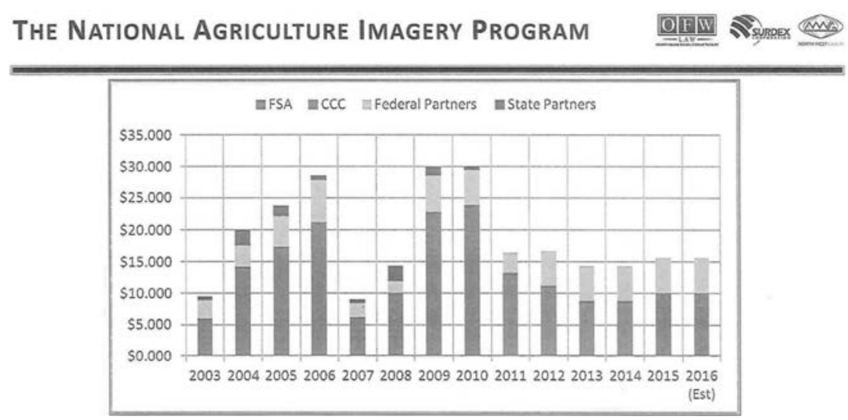
Receiving services from private vendors:

- Agricultural industry:
  - Precision farming systems.
  - Agronomic services.
  - Private insurance offerings.
  - Irrigation consultants and monitors.
- Tool for obtaining carbon offsets where available.
- Basis for Google Earth, Microsoft Maps, and OPS navigation systems used by farmers.
- Forestry management companies:
  - Inventory and financial planning.
  - Fire tracking and mitigation.
  - Riparian analysis.
  - Fire inventory.

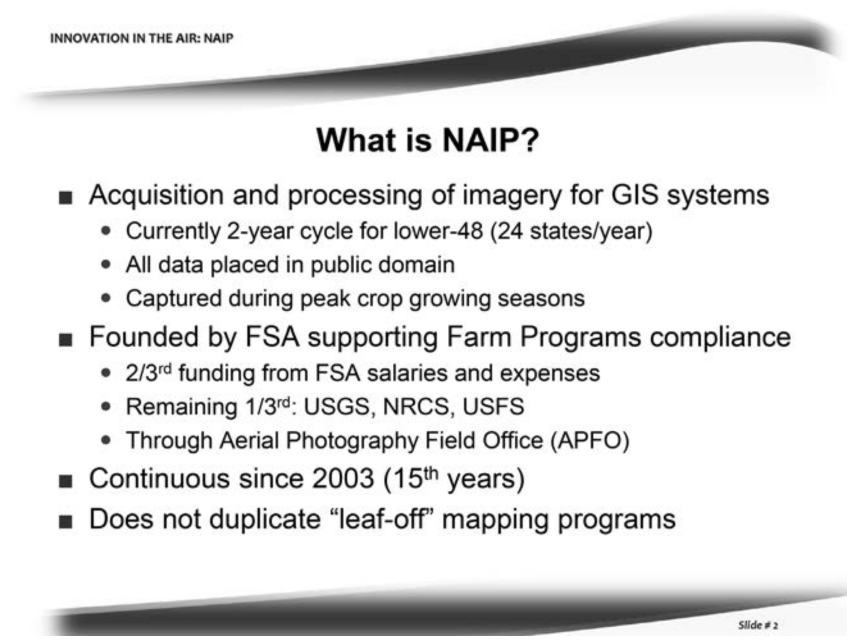
ATTACHMENT C

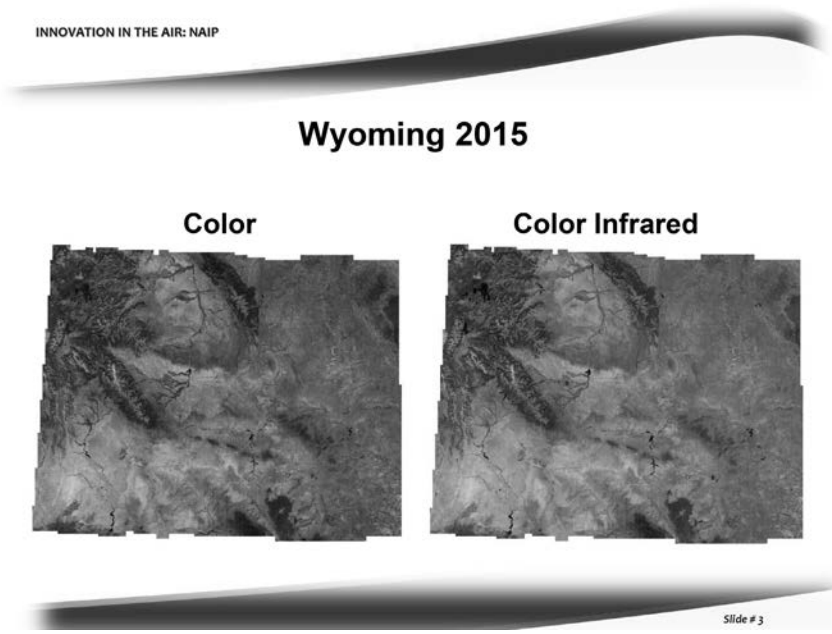
Funding Challenge

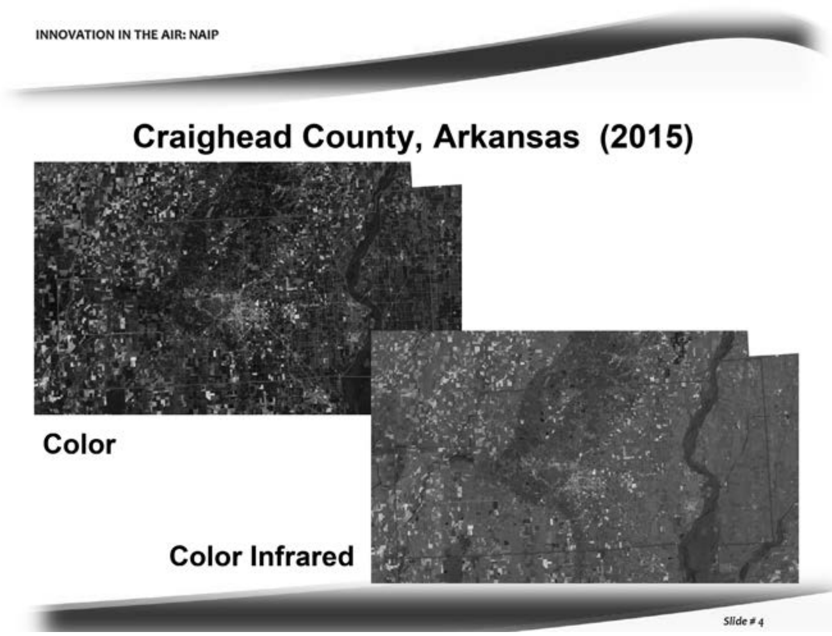
CCC Funding Replaced FSA S&E Funding for 2011–2014



POWERPOINT PRESENTATION




INNOVATION IN THE AIR: NAIP
Wyoming 2015
Color
Color Infrared
Slide # 3


INNOVATION IN THE AIR: NAIP
Craighead County, Arkansas (2015)
Color
Color Infrared
Slide # 4

Visualization (Wyoming, 2015)

Early Access Web Services (EAWS)

- *Preliminary imagery uploaded <5 days after acquistionn*
- *Earlier analysis, more timely reporting*

Color and color infrared viewed on IPad

Mississippi, 2016

INNOVATION IN THE AIR: NAIP

Imaging Requires up to 25 Aircraft Each Year

- *During peak crop growing periods*
- *Flight up to 35,000' (nearly 7 miles)*
- *Multispectral sensors: color and color infrared simultaneously*
- *Total investment of $2.5M-$3.5M for each aircraft*

Slide # 7

INNOVATION IN THE AIR: NAIP

What Technology and Government/Contractor Partnering Has Done for NAIP and Its Users…

- **Improvements…**
  - **Coverage**: partial state to complete state
  - **Resolution**: 2-meter to trend to 0.5-meter
  - **Method**: film to multispectral digital
- **Benefits…**
  - **Accuracy**: none to national map accuracy standards
  - **Currency**: 3+ year cycle to 2-year
  - **Delivery**: 90 days to 5 days initial/30 days final
  - **Costs**: continuous reduction

Slide # 8

INNOVATION IN THE AIR: NAIP

FSA: Updating Farm Records

Visual Interpretation

Tabular Farm Records

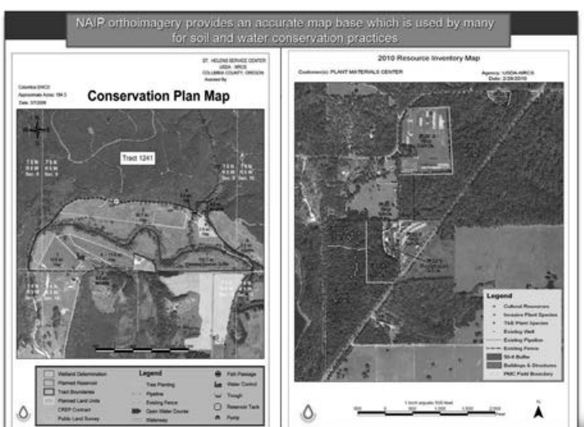
- Ownership
- Land use
- Acreage
- Crop history

Graphics Courtesy of FSA

Slide # 9

INNOVATION IN THE AIR: NAIP

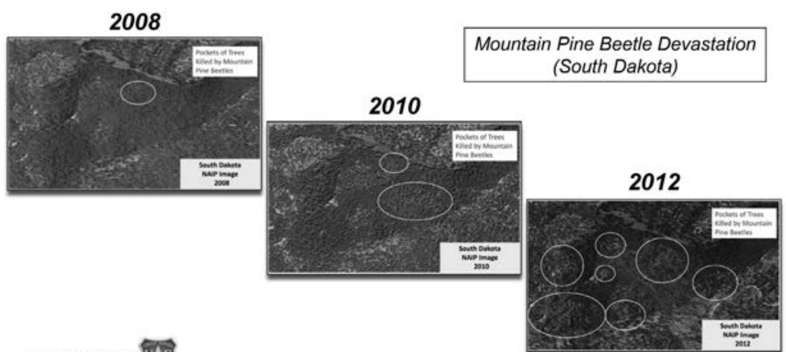
NRCS: NAIP Provides Accurate Base Layer



Graphics Courtesy of NRCS
Natural Resources Conservation Service

Slide # 10

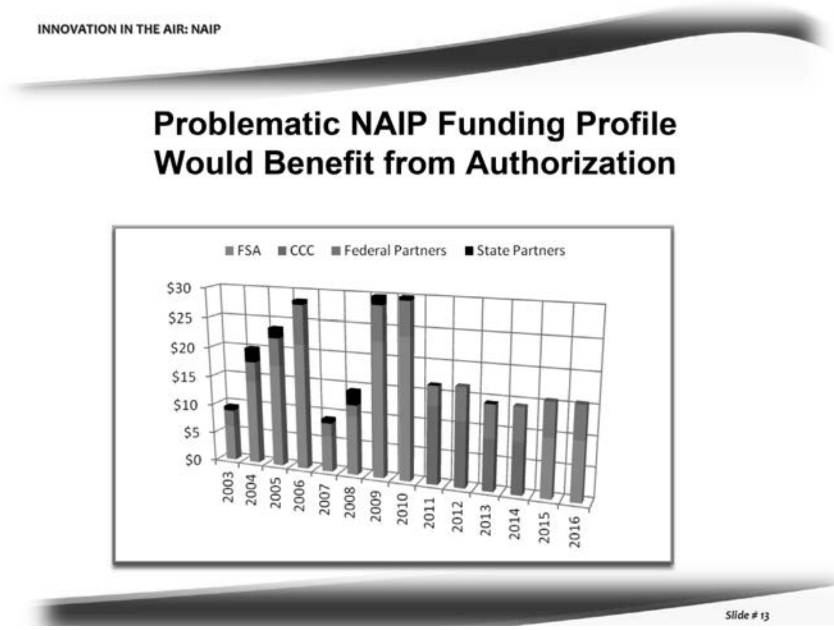
Tracking Infestation with NAIP Imagery



Graphics Courtesy of USFS

Who Else Uses NAIP?

- Nearly every federal agency
  - Departments of Interior, Commerce, Census
  - Department of Homeland Security
  - National Geospatial-Intelligence Agency
  - US Army Corps of Engineers
- State and local government
- Private engineering, environmental, mining, oil & gas, planning



Mr. LUCAS. Thank you, Mr. Crago.

Mr. Blair, whenever you are ready, you may proceed.

STATEMENT OF ROBERT BLAIR, VICE PRESIDENT, AGRICULTURE DIVISION, MEASURE, THE DRONE AS A SERVICE® COMPANY; OWNER/MANAGER/OPERATOR, BLAIR FARMS, KENDRICK, ID

Mr. BLAIR. Okay, thank you.

Good morning and thank you, acting Chairman Lucas, acting Ranking Member Graham, and Members of the House Subcommittee on General Farm Commodities and Risk Management. I am honored to be here today and I appreciate this opportunity to discuss the benefits of Unmanned Aerial Vehicles, UAVs for short, in agriculture and some of their challenges. My name is Robert Blair, a fourth generation north Idaho farmer raising wheat, barley, peas, lentils, and garbanzo beans on the rolling hills of the Palouse. I am also the VP of Agriculture for Measure, the leading Drone as a Service® Company. We put pilots and systems in place for agriculture and other industries to collect data and return it to the customer in a timely manner.

Agriculture has a tremendous challenge and responsibility of producing enough food to feed nine billion people by the year 2050, and doing so sustainably. Global agriculture is under increased pressure from different sectors to reduce water use, reduce erosion, and reduce inputs, while increasing crop quantity and quality. The agriculture industry cannot do this alone, but utilizing precision agriculture technologies, especially UAVs, those working and managing the land can be successful in this mountainous challenge.

For five generations, my family has incorporated new farming technologies and practices to raise better crops with less labor and inputs. Our farm was started in 1903, and my family has gone from using horses to continually updating tractors through the years, tractors that have computers and technology, allowing for placement of inputs exactly where they are needed from information collected from a UAV.

Many things affect crop production, especially weather and management. The slide you are looking at is from a 2015 study conducted by Measure and multiple sponsors, many in agriculture. The study shows crop yield gap reduction potential is reduced approximately 20 percent. This study also shows that UAVs can positively affect the management gap by 25 percent. Based upon my own experiences, UAVs can also reduce the impacts caused by weather.

Any aerial data needs to fit into a cab to be useful, otherwise it is just a picture. Today's agriculture machinery has the capability to apply multiple products, either full boom, in sections, or by individual nozzles. Data collected from UAV can be used by the farmer to do crop application in all three instances.

With the announcement of Part 107 on Tuesday by the Federal Aviation Administration, there is a certainty that UAV operations are here to stay in the United States, and agriculture can benefit. However, there is still work that needs to be done. Agriculture cannot wait for a slow application process to fly in restricted areas that results in losing a generations' worth of information. Capturing photos and videos from a UAV is not enough. Agriculture needs friendlier regulations in place that allow for UAV application of products. Furthermore, Congress and USDA need to start working today to incorporate UAVs into the next farm bill, while the FAA should strongly consider giving agriculture a seat at the UAV rulemaking table.

I started my precision ag journey in 2003 doing simple mapping with a PDA and a magnetic receiver. Holding everything at the same time was difficult, as you can see here, trying to pull out the stylus. Well, following the footsteps of what farmers have done for centuries, I created the solution to the problem by riveting a piece of metal on the brim of my hat to hold the receiver. This same hat represents an opportunity today to start shaping a new solution for the Risk Management Agency and crop insurance industry by utilizing UAVs to assist and adjust for claims. Currently when a hailstorm damages my crops, I would go out in the field with the adjuster. After walking into the crop where I am guessing damage occurred, the adjuster or I would throw the hat and do the official inspection. UAVs can collect high resolution images ahead of boots-on-the-ground inspections so farmers and adjusters can go to those exact areas that are damaged. No more hat throwing.

We are in the information age where timing of data is becoming more critical every day. The precision agriculture industry is already trying to put a fire hose worth of data through a straw, and with the announcement of Part 107, the amount of data collected will only put more strain on an inadequate Internet infrastructure in rural America, and will only compromise the ability of American farmers to compete in a global economy.

With today's low commodity prices and tighter margins, UAVs and companies like Measure can help reduce costs, increase productivity, and turn precision agriculture into surgical agriculture. I am very optimistic about the future of agriculture and UAVs, because in America, the sky truly is the limit and UAVs can help keep farmers where they belong, on the farm.

Acting Chairman Lucas, acting Ranking Member Graham, and Members of the Subcommittee, thank you for the opportunity to testify before you this morning. I look forward to answering your questions.

[The prepared statement of Mr. Blair follows:]

PREPARED STATEMENT OF ROBERT BLAIR, VICE PRESIDENT, AGRICULTURE DIVISION, MEASURE, THE DRONE AS A SERVICE® COMPANY; OWNER/MANAGER/OPERATOR, BLAIR FARMS, KENDRICK, ID

Good morning and thank you Chairman Crawford, Ranking Member Walz, and Members of the House Committee on Agriculture. I am honored to be here today and appreciate this opportunity to discuss the benefits of drones in agriculture and some of the challenges that impact its adoption and implementation.

My name is Robert Blair and I am a fourth generation north Idaho farmer raising wheat, barley, peas, lentils, and garbanzo beans on the rolling hills and canyon tops of the Palouse growing region. I am also the VP of Agriculture for Measure, the leading Drone as a Service® Company that offers a drone flying service to agriculture and other industries. We put pilots and systems in place to collect data, do analytics, and return the data to the customer in a timely manner.

It is vital to the national security of the United States of America and to the rural communities throughout that agriculture remains strong and viable. Rural communities greatly depend upon the economic success of agriculture but it goes farther than that. All of America, along with those in many other countries, depends upon U.S. agriculture success as well. I truly believe that agriculture technology, especially the use of UAVs (Unmanned Aerial Vehicles), sUAS (small Unmanned Aircraft Systems), or drones, as many people call them, will pave the way from precision agriculture to surgical agriculture.

Agriculture has a tremendous challenge and responsibility of producing enough food to feed nine billion people by the year 2050 and doing so sustainably. Agriculture domestically and internationally is under increased pressure from many different sectors to reduce water use, reduce erosion, reduce pesticide use, and reduce nutrient applications while increasing crop quantity and quality. The agriculture industry cannot do this alone, but by utilizing precision agriculture technologies, especially UAVs, those working and managing the land can be successful in the mountainous challenge.

Agriculture Technology Background

The agriculture industry has always been on the leading edge of incorporating technology. From the beginning of time humans evolved from poking their finger in the ground to using a stick to plant seeds. The Industrial Revolution saw inventions like John Deere's plow, McCormick's reaper, and Eli Whitney's cotton gin help to increase productivity, increase quality, and to replace rural labor that was migrating to cities.

My Great, Great, Great Uncle started the farm in 1903, the same year Henry Ford started his company that gave us assembly lines, the same year the Wright Brothers had the first successful manned powered flight, and the same year of the first successful west to east radio signal transmission. These innovations are the corner stones for today's agriculture equipment and precision technologies.

I started my precision agriculture journey in 2003 by using a simple PDA (Personal Data Assistant) to do simple mapping. Holding the device, the stylus, and the GPS receiver brought about a challenge of needing a third hand which led me to creating my own innovation by riveting metal on the brim of my hat to affix the magnetic GPS receiver to so I could run the stylus and hold the device.

From that point on, I didn't look back. I incorporated a yield monitor, which led to saving 20–25% of nitrogen costs; autoboom, which has saved me between 10–15% on seed, fertilizer, and pesticides; and autosteering, which has reduced my overlap between 3–5%.

It was a very exciting time in 2004 learning about these technologies, incorporating them on my existing equipment, and trying to figure out how they could best serve me and my quest to be a better manager and steward of the land. It wasn't until I flew in a manned plane that summer that I realized aerial imagery was the missing piece to the precision agriculture puzzle.

Agriculture UAV Timeline

Being able to see crops growing from the air in 2004 provided a perspective I never had before. I could see areas in my crops that were doing very well and others that were falling down. When scouting a field, problem areas are hard to identify until I am in the middle of the worst part. Being able to see my fields from the air was an "ah ha" moment for me.

At the time I did not realize that the person I was working with was introducing me to remote sensing. He was using a modified camera with a filter to try to capture images to produce a Normalized Differential Vegetative Index (NDVI), a form of vegetation health analysis.

However, the crop "production line" does not shut off or get put on hold while aerial data is being captured and processed; the crops keep growing. I had to wait at least 3 weeks for the plane to come to my farm and then another 3 weeks to get the information that I was paying $6 an acre for. Too much time had passed to where I could take action to address issues. The information needed to be timely. We have come a long way since I saw an ad for a UAV in 2006 but the need for timely information has not changed.

In the early days of experimenting with my UAV I discovered many shortcomings with the technology. Existing agriculture software was inadequate at utilizing UAV data, photo stitching software was practically non-existent, and analytical processing software was almost not even thought of. I was at the cusp of what this new technology could achieve.

In 2008, I filed the first petition for exemption to the U.S. Federal Aviation Administration (FAA) for commercial UAV use in agriculture, along with providing the FAA documentation on guidelines of how they should be used; many of my points are very similar to the current exemption rules. I also petitioned to try and obtain a seat at the FAA rulemaking table for agriculture. To this date agriculture still does not have a seat at the table.

Around the same time in 2008, many people outside of agriculture saw the possibilities of what this technology could do and companies sprang up overnight building less expensive UAVs and better software; technology that farmers could afford. I no longer needed to worry about building my own UAV, modifying cameras, cobbling software together or trying to understand hard to use autopilots and flight software. It all comes down to being able to put UAV collected data into the cab of a tractor, applicator, or mobile device.

On June 18, 2014, the FAA defined what constituted as commercial *versus* hobby UAV operations. Since that time, I have not piloted a UAV over my own property; instead, I have complied with the rules and had certified pilots operating under FAA Section 333 exemptions to gather data over my farm. An example of the distinction made between commercial and hobby use is that while I can fly a UAV over my property and take all of the pictures and video I want, the moment I use that information to make management decisions, I am a commercial UAV operator.

Over the years I have been asked many times "Who will be flying UAVs, the farmer or a service provider?" With my experience in this industry, I see a future of service providers flying for agriculture. Farmers, ranchers, crop advisors, and agronomists have enough on their plate let alone becoming an aviation expert, remote sensing expert, software expert, and/or geographic information systems (GIS) expert. Instead, UAV service providers like Measure can collect the data to make the jobs of those with boots on the ground easier. A crop advisor friend stated, "I am currently managing 20,000 acres and with your service I could double the acres along with having better information for the farmer."

Part 107 was announced on Tuesday, June 21, 2016. There are a couple of provisions beneficial for agriculture such as obtaining a remote pilot certificate instead of needing a full pilot's license and not being required to have a visual observer. Both of these provisions will save costs making it less expensive to conduct business.

However, I believe UAV service providers like Measure will still be needed due to the time required for flying, processing imagery, and trying to make the imagery into actionable information. Operating safely is a priority of Measure and we will use highly trained and certified pilots to carry out flights.

While Part 107 is a major milestone for the UAV industry there is still work that needs to be done. Beyond line of sight (BLOS) operation will be needed to cover the millions of agriculture acres in the United States in a timely manner. Rules to fly at night with thermal cameras can collect data with higher accuracy due to the cooler evening temperatures. Also, further clarification is needed to conduct aerial application of pesticides with UAVs.

UAV Benefits and Opportunities

Before I had even heard of a UAV I saw tremendous potential for aerial imagery that could help my farm and the agriculture industry. I asked myself questions such as: "Can I apply nitrogen as needed and where it's needed during the growing season with certainty," "Can I identify weed infestations and treat twenty percent of the field instead of 100 percent," or "Where should I go to do a visual observation, take a soil sample, take a tissue sample, or do a combination of the three?"

I have been fortunate to speak domestically and internationally on the benefits of precision agriculture, remote sensing, and UAVs and listen to people's questions on how could this technology be used on their farming operation. I have also benefited from doing two different agriculture fellowships that allowed me to interact with thought leaders and technology adopters at all levels in South America and Europe. These experiences have provided me with a better understanding of what UAVs can do for agriculture.

Last year Measure did a high-level, two-part study on agriculture UAVs with many different industry partners as co-sponsors. The highlight for me was the part of agriculture crops that are lost to weather and management. Roughly twenty percent of a crop is lost and the report indicated that UAVs can help gain back ¼ of what is lost due to management. I believe there can be even larger gains because better management and direct application can lead to gains against weather.

My experiences helped me gain a unique understanding of how UAVs can help agriculture today and in the future. Below I will list and briefly describe where UAVs can be of service to agriculture.

- General Scouting—UAVs can assist farmers and agronomists/crop advisors with their scouting by covering the acres in advance of needing to put boots-on-the-ground. Currently those in agriculture go into a field to find a problem. UAVs can scout ahead of time, locating specific areas that would need further inspection. Another scouting benefit of UAVs is the amount of area it can cover. A UAV can cover 100 percent of a field, while the example included in the testimony only covered around five percent.
- Nutrient Management—Fertilizer is a major expense for most crops. UAVs can be used to identify and monitor production zones created for variable rate application of nitrogen. This type of application not only reduces costs for the farmer but also helps reduce impact on the environment by applying what is needed where it is needed.
- Irrigation Management—In irrigated crops water management is critical. UAVs can help identify zones to apply water at varying rates and identify irrigation equipment issues such as a plugged nozzle, a worn out nozzle, *etc.*
- Weed Identification—UAVs can obtain high enough resolution imagery that can show weeds between the rows before a crop canopies. The ability to use this data so a farmer can determine the threshold level on treating an area *versus* not applying can save thousands of dollars at the farm level.
- Insect & Disease Detection—While this is very similar to weed detection, it is more difficult to achieve in most cases. The creation of new sensors and a better understanding of where these pests show up on the spectrum chart are things the agriculture and UAV industry need to strive for.
- UAV Aerial Application—Japan has been doing aerial application of pesticides for almost thirty years. In the United States we are just getting started. These UAVs can be used to do spot applications in fields for small pest areas along with operating safely in difficult terrain such as pasture hillsides and grazing land. It could also operate safely over fields that are located within urban areas.
- Crop Insurance—Crop insurance is the cornerstone of risk management for farmers. UAVs could provide high resolution images to identify the area of a field that has been damaged by weather to assist the crop adjuster. Currently, the area designated for damage counts is identified with the toss of the farmer's or crop adjuster's hat. Where the hat lands is where crop inspection begins. Using UAVs to determine the severity of weather damage would be an improvement upon this process.
- Crop Stand & Germination—UAV imagery can be used to detect how well a crop has been established and/or if there are germination issues so the farmer can determine if he/she should reseed. In the case of sugarcane, understanding

what percentage of the sugarcane crop is viable at ratoon * 2 or ratoon 3 is important so the farmer can determine if he can leave the existing crop in another year or if it should be worked up and planted to something else.

- Cattle—A thermal imaging camera could be used in a feedlot situation to detect sick animals along with detecting a cow in heat that is ready for artificial insemination. Furthermore, we can use thermal data to locate cattle on the range.

These are just a few innovative ways that UAVs can be used today. Just imagine what they could do tomorrow on farms and ranches to help American agriculturists compete on a global scale and ensure that food is continually on the dinner table. We need to look at ways this technology can also be used by the United States Department of Agriculture (USDA) to keep up with the rapidly evolving and tech savvy agriculture industry. I believe there are many uses that each department could take advantage of including:

- Risk Management Agency—Crop insurance claims, reporting and validation.
- Farm Service Agency—Crop reporting accuracy, especially with spring crops.
- Animal, Plant, & Health Inspection Service (APHIS)—I have had discussions with Under Secretary Osama El-Lissy about using UAVs to inspect cargo ships and containers to identify insect larvae and nests. Also, how UAVs can be used in the battle to eradicate the boll weevil by identifying host plants in non-cropped areas and then do an herbicide application by UAV instead of by foot.
- Natural Resource Conservation Service—Not only could UAVs be a program enhancement for the Environmental Quality Incentives Program (EQIP) or the Conservation Stewardship Program (CSP), it could help to better assess residue in fields instead of using a 100′ string line with markers on it.

While I could go on listing more departments and uses, I believe this paints a great picture of why UAVs need to be a more integral part of the next farm bill discussion. Everyone from Congress to the farmer and agriculture organizations to UAV companies need to start talking now on how this technology should be used and incorporated at all levels. This is a tremendous opportunity for all segments of agriculture.

Challenges

The future of UAVs in agriculture is here. As we watch the creation of a brand-new technology and industry unfold before our eyes, questions emerge: who should be working on this new technology, how should it look, what time frame is acceptable, and how can UAVs be used safely? None of these are easy questions to answer, and in order to promote this technology for adoption, the following challenges must be addressed:

- Aging Agriculture—While I initially look at this as a benefit for using UAVs, it is also a major hurdle. The average age of a farmer and for the most part, those in supporting businesses, is between 57–59 years old. They are getting close to retiring and in most cases do not want to learn something new. My question to Congress, USDA, and the agriculture community is: "What can we do to incentivize the agriculture industry to adopt the use of this technology?" One thought is to provide a premium reduction on crop insurance for implementation of the technology that is reducing risk from weather.
- Local Expertise—In most instances there is not enough expertise to show farmers and ranchers the benefits of UAVs and how to use the data. Agriculture has relied upon universities and their Extension to be experts, but due to cuts in agriculture funding, that expertise has fallen behind. We need to act now to attract young people into agriculture and technology could be very attractive to a new generation of agriculturists.
- UAV Regulations—The FAA has the important responsibility and challenge to keep the sky safe while trying to incorporate UAVs into the most congested airspace in the world; no small task. I would like to pose some examples for the FAA to consider when it comes to how American farmers could benefit from using UAVs for agriculture:
    - Aerial Application—Japan has been using a helicopter UAV to apply pesticides for almost thirty years and that program is overseen by their Ministry

* **Editor's note:** *Ratooning* (from Spanish retoño, "sprout") is a method of harvesting a crop which leaves the roots and the lower parts of the plant uncut to give the *ratoon* or the *stubble crop.* Retrieved from *http://www.britannica.com/eb/topic-492099/ratooning. Britannica Online Encyclopedia.* Retrieved 2009–01–19.

of Agriculture, Forestry, and Fisheries. In the United States, UAVs are being flown under exemptions instead of permanent rules for pictures and video—not for pesticide application. I am hopeful that this week's announcement by the FAA accelerates this application.

  - Competing Countries—I spent 6 weeks on an Eisenhower Agriculture Fellowship studying precision agriculture, remote sensing, and UAVs in Argentina, Uruguay, and Brazil; countries that are direct competitors to U.S. farmers and commodities. Not only did I see the first UAV for agriculture fly in Uruguay at a field day in Rosario, but they streamed the video from the UAV to a large screen on a truck. I have never seen that level of technology used in a U.S. field day.
  - Timeliness for Agriculture—For 2 years I have been trying to fly over the test plots of one of the largest wheat breeding companies in the world with no success. The process to obtain permission to fly within restricted airspace in Walla Walla, Washington and other restricted airspace locations where agriculture is located could be better. The trials at Walla Walla were for drought tolerant varieties and the last time a drought was as severe as last year in the Pacific Northwest was in 1977. The lack of a timely process led to agriculture losing a generation's worth of data.

- Big Data—Ownership and integrity of the data Measure uses its UAVs to collect are very important and we work hard to make that a priority. However, with more technology evolution and use looming in the future, all segments in the agriculture chain need to make data security a priority.
- Rural Connectivity Infrastructure—Agriculture and natural resources are the major economic sectors that keep rural communities going. Many of America's farms and ranches are international companies that do business on the world market. At this early stage in agriculture UAVs, we are trying to put a firehose worth of data through a straw with Internet connection speeds on my farm at 5–8 Mbs down and less than 1 Mbs upload. America can and should do better.
- Agriculture Representation—Agriculture needs a seat at the FAA table to make sure rules that are proposed will work for our industry. The USDA motto of "Agriculture is the foundation of manufacture and commerce" is as true today as it was when it was first uttered, especially in ensuring the economic success of rural America.
- Safety—This is a critical challenge for not only agriculture UAVs but the entire UAV industry. Measure's mantra is "Safe, Legal, and Insured" and we try to live that and lead by example. Often, outsourcing to service providers whose responsibility is to fly within the current scope of unmanned regulations is the safest way to obtain aerial data. It is my hope that Measure and the agriculture UAV industry can help lead the way on this important issue.
- Investment—We are living in a time when the United States is putting less money into agriculture research when competing countries are increasing theirs. This trend needs to change for our national and global security. We are watching the birth of the UAV industry in agriculture; we must nurture it so it can mature successfully and become a benefit to American society.

Even though there are many more challenges that could be listed and that the growing UAV industry will be encountering, I am very optimistic that with good communication, increased understanding, and everyone working toward the same objective of safely incorporating UAVs into the National Airspace System (NAS) and the agriculture industry we truly will be successful.

Closing

Agriculture has evolved from poking fingers into the ground to using those fingers to select a specific spot on a screen to be captured by a UAV. Agriculturists have been doing remote sensing in shades of green since the beginning of time and now we need to help this new crop of agriculturists to see things in colors of not just green, but in red, yellow, blue and all shades in between.

The journey that UAVs have taken me on has brought me closer to my roots by looking at the technology used on my farm over five generations while at the same time making me ask more questions about the future. What will UAVs be doing besides pictures, videos, and aerial application in 5 years?

Again, agriculture cannot do all the lifting alone; we will need to work with industries, organizations, companies, and agencies we haven't had to work with before. However, agriculture does need a seat at the regulatory table for everyone involved to be successful.

I am hopeful that my testimony has planted one of many seeds on the road to the next farm bill. Congress and USDA will need to work with traditional agriculture organizations while expanding to those in the UAV industry to start laying the foundation of how this technology can be used and promoted.

However, without better connectivity and a stronger Internet infrastructure, rural America and all Americans will not benefit. Those utilizing precision agriculture and UAV data today are struggling greatly to deliver, in relative terms, this small amount of data today. America will need to invest into rural connectivity the same way America invested in a successful electrical infrastructure starting at the beginning of last century.

We are in the information age where timing of data is becoming more critical every day. We have larger tractors, combines, and implements that are equipped with the technology that can utilize the data collected from a UAV. I have been implementing these technologies on my farm for over a decade and I am very optimistic about the future of agriculture, because in America the sky truly is the limit. With today's low commodity prices and tighter margins, UAVs can help reduce costs while keeping farmers where they belong . . . on the farm.

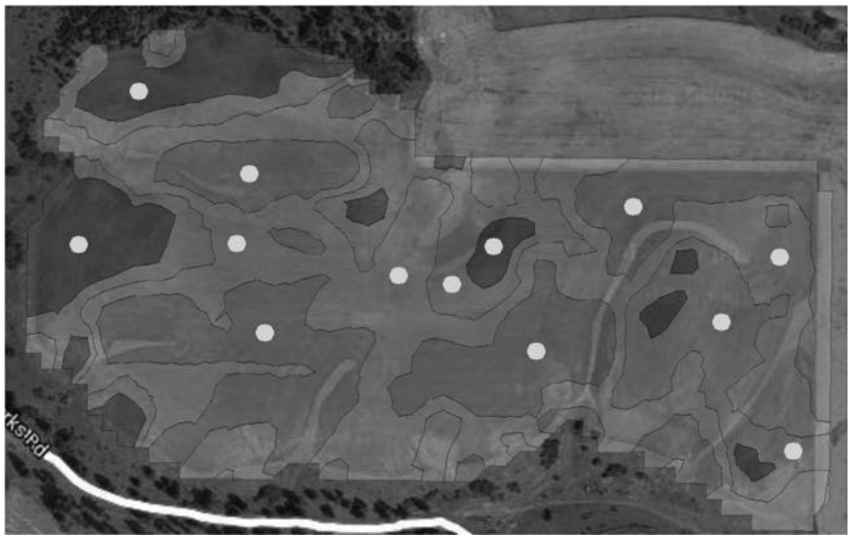
Chairman Crawford, Ranking Member Walz, and Members of the Subcommittee, thank you for the opportunity to testify before you this morning. I look forward to answering your questions.

[ATTACHMENT]

Since the farm was started in 1903, five generations have been involved with major technology innovations in agriculture moving from horses to tractors to autosteering to unmanned air vehicles (UAV). This new generation of farmers and ranchers have grown up with computers and precision agriculture and we need to ensure today that there is a strong infrastructure in place for these leaders of tomorrow.

In 2006 I became the first farmer in the United States to own and use a UAV. My two sons, Dillon and Logan have learned what this technology can do and how it can be used for over a decade to take pictures. They will need additional rules in place for uses such as aerial application by UAVs.

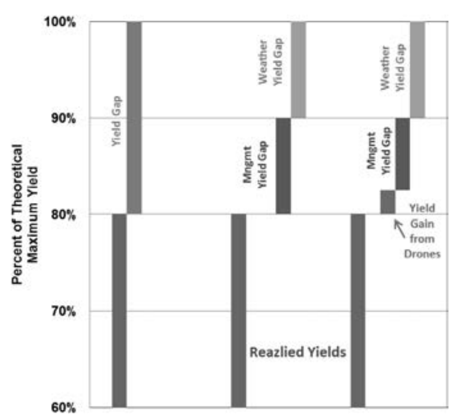
Scouting is traditionally done by sitting on a four-wheeler and driving through a field to find problems. This is inefficient, time consuming, and does not see all of the acres. Above, the green line is twenty feet wide and follows the tracks of the four-wheeler. The twenty feet represents being able to see into the canopy 10′ on each side of center which is less than five percent of the field.



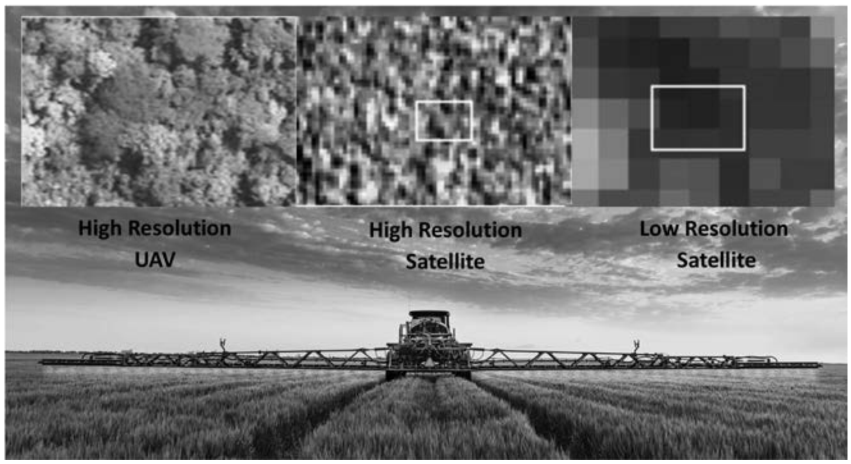
Incorporating a UAV to detect problem areas, farmers can place markers on the field like the ones in green to scout to, instead of hoping to see problems just driving or walking through a field. We can also create management zones and adjust inputs based upon productivity potential.

Estimated Yield Increases

- Closing the yield gaps
  - Estimated yield gaps range from 15% to 30%.
  - Approximately 50% of gap is due to weather.
    - ➢ Remainder due to sub-optimal management and information.
- Based on research and interviews, drones are estimated to reduce management yield gap by 25%.



In a 2015 study conducted by Informa for Measure and sponsoring agriculture partners it highlighted that UAVs could recover 25% of the yield lost by improper management. I believe that utilizing UAVs during the growing season reductions in yield lost by weather can also be gained by increasing test weights, reducing shrunken and broken kernels, and increasing overall quality.



Images captured by UAVs have greater resolution that can show more issues to address in a crop. Solutions for treatment can be incorporated into the cab of a tractor or applicator for precise placement reducing costs and impacts on the environment.

Mr. LUCAS. Thank you, Mr. Blair.

The chair would like to remind Members that they will be recognized for questioning in order of seniority for those who were here at the start of the hearing, and after that, Members will be recognized in order of arrival. I appreciate Members' understanding, and with that, I recognize myself for 5 minutes.

Gentlemen, the Committee just concluded a six-part hearing series focusing on the farm economy and the downturn of the last couple of years. Things in farm country, we would all agree, are starkly different than they were just a couple years ago when the 2014 Farm Bill was signed into law. In fact, percentage-wise statistically, the 3 year drop in net farm income that we have encountered is, in some ways reminiscent of the Great Depression and some commodity years, perhaps even worse.

That said, though, given the downturn in the farm economy, how has that affected the utilization and the adoption of imagery in production agriculture? Basically what I am asking is when we had the higher prices, to what extent were farmers willing to adopt the new technology, and now with the significant drop, how has that affected their willingness to step up and use the services that have been developed and are being developed?

And with that, in no particular order, I will start with Mr. Blair, and if you would care to offer a response, and then your colleagues, if they would like to comment.

Mr. BLAIR. Okay, thank you, Chairman Lucas.

For me as a farmer, we have seen going from a $6 week down to $5 week. Talking with clients around the company or potential clients, it is hard to sell. They are not adopting it, and then if we look at the lending institutions and the bottleneck created there, they don't understand the technology and the benefits they provide as well, creating further hurdles in adopting this technology.

We need to work harder in getting the word out as to what this technology can do, from universities, from land-grant system extension, private-sector, and USDA system. Here is the return on investment: Last year, I raised 105 bushel wheat on dry land in a drought year. Because I varied the rate of nitrogen, I was able to not only have very good yields, I had less impact from that drought by better quality, less shrunken and broken kernels, and less dockage. Furthermore, on my soft white wheat, because I had low protein, I gained an additional $10 an acre because I had that low protein from a premium. The technology can pay. We have not done as good of a job as we can showing what that return on investment is at the ground level.

Mr. LUCAS. Mr. Crago or Mr. Faleide.

Mr. FALEIDE. I can comment on that on adoption. It is interesting over the years that it has been a difficult sell. I think whenever there are hard times, people look at different ways of being more efficient.

In the mid-1990s when we were working with the sugarbeet industry, we saw a definite increase of usage by the company to push it to the farms because they needed to grow more sugar pounds per acre, and there was an advantage to monitor and manage the fields with nitrogen to create more economic profit. Then times started getting better in the farm industry in the late 1990s economically, especially in the 2000s, and recently very well. We actually saw more of a drop off or a complacency of using technology or data to drive the machines. Now most farmers were getting the equipment in their new tractors, and it has become OEM required because you can't sell your tractor again if you don't have the proper equipment. So that was a lot of the argument I was getting.

Now actually, we thought in the last year or so that we were going to see a drop off in interest because of the economic problems. We are seeing the opposite, partly because our company is ready to deliver. We can deliver any image to any field that the satellite rolls over at a moment's notice. We have the distribution system in place. We have the big data infrastructure behind us, and we are getting data. Now we still need more images. We need more images from satellites. We wanted more imagery from aerial and to incorporate the UAV data as well, which we are doing. But we are finding actually that we are seeing an uptick of interest because we have an actionable solution that can provide it like that, and that is part of the whole problem of bringing data and imagery to the agriculture sector. We do not have enough infrastructure of satellites on my end. We are working with many satellite companies to get more satellites up, and that is going to happen over the course of the next 1 to 2 to 3 years. But, right now, we are actually seeing an uptick on information.

Mr. LUCAS. Mr. Crago, any thoughts?

Mr. CRAGO. Well, I am not a farmer, but I have worked with the USDA for close to 20 years now, and what I have seen is the desire and requirement of the APFO in Salt Lake City is really being a base for providing fundamental information and data to the farmer, and providing it in a manner that is fairly open to them.

From my perspective, one of the areas that really requires some work is in the implementation of tools and customized tools, specifically as it relates to precision agriculture and other uses farmers make of that in being able to use the data. And so, in my perspective in my work, we really are trying or attempting to provide a base data layer set that augments what these other two gentlemen have been talking about in terms of being able to interpret that data in manners that fit a particular farmer's issue, and there are a number of them. I appreciate that.

Mr. LUCAS. Thank you, Mr. Crago.

My time has expired. The chair now recognizes the ranking gentlelady for 5 minutes.

Ms. GRAHAM. Thank you very much, Mr. Chairman. They left, but there was a group of Future Farmers of America in the back. I wanted to recognize them, because my question sort of segues from that.

Mr. LUCAS. I thought they were a bright looking bunch.

Ms. GRAHAM. We have bright ones in Florida as well, so it is consistent.

One of my early meetings with FFA I was sitting there, and they were providing a presentation on UAVs, and I was just amazed at all that they were able to do with this technology, and recognize that the world that young farmers are growing up in. We really want to encourage young farmers to get into farming and have it as their life work, is changing so rapidly.

So you all are experts in this area of UAVs and the new technologies in aerial imaging. I am wondering, what do you see? What do you think 10 years from now those new FFA groups will be involved in that we don't even, we may not be aware of it on the horizon, but certainly would be interested in what you all see as the next technology breakthrough and advancement in farming?

Mr. FALEIDE. Just my viewpoints that, my youngest boy is now in college and my two older boys are mid-30s. But I told them a few years ago, I said it is up to you guys to figure out how to take our technology to the next generation, and they are doing that. They have worked for me and actually, my youngest is interning with me. It is interesting how the younger generation is so interested in the social media instant information, and everybody catches themselves: what is the answer for that? I will Google it, right? So that generation is now wanting the data immediately. Our generation tended to say we could take a while to get that answer. There is no time now to wait. And so the expectation of the younger generation is going to require more infrastructure to instantly provide that data to that young person.

We are working with companies to create persistence imagery, 24/7 imagery over your field in certain locations of the country or the world. That generation wants it now, and that is going to be the main thing is the phone, the mobile device is a part of their social being. That is what the answer is going to be in my belief, that they are going to demand data, and the infrastructure has to be in place. The fiber has to be in place in the rural areas, or they will not agree with that policy if it is not done.

Ms. GRAHAM. Thank you. Does anyone else have any ideas? Mr. Blair?

Mr. BLAIR. Yes, thank you. Thank you, acting Ranking Member Graham. I, too, wore the blue jacket and it is exciting to see these young kids growing up in this time. I grew up on an open deck tractor pulling clutch and pressing brake on a Caterpillar, not fun. Those were the good old days.

Today, what we are seeing is an exponential increase of how technology is evolving. I fought doing e-mails. I liked letters and phone, face-to-face conversation. Now give me an e-mail. I fought it, too. Back in the mid-1990s, one of the crop protection providers sent out freebies. It was a Velcro box. Open it up, here is our product, and you open the pages, and here is this robot hovering over the ground sucking up the weeds. Another one they sent out showed a robot on tracks picking it up and eating them. We are heading in that direction. Today, we are taking pictures and videos. Tomorrow, are we going to be putting lasers on UAVs to spot treat for disease like fire blight in apples, maybe, or the orange industry?

We have done flights down there for lettuce, string beans, and sugarcane, and we believe that technologies like thermal imaging will get better and that we can look at transpiration from those crops to detect earlier these disease issues that affect their quality. So we will be evolving quickly with new sensors and new platforms.

Ms. GRAHAM. Thank you. My time has expired. It would be great if we could develop a laser to take out fire ants. That would be great.

Anyway, I yield back, Mr. Chairman. Thank you all very much.

Mr. LUCAS. As Mr. Blair knows, you have not lived until you have been on that tractor with the heat coming off the engine and the exhaust in your face. The good old days.

The chair now recognizes the gentleman from Alabama, Mr. Rogers, for 5 minutes.

Mr. ROGERS. Thank you, Mr. Chairman.

Mr. Blair, Auburn University is in my district. It is a research university. Engineers and scientists there have been studying how the data collected by Unmanned Aerial Systems carrying different types of sensors can be used to improve how we manage agriculture and forestry. One of the current limitations in deploying UAS over larger agricultural fields or forests is a rule that our aircraft must be in view of the pilot during operation. Now the forestry industry is significant in Alabama. When flying UAS over forests, maintaining this line of sight between the pilot and the aircraft is particularly difficult. What kind of development work is being done in your industry to alleviate the concerns of the FAA and ultimately allow the UAS to fly safely beyond the line of sight?

Mr. BLAIR. Thank you, Mr. Rogers, for that question. Line of sight and flying beyond line of sight is very important, not only for agriculture, but for the natural resource industry as well, and forestry. Idaho, about 80 percent or around 70 percent are public lands and mountains. We need that beyond line of sight.

What is being done, the FAA has a pathfinder program, and I know there are companies working on this beyond line of sight issue. Right now, the technology can allow and is good enough to allow for UAVs to already fly safely beyond line of sight. It comes down to regulations and being able to isolate or locate areas where we could fly line of sight in commercial research purposes that can benefit both agriculture and the forestry industries.

Mr. ROGERS. Okay, thanks.

Mr. Crago, given the increasing discussions about Americans' privacy concerns, how can we be sure that these systems will maintain American privacy and that the data collected won't be shared with outside groups?

Mr. CRAGO. Thanks for the question. Privacy is a big issue, and I know that it has raised its head in a number of instances.

In the case of the aerial imagery that is being taken for the NAIP Program, there is a longstanding rule and protection of the information within FSA to the extent that I am not aware of any privacy issues that have ever arisen out of aerial imagery taken for the NAIP Program at 30,000′ or at 20,000′. This imagery is highly technical in nature, and the distribution of private information as I know the contractual requirements put on us is extremely well-protected within FSA. I am not aware of any issues of that nature.

Mr. ROGERS. Thank you, Mr. Chairman. I yield back.

Mr. LUCAS. The gentleman yields back. The chair now recognizes the gentleman from Georgia, Mr. Austin Scott.

Mr. AUSTIN SCOTT of Georgia. Thank you, Mr. Chairman, and Mr. Blair, we have heard a lot about a number of different technologies, but they all provide imagery.

How does a farmer know which type of imagery is right for his or her operation, and what factors should a farmer consider when deciding on which imagery or how imagery might fit into their farm?

Mr. BLAIR. Thank you, Mr. Scott, for that question.

The type and size of imagery is dependent upon the management style of the farmer and what their goals are. It is my job to help them figure out what their goals and what their objectives could be. Are you looking for disease or insects on leaves? We need higher resolution. If you are looking at nutrient management, less resolution images can work fine. But it comes down to our equipment, how can that react, and right now, all three technologies, satellite, manned aircraft, and UAVs are collecting good data. We need to get the word out there on how to utilize it better and for that return on investment.

Mr. AUSTIN SCOTT of Georgia. It seems to me that one of the key factors of the UAV is that the individual farmer has the control over the time at which the imagery is taken, and that that would be one of the key differences where they don't have the control with the other technologies. I may be wrong about that, but——

Mr. BLAIR. Yes, Mr. Scott. It is timelier information. We can fly under the clouds where a lot of times satellite can't get through. We can put different sensors on there, like thermal imaging, and collect higher value data in a lot of instances, and get that higher resolution image of about 2 centimeters. The timing right now, we can cover a lot of territory and ground. We just need that beyond line of sight would be very, very helpful to incorporate this technology.

While Part 107 has been useful and is giving us in the industry some permanency with UAVs, there is still work to be done and line of sight is one of those.

Mr. AUSTIN SCOTT of Georgia. Mr. Crago, why does the NAIP Program use manned aircraft when we have satellites that can provide similar imagery, and can you provide us specific examples where the manned aircraft would be able to provide, would be a better source for the imagery than the satellites?

Mr. CRAGO. Well, if you understand the requirements under the NAIP Program, the NAIP Program is designed for agriculture crop management. So what that means is that the imagery needs to be taken when the crops are at their peak. So if you take the State of Texas, for example. The State of Texas is divided into four acquisition seasons that are defined by the APFO, and the window to acquire those seasons ranges from anywhere from 2 weeks to 3 weeks. So what is required is an extreme amount of capacity to be able to acquire that imagery in an extremely short period of time. The comparison between satellite acquisition, which is completely dependent upon the orbit of the satellite and the timing of it, wouldn't facilitate, or generally wouldn't facilitate, the ability to acquire that imagery within that particular growing season. And so in the case of the NAIP Program, you can see as many as six or seven aircraft being mobilized to a particular area for a 2 day wet weather window in the ability to acquire all of south Texas.

And so notwithstanding that, satellite plays a very valuable role in being able to acquire imagery, but in terms of being able to address the seasonality of the USDA's requirements, the only current way of achieving that is fairly massive manned aircraft sensors that can address that.

Mr. AUSTIN SCOTT of Georgia. Thank you. I am down to 30 seconds, but Mr. Faleide, you have been in this business a long time, and one of the issues that we wrestle with today with data is who owns the data? And I would be interested in your opinion on who you think should own the data, and whether or not there is a difference between satellite imagery and UAV imagery, and who should own the data?

Mr. FALEIDE. Well, thank you. Let me start with those different platforms. These UAV aerial and satellite are just platforms for a camera. Each one has different abilities occurring at different resolutions. Like Mr. Crago said, there are airplanes that come in and specifically target at high resolution. Satellites will come in more commonplace and see general areas. Now the satellite infrastructure is improving rapidly, but you have to put satellites in the category right now is the best I can get on a satellite right now is 31 centimeters. It is going to move to 25 centimeters, up to 30 meter resolution, depending on what you want. Airplanes fit in the category of about 6″ resolution to approximately 1 to 2 meter resolution, depending on how you scale your lenses. UAVs will be in the 1 millimeter range to about 6″ level. So each one has its own category, so it depends on what you want to do. The more infrastructure of satellites that come in, you are going to see more infrastructure.

Now as for privacy, the common rule of thumb is if I can't identify your face and know who you are, if you are just an object that is there, I have not gone past the privacy issue and the idea of who owns the data, we have taken the opinion that whoever pays for that data owns that, as long as I don't enter into your privacy situation. But once I can identify you, then I am going into a different realm and that can be problematic.

Mr. AUSTIN SCOTT of Georgia. My time has expired. Gentlemen, thank you for being here.

Mr. LUCAS. The gentleman's time has expired.

The chair now recognizes the Vice Chairman of the full Committee from Texas, Mr. Neugebauer, for 5 minutes.

Mr. NEUGEBAUER. Thank you, Mr. Chairman. This device I have in my hand here would be a flashlight if it wasn't for the applications that are attached to it, and so one of the things I was wondering is Mr. Lucas and I sit on the Financial Services Committee, and we have seen a lot of interesting technology take place in that sector, and what was done is that there have been a lot of applications developed for financial products. But we have a bigger sector of potential users.

I guess one of the questions I would have this morning is as the technology with UAV or satellite resolution, all that, as that is getting better, are they keeping up with the technology, and I will let whoever wants to jump on that first. Yes, sir?

Mr. FALEIDE. Yes, I believe it is. At the beginning, based on the lower resolution imagery that we could pull in from satellite, we could look at a pattern within a field about every, let's say, 100′, and bring that down to a level to control a 30′, 50′ applicator. Okay? And now with the higher resolutions, the industry is looking at while there is more data here, we are now able to boom control where we can split a boom, a 130′ sprayer from the green machine would maybe have about nine to eleven sections. I can change those sections. Other companies are also bringing in nozzle control where the planters are going down to individual row units to variable rate that, or sections that requires higher resolution. So the more infrastructure that the OEMs and the machinery companies can start splitting these equipment into different rates, it requires higher and higher resolution imagery.

So I believe the industry is adapting well. It is maybe not as fast as I want it, but it is adapting. Yes.

Mr. NEUGEBAUER. Mr. Crago?

Mr. CRAGO. What we see is really two movements in it, and the first one is the standard type app that you would download onto your phone and operate on your phone. And to some extent, there are some, at least, visualization capabilities coming in that area.

But equally important or possibly more important is cloud type where the iPhone or your smartphone is used to access some activity in the cloud, and that activity may be some form of remote sensing interpretation. So it could be different bands or spectrums of the imagery that is acquired, or things like change detection where it is comparing one vintage of imagery to another. There clearly is movement down, literally on the app on the unit, but maybe more importantly in the cloud where the handheld unit is used to access that through the cloud. It is moving, yes.

Mr. NEUGEBAUER. Yes. Mr. Blair?

Mr. BLAIR. Thank you for the question.

Applications are keeping up with the technology. Japan has been using a helicopter to spray for almost 30 years. We are just being able to do that here in the United States. The regulations aren't keeping up. That is what is not keeping up with the technology. Government programs are not keeping up with the technology either. We have a great opportunity, especially with UAVs, not only to do spot spraying applications after doing a flight and gathering that information. We have an opportunity to do crop adjusting, being able to gather that high resolution imagery to not only pinpoint the areas that have been damaged, but to hopefully assess where that damage is and how severe that it is.

So is our data engineered for Measure? In a 10 minute period when we were on the phone talking, he created a functionality in our software deliverable of just being able to put points on a map as I am viewing that I can go out and scout. It is moving fast.

Mr. NEUGEBAUER. Yes, I know several of my colleagues have brought up the line of sight thing, but I think that is a very important part of it. Particularly when you take in my district, for example, we have farmers that are farming 5,000, 10,000 acres, and for example, a UAV to be effective on that, rather than following the UAV around in your pickup, being able to program that UAV to go do a particular mission and come back and, I guess, download that information. The same way with the ranching, in my district we have ranches that are 20,000–30,000 acres, and so if you are going to have the digital cowboy that is going to ride the fence, you are going to have to be able to program that.

So what are some of the things that might be inhibiting the use of that technology, and what would be the message to this Committee?

Mr. BLAIR. Well, one of the things is the regulations. We need to have beyond line of sight for natural resource use. Agriculture is not populated. You are not flying over a lot of people. We can fly safely and have flown safely. I have been UAV since 2006, and have not had an incident with any aircraft. It comes down to communication, and that is very easy. I am going to be talking to the crop duster who is going to be flying that low.

The other one is we do need our agencies to be proactive as well in promoting this technology. How are we going to be using it? Thermal imaging to identify cattle, for identifying cattle rustlers in snow storms. I have had phone calls on a lot of these over the years. We haven't scratched the surface because we haven't had the regulatory certainty, and beyond line of sight is one of the most crucial rules that needs to be gone after for agriculture.

Mr. NEUGEBAUER. Thank you, Mr. Chairman.

Mr. LUCAS. The gentleman's time has expired. I would note to my colleagues that in the line, we have Mr. Gibbs, then Mr. LaMalfa, then Mr. Allen. With that, I turn to the gentleman from Ohio for 5 minutes, Mr. Gibbs.

Mr. GIBBS. Thank you, Mr. Chairman, and thanks for this hearing. It is a very interesting topic, as we know technology happens fast and regulation of public policy lags. You have said that.

One thing, I am also serving on the Transportation and Infrastructure Committee, and talking about drones and stuff, and it seems to me it is a no-brainer. Out in the rural area, far away from airports, the line of sight shouldn't even be an issue, especially if they are talking 400′. What is the maximum altitude you really need for a drone to work well to do what we are talking about here?

Mr. BLAIR. Well right now, 400′, that is really good. To cover acres we could fly higher, but it comes down to what resolution do you need? If we start flying the UAV higher, is that the most efficient way or do we go to satellite or manned aircraft as the most efficient?

Mr. GIBBS. I guess that may be my next question. The three components, your satellite, aerial, and drone, and I would think the drone, as a farmer, if I need real time data today, if I think I have a problem out in my bean crop or whatever, the drone would make a lot of sense, probably. I know the aerial is a wider spot. I guess that is the question I have. My understanding, the technology is adapting where we can go out and using these three technologies and determine insect infestation, disease, that is correct, right? I don't think anybody has said anything about yield. Can we determine possible yields through this technology?

Mr. BLAIR. Yes, we are able to predict yield with some certainty. There are a lot of things that can affect it. I don't talk about yield because that brings in a whole——

Mr. GIBBS. Yes, I know. I am going there next. I am going there next, but it has helped me improve my yields because I have had better information.

Mr. BLAIR. Yes.

Mr. GIBBS. Have I been able to predict, no. That is why I use a yield monitor to give me that actual value.

Mr. BLAIR. Well, I guess that——

Mr. GIBBS. I am going to the 50,000′ question, the macro question. Is the technology moving towards where through the aerial or whatever where an entity could come and fly over a wide area of Iowa or whatever and kind of get a good handle in August, September, what that corn crop is going to be? Because USDA has crop production reports and we see what the markets use them and that speculation. So is the technology moving that way? Will that be actually feasibly possible?

Mr. BLAIR. Yes, and with the different technologies out there, if you incorporate images and we create this database over time to understand what we are seeing in those images at the different resolutions, along with using weather data, there is a lot of very good electronic weather data out there as well, and when you incorporate those two together, we should be able to do some very, very good predictive predictions on yields for agriculture, for NASS reporting, on down the line.

Mr. GIBBS. So that is really going to be a big public policy question, because that does give an entity the possibility to get real-time data ahead of anybody else, and it could affect the markets. It is just an interesting policy question that I don't think anybody has really discussed yet.

Obviously, the technology is coming, since I started farming in the mid-1970s, the changes are just immense, and it is just incredible. It is like the technology builds on itself. Mr. Chairman, the way this technology goes, it is hard for the public policy to stay with it, but in this aspect, there are a lot of aspects that we have to adopt this technology or we will fall back globally, because I am sure that is another aspect of it. Where do you see it happening in like Brazil with their bean crop? What do you see happening with our competitors?

Mr. BLAIR. Well, I have been fortunate to travel and visit a lot of these countries and talk with farmers and researchers. They are outpacing us on adoption of the technology because they have had to. Their economies and some of those factors that are forcing them to look at their margins, technology is allowing them to stay profitable.

We have had it good as farmers in the United States and haven't really had to look at this until now when the commodity prices are dropping.

Mr. GIBBS. Yes.

Mr. BLAIR. Now we are turning to this technology, what can it do? It becomes more attractive, but those challenges are there. We need to push this forward to be more competitive with our competing countries.

Mr. GIBBS. Thank you. Thanks for being here. Thank you, and I yield back.

Mr. NEUGEBAUER [presiding.] I thank the gentleman. Now the gentleman from California, Mr. LaMalfa, is recognized for 5 minutes.

Mr. LAMALFA. Thank you, Mr. Chairman.

Mr. Blair, I appreciate you and the whole panel being here today. My question is pointed at you here first.

I enjoyed some time on a D8 slide bar track layer during my formative years, cutting teeth on tractors as well, and the first pass over the fields is a nice one there. There is not much dust to deal with, but that second or third one, that is the tougher deal. So I relate to that totally.

Let me touch on: I missed part of the testimony getting here, but the FAA with their rules released, what do you see are the latitude that you have, or is there more latitude needed with the FAA rules that are in place? We have FFA in here now. FAA rules that are in place, and do you see the latitude in order to do the work that needs to be done using the UAV technology?

Mr. BLAIR. Thank you for that question. I mess up FAA, FFA a lot over the years. That is a tongue twister, so I am right there with you.

Part 107 is a great start. It allows us to be more flexible. We no longer have to try for exemptions to operate commercially, but there are still areas that can be improved. One of them is being able to fly in restricted air space. Agriculture land doesn't know boundaries in the air. It goes right into restricted air space. In the last 2 years, we have been trying to fly for one of the larger wheat growing companies in the world to no avail. We have lost a generation's worth of data because of we could not fly inside there.

What do I mean by that? Last year, we had the worst drought since 1977, a generation ago, and we couldn't collect that data on drought tolerant varieties. So those processes need to be more responsive for agriculture to——

Mr. LAMALFA. Is the FAA rule the one that precludes the restricted air space, or is this more you are talking military bases that already have this in place?

Mr. BLAIR. No, this is for restricted air space. You still have to file to fly inside these restricted areas, that 5 mile——

Mr. LAMALFA. Is it because of the FAA rule or because of military rule?

Mr. BLAIR. FAA rule.

Mr. LAMALFA. Okay, thank you.

Mr. BLAIR. And some of the other things beyond line of sight is another issue that we need to address, and also make it easier for UAV operators to do aerial application.

Right now, what the exemptions have done is try to shoehorn UAVs into existing regulations instead of creating their own, and Part 107 has not addressed Part 137, which is aerial application.

Mr. LAMALFA. Okay. I wanted to touch on, you might call it privacy or a lot of things. When you use your own UAV on your own stuff or you have a contractor doing it for you at your request, do you see the FAA rule allowing for some type of prosecution or restriction of people basically poaching, like you might have an extremist group that wants to come look at your junk pile or see what you are doing with your water, or how you are managing your chemical containers? Flying over your place, screwing around, looking at that stuff. Do you see enough teeth in that to be able to keep people from snooping around your property?

Mr. BLAIR. Well, right now I can drive down a road, take my iPhone out, and take a picture. There is nothing to stop me from doing that. I can be in a manned aircraft, hot air balloon, ultralight and take the same pictures and it is not an issue. But because of the negative connotation of the word drone, now all of a sudden using that iPhone has become an issue. But to address the example, there is a concern, especially in the agriculture industry of certain groups and sectors using this information maliciously. How do we stop that? The laws and regulations should not be around the UAV, but it is the use of the information.

Mr. LAMALFA. Okay. Just for my own info, what is the lowest elevation someone can fly over your place in this scenario?

Mr. BLAIR. With a UAV, you mean?

Mr. LAMALFA. Yes.

Mr. BLAIR. I do not believe they can, well, we cannot fly over someone's property without their permission, and will not, and I am not certain of that low altitude.

Mr. LAMALFA. Is a frontier justice allowed if you find somebody flying over your place?

Mr. BLAIR. In the words of one of my elected officials long ago, "Shoot, shovel, and shut up" so I am sure that will happen.

You are going to see those instances. People are going to do some crazy things out there. In my state, people have shot at manned helicopters.

Mr. LAMALFA. Okay. I will yield back. Thank you, Mr. Chairman.

Mr. NEUGEBAUER. I thank the gentleman, and now the gentleman from Georgia, Mr. Allen, is recognized for 5 minutes.

Mr. ALLEN. Thank you, Mr. Chairman, and thank you for joining us today. I am going to kind of present this to all three of you and get your comments on it.

Of course, I grew up on a farm and it was a little different back then, but I did have an experience in my district to plow a couple of rows or plant a couple of rows of peanuts, and we cranked up the computer and we planted 14″ over from the year before, basically, and I didn't know exactly why we did that, and I also did not touch the steering wheel during this process. And I tell you what it made me think about is from a business experience now we use technology in the construction industry to accomplish a lot of the same things we are doing in agriculture as far as equipment and how to use that equipment efficiently. I will tell you one of the most difficult decisions that we had every year in the construction business was: how much do we invest in this? Because it always seemed like I said we are not going to spend any more on this, and then the next year, okay, we got to buy this. We have to have this. And then, of course, trying to justify the investment, and then what is that going to yield? What is that going to do to my bottom line, and what is that going to do to my longevity as far as this business is concerned?

The third thing is the fact that this Subcommittee and this Committee is here to promote not only what you are doing, but agriculture, and what is it that we can do, and maybe you can think about this and file something like a report on just what we can do in the next, well, maybe this Congress to help you accomplish some of these goals that you have, and as I like to term it, get the Federal Government out of your way.

So we will start right here.

Mr. FALEIDE. Very good comment, sir. The industry has focused on hardware, like you were mentioning when is that device going to be antiquated? And that is a tangible object, and it is very easy to put value to that. What has been very difficult to put value to is the data itself. We are now seeing, and a good friend of mine who worked with us and started some of this, Gary Wagner out of Crookston, Minnesota, one of the pioneers of precision ag. In his presentations years ago, he said this data is so important, it is going to put value to my land. Some day this data is going to and with the land sale, because that history of that data, that device that captured it is long gone, no value. So now the intangible data now becomes tangible. And so it is very important that we start looking at information as the value point, not the device, not whether it came from what color a machine or anything.

What your latter part of your question about what can we do as a government, the key is to make sure that the regulations allow that flow of data to not be restricted and to make sure that the infrastructure is in place that the data can flow, just like I said before about the fiber optic infrastructure. We have to have those kind of infrastructures to make data flow very easily and also very economically. So that if the government can help in that process, I think that is a good move for the future.

Mr. ALLEN. Okay, very good.

Mr. CRAGO. Yes, I agree completely. I think that the value of the data is not being fully recognized yet, and in my particular world with respect to the NAIP Program, the ability of everyone, farmers, government regulators, to have access to this open data is of paramount importance, and equally important is the maintenance of the legacy data and bringing it forward with current data. The value of being able to analyze the past with the present and predicting into the future in a lot of the things that my colleagues here have said is key, and having that data open and having it widely available is essential to this, to the process. Yes.

Mr. ALLEN. Mr. Blair, you have 1 second. Sorry.

Mr. BLAIR. Thank you. Real quick, risk management is the key. Using the technology to do crop insurance, we need to work on that, both for adjusting and on the severity of the claim and the area of the claim.

Mr. ALLEN. Also lenders, right? I mean, as far as you know, you have crop investment and you have the lender, and then you have the crop insurance. But this information would be invaluable to lenders to be able to justify loaning the money, wouldn't it?

Mr. BLAIR. Yes, it helps, how I view this, if we incorporate the technology, the grower is doing a better job at averting risk. The grower should actually get a premium reduction because he is making those weather and management decisions right there. If I am utilizing this technology on my farm, why do I have to pay the same premium as my neighbor, and I have less risk in the insurance industry?

Beyond line of sight and then Internet infrastructure as well.

Mr. ALLEN. Okay.

Mr. BLAIR. Thank you.

Mr. ALLEN. I yield back.

Mr. NEUGEBAUER. I thank the gentleman.

This has been a very informative hearing, and a very important hearing, because one of the things that we know is there are a lot of challenges for agriculture today. Farmers are competing in a global marketplace that is maybe not always on a level playing field, dealing with weather and other factors. Obviously, we want to make sure that our producers have all the tools that they need to be as competitive as they can, and more importantly, to be economically viable. With the prices we are seeing right now, yield becomes a very important part of having a successful farming operation.

I thank our witnesses today. One of the things that I always want to encourage our witnesses is that you come up here and give us almost an hour and a half of your time, and I know the preparation that you put in requires additional time. We appreciate that. I would hope that this is an ongoing dialogue, because we want to make sure that we are facilitating this technology and this tool and making it as an effective tool as we can for our producers.

Before I adjourn the Committee, I would yield to the acting Ranking Member for any comments.

Ms. GRAHAM. I just want to echo what you just said, Mr. Chairman. Thank you very much.

I have such a respect for folks who are willing to come up here and help us understand these issues in a greater way, and I know it takes a lot of time and so just thank you very much. It was very interesting, and we learned a lot, and we will take this information and you will help us do our jobs better, so it is very much appreciated.

Mr. NEUGEBAUER. Under the rules of the Committee, the record of today's hearing will remain open for 10 calendar days to receive additional material and supplemental written responses from the witnesses to any questions posed by a Member. This hearing of the Subcommittee on General Farm Commodities and Risk Management is adjourned.

[Whereupon, at 11:15 a.m., the Subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

SUBMITTED STATEMENT BY HON. ERIC A. "RICK" CRAWFORD, A REPRESENTATIVE IN CONGRESS FROM ARKANSAS; ON BEHALF OF ANDREW D. MOORE, EXECUTIVE DIRECTOR, NATIONAL AGRICULTURAL AVIATION ASSOCIATION

June 30, 2016

Hon. ERIC A. "RICK" CRAWFORD,
Chairman,
Subcommittee on General Farm Commodities and Risk Management,
House Committee on Agriculture,
Washington, D.C.

Introduction

[The] National Agricultural Aviation Association appreciates this opportunity to submit comments to the record on the recent hearing held June 23, 2016 by the House of Representatives' Committee on Agriculture, Subcommittee on General Farm Commodities and risk Management titled "Big Data and Agriculture: Innovation in the Air."

Since 2005 the Federal Aviation Administration (FAA) has been working to develop a regulatory framework to integrate unmanned aircraft systems (UAS) into the National Airspace System (NAS). In 2012 those efforts were doubled following the passage of the Federal Aviation Modernization and Reform Act (P.L. 112–95), which has culminated in the now-finalized small UAS rule, the first step in the "integration" phase, as outlined by the FAA's UAS roadmap. Throughout this process the National Agricultural Aviation Association (NAAA) has been engaged in informing the FAA of our safety concerns with UAS and potential uses of UAS in the agricultural aviation industry.

NAAA works to support the agricultural aviation industry which is made up of small businesses and pilots that use aircraft to aid farmers in producing a safe, affordable and abundant supply of food, fiber and biofuel, in addition to protecting forestry and controlling health-threatening pests. In NAAA's communications with FAA's UAS Integration Office, NAAA has stressed that above all else UAS, particularly small UAS (sUAS), need to be identifiable, visible and safely operated to agricultural aviators (ag aviators) given agricultural aviation is one of the sectors of general aviation whose missions are performed as low as 10′ above ground level and usually not above 500′ when ferrying to a field to treat a crop or forest.

NAAA urges the Subcommittee on General Farm Commodities and Risk Management to consider the great risk that accompanies UAS integration into the NAS should the FAA not increase safety precautions for UAS, and to support the safety provisions outlined below.

Importance of Aerial Application Industry

NAAA consists of over 1,900 members, and represents the interests of small business owners and pilots licensed as commercial applicators that use aircraft to enhance the production of food, fiber, and biofuel; protect forestry; protect waterways, pastureland, and ranchland from invasive species; and control health-threatening pests, including mosquitos that spread West Nile virus and Zika virus. Almost 20 percent of crop protection product applications to commercial farmland are made aerially. As a result, NAAA estimates that 71 million acres of cropland are treated via aerial application in the U.S. each year. This does not include pastureland, rangeland, forestry-land and other areas also treated via aerial application. Aerial applications are often the only, or most economical method for timely pesticide application. Additionally, aerial application is conducive to higher crop yields, as it is non-disruptive to the crop and causes no soil compaction, thus improving soil health and crop yields. This results in more food and fiber being produced using less land, allowing the land to be repurposed for other uses, including habitat preservation for endangered and/or threatened plant, animal, and aquatic species beneficial to the environment, and for preserving vegetative ecosystems important to the sequestration of carbon and water purifying wetlands.

Because of the importance of the aerial application industry, it is vital a safe, low-level airspace exists to ensure these pilots can continue to do their jobs safely. Ensuring safe low-level airspace includes minimizing obstructions which are difficult to be seen and identified by the pilots. In addition to aerial application operations, aircraft users of low-level airspace include: Emergency Medical Services (EMS), air tanker firefighting aircraft and their lead aircraft; power line and pipeline patrol aircraft; power line maintenance helicopters; fish and wildlife service aircraft; animal control aircraft (USDA–APHIS–ADC); military helicopter and fixed-wing operations; seismic operations (usually helicopters); livestock roundup (ranching or animal relocation); aircraft GIS mapping of cropland for noxious weed populations and the like; and others.

Safety Recommendations

NAAA understands that UAS will be used for crop sensing as another tool to make precision applications and scout for livestock, among other uses, joining satellite and manned aircraft that also perform these services.

A January NAAA survey found that about three percent of NAAA members have begun to use UAS at their operations, and nearly 15 percent are looking into using UAS. Moreover, the world's largest agricultural aircraft manufacturer and NAAA member—Air Tractor—has purchased a UAS company and will be looking into their use to aide aerial applicators to perform crop-sensing and aerial imaging services. But NAAA believes it's vitally important to both the manned and unmanned aviation industries to integrate UAS safely into the NAS to prevent tragic loss of life and prevent backlash against UAS from the public.

Birds provide an apt example of what could happen if a drone hits a manned aircraft. According to a joint report by the FAA and the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA–APHIS), between 1990 and 2012 over 131,000 wildlife strikes occurred with civil aircraft, 97 percent of which were the result of collisions with birds, with 25 resulting in fatalities.

It doesn't take a very large bird to do significant damage to an airplane. As the photo here indicates, a turkey vulture, which has an average weight range of between 1.8 to 5.1 pounds can break through an ag aircraft windshield. Even smaller birds such as a mallard duck have broken through ag aircraft windshield and that species of waterfowl only weighs 1.6–3.5 pounds.[1] NAAA especially fears what will happen if a sUAS weighing as much as 55 pounds traveling at 100 mph—both allowed under FAA's finalized UAS operations rule, Part 107—will do to an agricultural aircraft when much smaller birds are known to do significant damage. Birds consist of hollow bones, feathers, sinew and muscle, whereas UAS are made of more solid materials, particularly the batteries.

Above: Luckily, operator Steve Fletcher only sustained minor injuries when a turkey vulture blew out the cockpit window of his Air Tractor 802 while he was flying.

NAAA is concerned that the widespread use of UAS as projected in agricultural areas without devices that allow ag aviators to track and see these aircraft will result in incidents similar to bird strikes, which can ultimately prove fatal. Not only could this result in harm and death for agricultural pilots and chemical spills result-

[1] "Fowl Play: Aviation Bird Strikes Could be a Harbinger of Things to Come Once UAVs Are Approved for Agriculture," *Agricultural Aviation*. May–June [2014]. Pages 12–15. (see *Appendix*). **Editor's note:** the article referred to has been retained in Committee file. It can also be found at: ***http://www.agaviationmagazine.org/agriculturalaviation/20140506?pg=14#pg14***.

ing in environmental endangerment, but it could also result in a black eye for the promising UAS industry.

The agricultural aviation industry places a great amount of importance on the ability to see and avoid obstructions and other aircraft in the airspace in which they operate. While this principal is the backbone of safety for our industry and all air traffic operating under visual flight rules (VFR), it can only be utilized effectively when all aircraft do their part in sensing and avoiding other aircraft and, hence, avoiding collisions.

The necessary technology to allow UAS to "sense and avoid" other aircraft has yet to be proven commercially viable. NAAA believes until this technology is developed, UAS operators in agricultural areas should be required to be equipped with strobe lights on the UAS itself, and, to assist with identification of UAS operating areas, on the UAS operator's ground vehicle. Automatic Dependent Surveillance-Broadcast (ADS–B) Out technology is a key component of the FAA's Next Generation Air Transport System (NextGen) that allows the identification of aircraft based on transponder and GPS signals, and allows nearby aircraft with the proper reading equipment to identify their exact location. Proven, ADS–B-like systems designed for UAS are currently on the market and should also be a requirement for UAS in agricultural areas, allowing low-level manned aircraft to identify them. These units weigh as little as 300 grams and cost as little as $1,200. An ag aviator equipped with ADS–B In technology in his cockpit would be informed of a UAS in his vicinity, then he would know to look for an aircraft, such as a UAS, that should also be equipped with a strobe, outside of the cockpit. This would then enable him the necessary information to then sense and avoid the object.

NAAA also believes the FAA should require that UAS in agricultural areas be painted in colors which make them readily distinguishable from the background. This, coupled with an ADS–B-like system and visible lighting, will greatly improve our pilots' ability to protect themselves from potentially deadly UAVs.

NAAA was pleased to see Part 107 will continue to require UAS to give way to manned aircraft, and believe this practice should continue to ensure human safety. NAAA is concerned, however, that FAA has set a low-bar for entry for UAS operators by not requiring that they demonstrate the ability to safely operate a UAS, or that they be certified pilots well versed in the safe function of our national air space. Moreover, NAAA believes that UAS should be certified to be safely manufactured and maintained like agricultural aircraft and other manned aircraft must be.

Conclusion

NAAA's goal is to ensure a continued safe operating environment for aerial applicators and UAS users throughout the UAS integration process. Given that crop sensing and aerial photography are among the top growth areas for UAS, we believe it is vital that the future fleet of unmanned aircraft are marked and piloted by responsible, knowledgeable professionals.

NAAA urges the Subcommittee to support future UAS safety efforts to prevent future accidents that would setback the UAS industry for years to come.

Thank you, and please feel free to contact me if you have any questions.

Sincerely,

ANDREW D. MOORE.
Executive Director.

SUBMITTED STATEMENT BY CHRISTOPHER C. DOMBROWSKI, PH.D., CHIEF TECHNOLOGY OFFICER, TERRAVION, INC., SAN LEANDRO, CA

Innovation in Aerial Imagery and How It Can Be Useful to Farmers

TerrAvion helps farms take a high tech approach to improving yield and revenue, with the first cloud-based, next day aerial imaging and data analytics service for agriculture. From small family farms, to the largest agribusinesses, TerrAvion provides producers with images and data that accurately detail the conditions of every acre, allowing farmers to identify problems before they can impact yield. As we move into the future, with our ever growing population, we will have to rely on precision agriculture, and just plain farm smarter.

Our company began with our founder and CEO Robert Morris, who served in U.S. Army as the Tactical Unmanned Aerial (TUAV) Platoon Leader in Afghanistan. The platoon was the first of its kind in Afghanistan, and helped uncover critical intelligence that altered the course of a number of strategically important operations.

When he returned to civilian life, in 2012, a farmer friend said to him, "You ran a drone platoon in the army. I need to see all of my crops every week. Can I use drones for that?" The friend was not able to survey the entirety of his fields in the time he had. It was the same problem that the army had solved with drones and stealth aircraft.

Robert explored the market and quickly ascertained that, as useful as drones can be, they would not provide a scalable, and affordable, service to the people that needed it most, the farmers. The other option of plane-based imagery was available, but they charged $6–$15 per acre, per pass (fly by), and the imagery was not sent for weeks! Not only was the cost prohibitive, the delay in receiving the imagery caused the data captured to be too out of date for anything but a few, limited uses.

Due to his time in the military, Robert know that it was possible to deliver imagery much more quickly. Our imagery is available next day, and we are working on cutting that time down. He ultimately decided to partner with an expert in computer imagery and equipped light aircraft with the hardware necessary to collect large amounts of data and deliver it to TerrAvion's servers in real time, where it could be packaged and sent to individual clients. For far less than the cost both in time, and capital of procuring a drone, or drone service, a producer can subscribe to TerrAvion's cloud-based service and not have to worry about the extra management. Electric drone collection uses 20 times more labor per acre than TerrAvion. This model simply doesn't work for growers who are trying to control costs or for a populous expected to reach nearly 10(9) billion people by 2050. Last year TerrAvion collected more acres per week than all electric drones combined did in a year. With TerrAvion, the farmer can focus on their farm.

TerrAvion's core focus is to provide growers with high quality aerial imagery that is current and actionable. For most of our customers this means imagery delivered once per week within 24 hours of capture. By cutting down the time it takes between gathering the data, and putting it in the farmer's hands, we allow them to act on the imagery in a meaningful way. With our subscription based plan, we can take more images and avoid weather and time constraints that affect other services, namely drones and satellites. The high frequency of flights gives the grower the ability to rapidly detect issues and target problem areas in the fields, as well as monitor the efficacy of different fertilizers, pesticides, seeds, *etc.* While about 90% of our customers sign up for annual subscriptions we are also provide single and multishot services for a variety of needs and purposes. As we continue to grow we will apply our services to the crop insurance adjustment sector. In the past, we have provided our customers with timely imagery of their crops after disasters such as wildfires or flooding. This information allowed them to document damages and calculate the acreage affected, a useful tool for farmers and insurance companies alike.

Our current offerings can be summed up by the following list:

- Visible imagery:
  - Provides overview of entire operation in one image.
  - Directly comparable to what would be seen on the ground.
  - Directed scouting, where to focus manpower, where you don't need to check.
- IR:
  - Color Infrared, a traditional imaging technique allows for rapid detection and assessment of vegetation.
  - NDVI (Normalized Difference Vegetation Index) allows for the assessment of plant health and vitality.
- Thermal:
  - Water management, leaks and plant growth associated with leaks have a strong signature in the Thermal Band.
  - Stressed plants can be distinguished from non-stressed plants easily in the Thermal Band.
- Analytics:
  - Through image processing useful information can be extracted into tabular form. Vegetation mean, planted acreage, quality variation, *et cetera.*
  - This tabular data can easily be compared, field to field, region to region, or track a crop through time.
- Big Data:
  - Our data can be combined with other GIS ready data such as weather, soil chemistry, irrigation data, treatment regimens, *et cetera.*

◦ Analysis and planning can be done combining all available data.

These offerings lead me to point another advantage of the precision agriculture movement, and of TerrAvion in particular. We manage all of the technological burden. We collect and process the data and make it deliverable through a standard web browser or mobile application. All we require from a customer is the location and geometry of the area they need flown and when. Our API is fully supported and has already been integrated with several of the largest agricultural retailers in the U.S., allowing our customers to quickly, and easily, access their imagery in existing management systems.

TerrAvion provides full documentation and training programs, free of charge, to teach growers who are not used to using aerial imagery so that they may manage their crops more efficiently. This support provides a tremendous value to the grower and reduces a primary barrier to entry into the usage of aerial photography. While we provide some analytics, and that amount is growing, TerrAvion knows that technology is not going to replace farmers, or their personal knowledge. We seek to provide them the support they need to move forward in a rapidly changing world. In our minds, we work for the growers.

Because of all of the reasons listed above, growers can farm smarter. Aerial imagery allows for farmers to target problems areas, drastically reducing labor costs as well as other inputs. The extra time provides farmers the ability to improve the entirety of their field, increasing yield, while decreasing their investments. With our service a grower can view the entirety of their crops in one place and have confidence that the choices they are making are accomplishing results.

As recently as 5 years ago, what we do would not have been possible at a large scale. The speed of image processing and cloud computing has made this service accessible to every grower. Sensors are constantly evolving, giving farmers more and more insight into the plants they see every day. With our plane-based systems we have the ability to add more sensors to our collection at a minuscule increase in cost. And now, we can do this at a resolution that is competitive, or better than drones and satellites at lower cost that is better or competitive.

What makes TerrAvion different/unique among aerial imagery options? Among other mapping and technology options?

- High revisit and up to date images.
- Rapid delivery of imagery. We strive for 24 hour turnaround from capture to delivery to the customer.
- Subscription-based service. Cost is for a season of up to date images, not per pass. 90% of our customers use annual subscription, about 10% do single or up to three passes.
- Cost and scalability are unbeatable.
- Easy integration with other management systems.
- Our company is built on serving the needs of farmers/the market and not on technology/silicon valley hype, that being said we are always innovating.
- We have the ability to survey large areas for insurance adjusting after natural disasters

What new, innovative practices is TerrAvion employing?

- Distributed collection brings collection costs down.
- Cloud-based storage, processing, and delivery reduces infrastructure overhead bringing costs down.
- Distributed labor force allows for 24 hour coverage and overnight delivery.
- Image processing and analytics as a service.

How is this different from something farmers could get 5 years ago? 10 years ago? 20 years ago?

- Speed of collection and rate of delivery.
- Cloud computing has allowed for the processing and delivery of data on a scale what would have been cost prohibitive even 5 years ago.
- Sensor size has dramatically increased while costs have decreased in the past 20 years.
- Competitive or better resolutions than satellite and drones.

What challenges for farmers can be mitigated by using TerrAvion?

- Directed scouting, documentation, and overall labor reduction.

- Crop management: problem detection (pest, disease, water, *etc.*), yield prediction, side by side trial comparisons, informed decision making.
- Big data analytics.

○