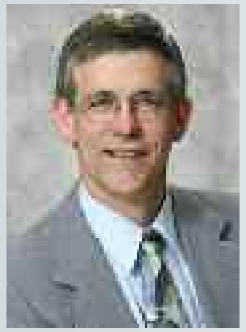

Dear Colleagues,

It's been another productive and interesting year for research in the Jerome J. Lohr College of Engineering. Our faculty continue to improve their knowledge and understanding in their respective disciplines. In addition to successfully competing for research grant money, they expand their skills seeking new opportunities at those interfaces existing between established disciplines. As we reviewed our work, we were impressed at the level of collaboration among disciplines. So, we decided to highlight just a few projects that have these features.

These collaborative partnerships come at all levels. One project involves using biochar to improve the performance of a fundamental electronic device—the capacitor. Associate professor Qi Hua Fan in our electrical engineering and computer science department has partnered with associate professor Zhengrong Gu in agricultural and biosystems engineering, along with colleagues in chemistry and physics, to greatly improve the efficiency of capacitors and reduce their manufacturing costs at the same time! An added benefit of this type of collaboration is the ability to acquire new equipment. Gu and his team received a National Science Foundation award to purchase SDSU's first-ever transmission electron microscope.

Another type of collaboration that occurs less commonly is with industry. One example highlighting this is imaging engineer Larry Leigh's interaction with the internet giant Google. Google brings computing capabilities that most universities can only dream about. Through this partnership, Leigh has been able to perform global searches for satellite calibration sites in hours that would otherwise have taken months.

We continue to focus on the topic of precision agriculture as we believe it is the world's next critical research need. Precision agriculture is a quintessential example of collaboration. Our feature article on this topic showcases a transdisciplinary team spanning engineering, computer science, mathematics and statistics, agronomy, hydrology, climatology and economics. This diverse team is tackling a new problem affecting soybeans—white mold—which has the potential to affect a large percentage of soybean production in South Dakota and the surrounding region. Our team is partnering again with industry, in this case, SST Software, a company with one of the world's largest precision agriculture databases, to develop a predictive model so that producers can stay ahead of this devastating disease.

We continue to play an active role using our talents to address important problems for which solutions can greatly benefit mankind. While our level of external funding is down this past year, $5.2 million as compared to $5.8 million the year before, we are still following our long-term growth trend and have not slowed in the slightest when it comes to applying our skills to difficult and interesting problems. Feel free to contact our office at any time if you'd like to know more about research in the Jerome J. Lohr College of Engineering.

Dennis Helder, Ph.D.
Associate Dean for Research
Distinguished Professor of Electrical Engineering

ENGINEERING RESEARCH REVIEW 2016

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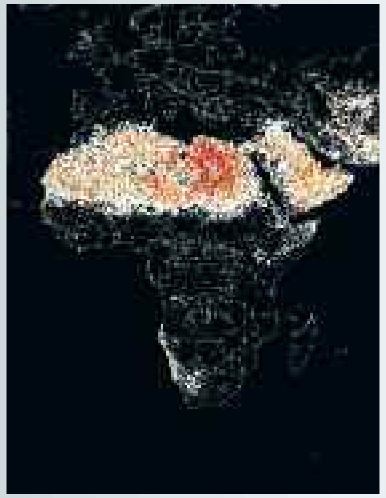
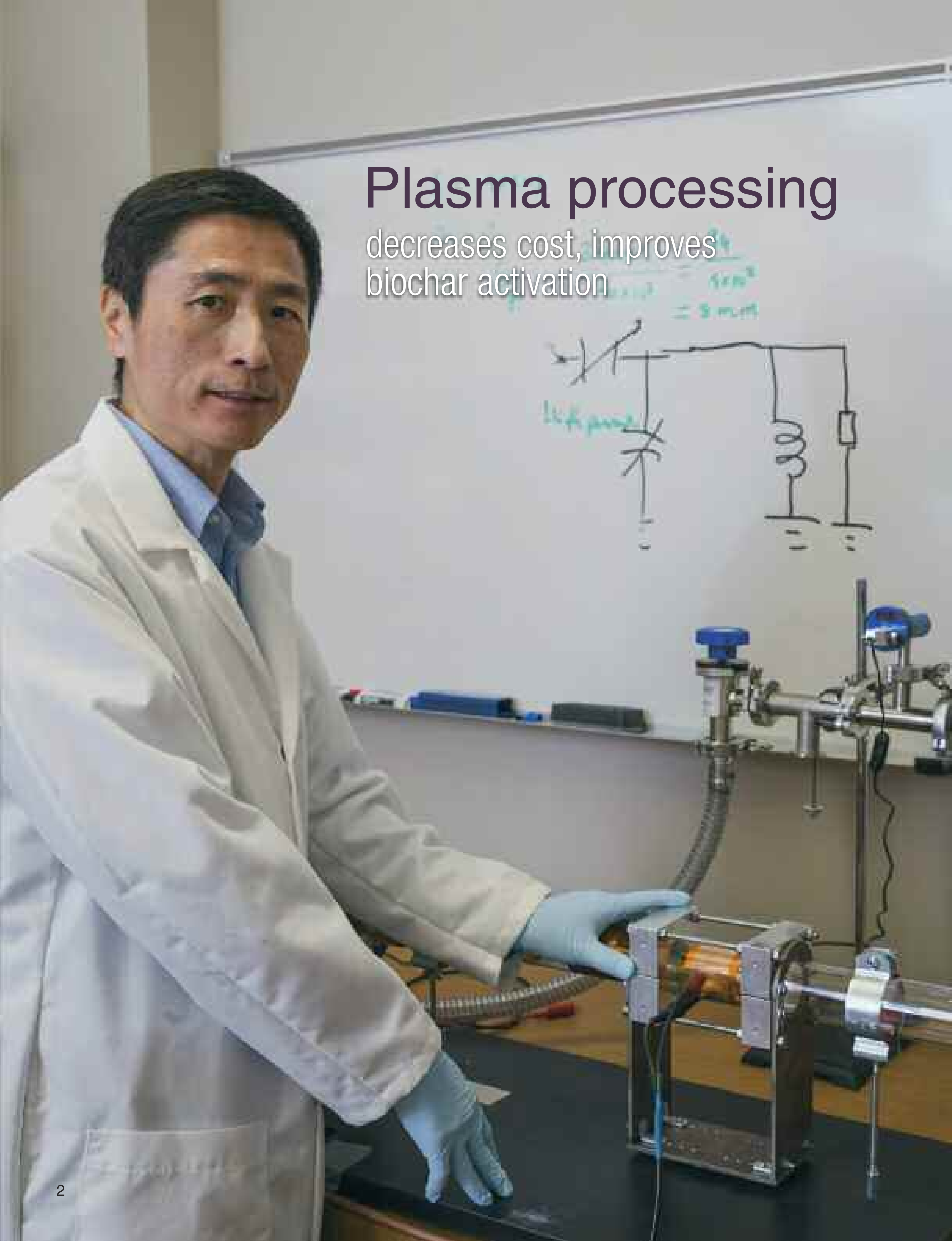


About the cover
This image of Africa and the Middle East is part of the first worldwide search to identify potential sites to calibrate earth-imaging satellite sensors, such as those aboard the Landsat series. A partnership between the SDSU Image Processing Laboratory and Google Earth made this possible. See story on pages 8-9.



Plasma processing

decreases cost, improves biochar activation

Plasma processing and biochar are a winning combination for associate professor Qi Hua Fan of the Department of Electrical Engineering and Computer Science.

Through a partnership with College of Agriculture and Biological Sciences researchers, Fan used oxygen plasma to efficiently etch biochar to coat the electrodes on supercapacitors. He collaborated with agricultural and biosystems engineering associate professor Zhengrong Gu whose goal is to use biochar to replace expensive activated carbon, thus decreasing the cost of these energy storage devices.

Furthermore, Gu, Fan and an interdisciplinary team of SDSU researchers secured funding for a transmission electron microscope, which will allow Fan to characterize the internal structure and morphology of the materials he develops.

Since 2014, Fan has been experimenting with ways to use plasma processing to more efficiently develop electro-optical materials.

Activating biochar

"Raw biochar needs activation to create the porous structure needed to trap ions," Fan pointed out. Traditional chemical activation requires a high temperature, in the range of 1,700 degrees Fahrenheit for 2 hours, and a chemical catalyst, followed by chemical washing and prolonged drying. This makes it an energy-intensive, time-consuming process.

The charcoal-like biochar can be made from crop residue, such as corn stover, wood or even dried distillers grain with solubles, known as DDGS. However, for this research, Fan used commercially available biochar made from yellow pine.

Several research groups had analyzed the specific capacitance and performance of this type of biochar, he explained, "so we had a baseline." In addition, a company could supply the quantities of biochar necessary to make sure that test results were repeatable.

To do the plasma etching, oxygen was used and excited by radio frequency energy through a dielectric barrier discharge. Fan then gave the activated biochar to Gu, who made the supercapacitors. The research was supported by a five-month, proof-of-concept grant from the North Central Regional Sun Grant Center. Two graduate students worked on the project.

Increasing capacitance, efficiency

When the researchers compared capacitor performance, they found that those made using plasma treatment had 1.7 times higher specific capacitance, 171.4 Farads compared to 99.5 Farads using chemical activation. "That's a big improvement," Fan pointed out.

The process took only five minutes with no external heating or chemicals needed. "It is very fast and consumes very little energy," he noted. "The energy required to activate biochar is equivalent to what we use for a light bulb."

In a paper published in the Journal of Power Sources, Fan, Gu and assistant physics professor Parashu Kharel explained, "oxygen plasma was capable of creating various pore sizes that would allow easy access for the electrolyte ions to the porous surface, leading to a higher capacitance than the chemically activated biochar."

In addition, oxygen plasma-activated capacitors had lower estimated resistance, 3.3 ohms as opposed to 14.5 ohms for chemically treated capacitors. This was attributed to the ions having easier access to the micropores and mesopores created by plasma processing.

And, Fan added, "Yellow pine is not the best biochar for supercapacitors." He expects a similar improvement in performance using biochar derived from other types of biomass.

However, he pointed out, the process must be optimized for each type of structure. "Activation depends on what kind of plasma, what conditions are used and how long we treat the material."

Fan has filed a patent application for the plasma activation process he developed. The next step will be to apply for funding to expand this promising processing technique for other types of biochar.

"No matter what kind of parameters we eventually end up with, this will be very efficient," he added.

Qi Hua Fan

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Opposite: Associate professor Qi Hua Fan is developing new electro-optical materials using this plasma processing equipment.

Below: Keliang Wang, a doctoral student in agricultural and biosystems engineering, places a tiny specimen of activated biochar into the probe, checks its position and then inserts it into the transmission electron microscope.

SDSU purchases transmission electron microscope

When associate professor Qi Hua Fan wanted to identify the nanosized features that plasma etching creates, he had to send his samples to another university for analysis using a transmission electron microscope. That will no longer be necessary.

Through a three-year, $775,155 grant from the National Science Foundation along with $332, 210 in university matching funds, SDSU researchers purchased a transmission electron microscope. Associate professor Zhengrong Gu leads the project, along with Fan, professor Heike Bucking and associate professor Ruanbao Zhou in the biology and microbiology department and assistant professor Cheng Zhang in chemistry and biochemistry.

The microscope uses a beam of electrons, rather than light, transmitted through a thin specimen. It is able to examine details in cells and materials at a molecular level.

"It's the most powerful tool we can use to study the microstructure of this material," Fan said. The tool will be important not only for Fan, but also for other materials scientists. Gu also plans to do imaging for customers outside the university.

"We will maximize the use of this instrument," Fan said. "We should be able to do very nice research work."

Satellite calibration

crucial to world's scientists

The effects of wind and waves on the coastline, damage from the Cherynobyl nuclear disaster in Russia and the impact of wildfires and even pine beetles in national forests can be tracked through earth-imaging satellites.

The Landsat series of satellites have been recording the condition of the Earth's surface since 1972. However, for the satellite sensor images to be valuable to scientists, they must be accurately calibrated.

That's where the expertise of the SDSU Image Processing Laboratory comes in.

Since 1990, SDSU engineers have been doing radiometric characterization and calibration of sensors on the Landsat satellite series through a partnership with the NASA Goddard Space Flight Center in Greenbelt, Maryland, and the U.S. Geological Survey Earth Resources Observation and Science (EROS) Center in Baltic.

Signals from satellite sensors produce digital images composed of pixels, according to image processing laboratory director Dennis Helder, who is also on the Landsat Science Team. Each pixel measures the amount of energy reflected or emitted from the Earth.

When those images are calibrated, they become datasets that scientists can use to document and analyze changes occurring on the Earth's surface over time—in the case of Landsat, for nearly 45 years. Otherwise, Helder noted, "they're only pretty pictures."

EROS is the national repository for Landsat satellite images.

Measuring radiance

Satellites basically take photos at different wavelengths, which correspond to different colors of light, explained David Aaron, who has worked in the image processing laboratory for 14 years. "The intensity of those different light colors is what's important."

The sensors measure spectral radiance—watts per square meter per steradian per micrometer—and store a digital number that has a linear relationship with radiance in the onboard computer.

Before the satellite is launched, the sensors are calibrated to an absolute radiometric number. However, Aaron pointed out, "Over time, they drift or change. What we do is monitor that."

One method of calibration involves deploying a ground crew to take measurements at the same time that the satellite passes over the location and then comparing those light measurements with those from the satellite sensors. This is commonly called vicarious calibration.

However, Aaron explained, the image processing team must take into account how much light is lost when it passes through the atmosphere. Consequently, the crew measures the sunlight that travels to the ground and runs those figures through a model called MODTRAN to predict what the sensors should see when a satellite passes overhead. From these readings, the engineers can adjust the calibration—the relationship between the stored number and radiance.

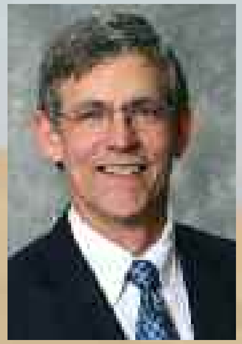
"We are one of a handful of laboratories that do this kind of work," Helder said, with the majority being federal laboratories. Only two other universities—University of Arizona and Rochester Institute of Technology—have remote sensing groups that work with satellite calibration.

Increasing reliability

"What the image processing lab does is absolutely critical to scientists," said David Roy, a senior scientist at the Geospatial Sciences Center of Excellence and coleader of the Landsat Science Team.

CONTINUED NEXT PAGE

In August 2010, Dennis Helder and Larry Leigh of the SDSU Image Processing Laboratory and Kurt Thome (pictured), a scientist from the NASA Goddard Space Flight Center, were part of an international field campaign that evaluated Tuz Gölü, one of the world's largest salt lakes, as a pseudo-invariant calibration site. Teams from 10 nations participated in the three-week mission in central Turkey. The silver box is called a reflectance standard because it relates the ground measurements to a known National Institute of Standards and Technology (NIST) traceable standard.



Dennis Helder

Director of SDSU image processing laboratory and associate dean for research

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"We are one of a handful of laboratories that do this kind of work."

Photo left: Imaging engineer Larry Leigh, assistant professor David Aaron and imaging engineer Morakot Kaewmanee take readings at a vicarious calibration site in southeast Brookings. The scientists must visit the site when the satellite passes overhead to calibrate the sensors.

Aaron, technician Pedro Valle De Carvalho E. Oliveira of the Geospatial Sciences Center of Excellence, Leigh and Kaewmanee measure reflectance of the sand at all slopes and orientations at the Algodones Dunes in California, one of the image processing lab's pseudo-invariant calibration sites (PICS), in March 2015. After the initial readings are taken, the team can use the PICS to calibrate sensors without revisiting the site.

"What the image processing lab does is absolutely critical to scientists."

—David Roy, senior scientist at the Geospatial Sciences Center of Excellence, coleader of the Landsat Science Team and head of the Web-Enabled Landsat Data project

Because of accurate calibration, Roy can analyze data collected at one location from 1972 until now and "know with some degree of confidence that any changes are due to human activity, weather and climate and not instrument artifacts or degradation."

During the last 40 years, the instruments aboard the satellites have become more sophisticated and their reliability has improved. The initial specification for Landsat 1 calibration was a 15 percent error margin, but, in reality, it was closer to 10 percent, Aaron explained. For Landsat 8, that has been reduced to 3 percent.

In an ongoing project, imaging engineers have improved the calibration of earlier Landsats, reducing the margin of error to 7 percent, according to Aaron. Using stable sites in remote areas where the surface properties do not change, the scientists were able to do what is called "backward calibration."

"This turned out to be a difficult task because the early Landsat instruments used detectors that were built from vacuum tubes," Helder explained. "Anybody old enough to remember old radios and televisions made using vacuum tubes knows how unstable they were."

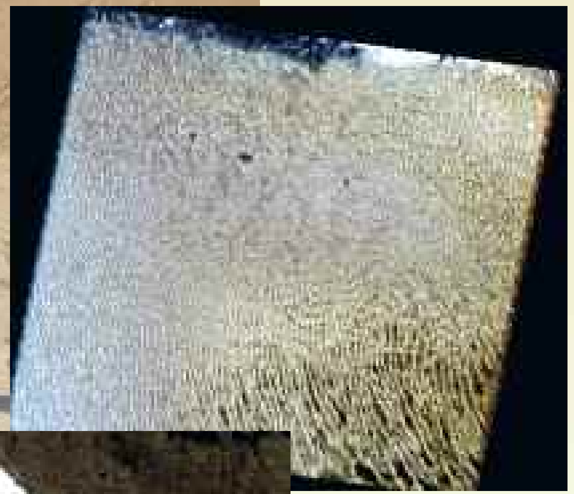
Decreasing calibration costs

Another satellite calibration approach uses pseudo-invariant calibration sites (PICS) to provide a less expensive way to calibrate satellite sensors. For example, the SDSU team has identified PICS in the Libyan desert based on 25 years of Landsat 5 data and at the Algodones Dunes in California.

"When a satellite observes these test sites, it should measure the same amount of energy each time," Helder said. "This approach is less expensive because you don't have to put a team in the field at the site or do a lot of data processing from the field team's measurements."

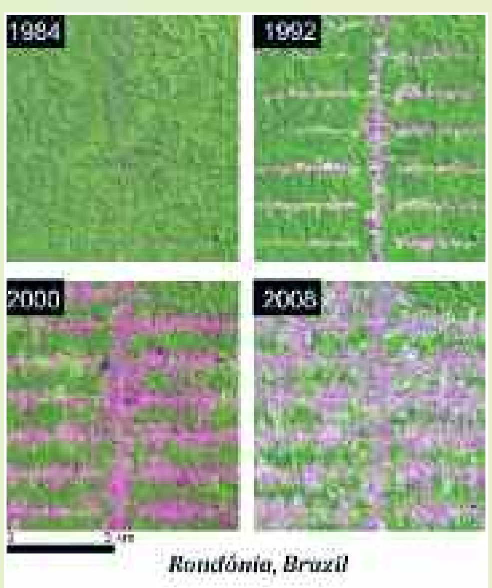
These advances have led the image processing laboratory to offer its calibration expertise to governmental and commercial agencies working with optical remote sensing satellites around the world. "We work with virtually all of the commercial satellite people in our country and many international agencies," Helder said, including Planet Labs, Digital Globe, as well as the RapidEye constellation and Surrey Satellite Technology Ltd.

"It is critical to broaden our horizons in order to ensure the world has the most accurate instruments possible to study global change," he added.



These satellite images show Libya 4 in the Sahara Desert, above, and Tuz Gölü, a salt lake in central Turkey, left. Both are pseudo-invariant calibration sites.

Landsat images track drought, deforestation in Brazilian Amazon



Assistant research professor Izaya Numata of the Geospatial Sciences Center of Excellence utilizes Landsat images to determine how drought has affected a heavily deforested area of the southern Brazilian Amazon. The area, which includes the states of Acre, Rondônia and Mato Grosso, experienced two major droughts within five years—one in 2005 and another in 2010.

"Accurately characterizing forest and other land-cover types to detect changes in time and space requires a well-calibrated Landsat time-series dataset—that's what we get thanks to the work done at the SDSU Image Processing Laboratory," Numata said. For the NASA-funded project, he and a team of scientists, including researchers in Brazil, are analyzing Landsat data from 1997 through 2014 to track the creation and expansion of the forest fragments as well as their reaction to drought.

Because the relatively new global Web-Enabled Landsat Data website contains data only from 2009 to 2011, Numata and his colleagues download Landsat data from U .S. Geological Survey Earth Resources Observation and Science (EROS) Center.

The researchers utilize Landsat datasets from six spectral bands, converting the radiance into reflectance. "We use the spectral mixture model to transform reflectance into fraction data including vegetation, soil, nonphotosynthetic vegetation and shade to better characterize and map the land-cover types in the Amazon," he explained.

This work will help researchers predict the long-term impact that global warming may have on these deforested areas.

Left: These composite images use three Landsat spectral bands— red (band 3), near infrared (band 4) and shortwave near infrared (band 5)—to show deforestation in a section of the Amazon forest in Rondônia, Brazil, according to assistant research professor Izaya Numata of the Geospatial Sciences Center of Excellence. What began in 1984 as fine lines expanded to a fish-bone shape in 1992 and eventually in 2008 to land spotted with forest fragments.

Free access increases use of Landsat images

An increasing number of scientists and professionals are utilizing Landsat images, thanks to a NASA-funded project that makes them accessible free of charge. Professor David Roy, a senior scientist at the Geospatial Sciences Center of Excellence, leads the team of researchers who work on the Web-Enabled Landsat Data project.

Monthly and annual Landsat data on the continental United States and Alaska for 2003-2012 are accessible at http://weld.cr.usgs.gov. The data can also be broken into specific seasons.

"The calibration work that the image processing group does makes it possible for us to make these meaningful products," Roy said.

Making datasets user-friendly

Roy and his team use algorithms to transform the Landsat datasets into a user-friendly format. Radiance is converted to reflectance and brightness temperatures and then projected into a single coordinate system, Roy explained. Corrections are made for atmospheric and directional effects and then multiple images from different dates are combined.

Previously, scientists had to purchase these images for anywhere from $600 to $4,000 per image and then manually apply the algorithms necessary to extract the information.

According to a 2012 U.S. Geological Survey report, free access has more than doubled the number of Landsat images downloaded.

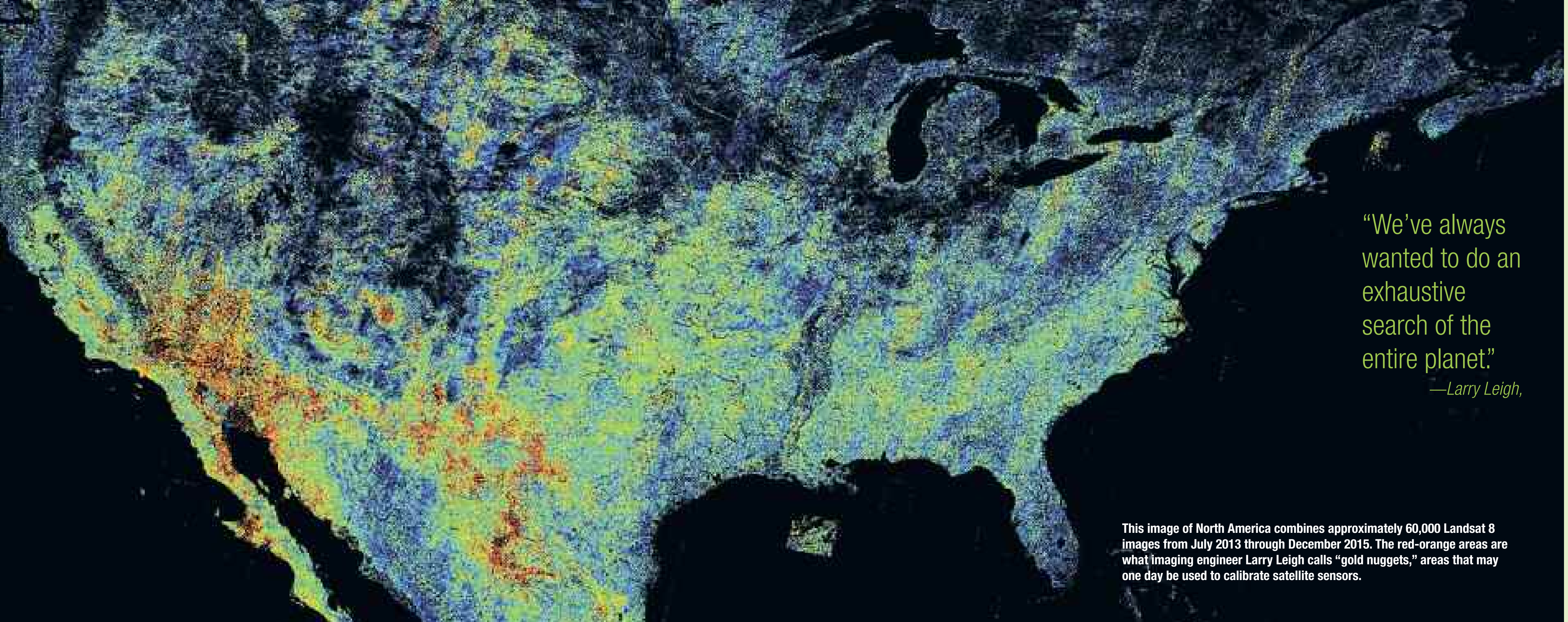
This map identifies fields on which crops are raised in the continental U.S. It was developed using Landsat 5 and 7 images for December 2009 to November 2010 accessed through the Web-Enabled Landsat Data project.

Tracking human activity

"The novel thing about Landsat is the 30-meter resolution," Roy said. "At 30 meters, you can really see human activity—roads, buildings and fields."

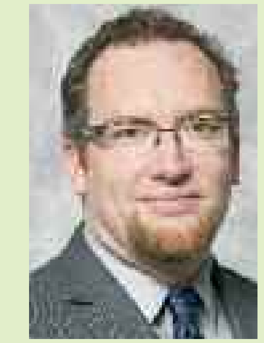
For a NASA study on land-use change, Roy and assistant research professor Lin Yan used Landsat 5 and 7 images of the United States from 2010 and applied an algorithm that automatically extracted cropland field sizes. They identified 4,182,777 fields with an average size of approximately 47.7 acres.

"In a period where evidence of climate change has become discernible and where the human global population has doubled, Landsat provides a crucial global multidecadal baseline for change," Roy concluded.



"We've always wanted to do an exhaustive search of the entire planet."
—Larry Leigh,

This image of North America combines approximately 60,000 Landsat 8 images from July 2013 through December 2015. The red-orange areas are what imaging engineer Larry Leigh calls "gold nuggets," areas that may one day be used to calibrate satellite sensors.



Larry Leigh

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Image Processing Laboratory

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Google Earth Research

High clouds to calibrate atmospheric bands

Having his head in the clouds took on a new meaning this summer for imaging engineer Larry Leigh. He and a graduate student are tracking deep convective clouds to calibrate sensors that look at the atmosphere, rather than the ground, through a partnership with Google Earth.

Satellites, like Landsat 8, have imaging bands that detect atmospheric water vapor, aerosols and thin subvisible cirrus clouds, Leigh explained. "Because these bands don't truly see the surface of the Earth, groundbased calibration targets cannot be used."

"Deep convective clouds live at around 33,000 feet, are very cold and have a specific and modelable brightness," Leigh said. Working with NASA's Langley Research Center, the image processing lab has developed a method to use deep convective clouds to calibrate these nontraditional atmospheric bands.

Using the Google Earth Engine interface, Leigh said, "We are able to track and trend the deep convective clouds." Based on the known properties of these clouds and the ground-based calibration of what are known as 'ground viewing bands,' Leigh said, "We are now able to do routine monitoring of the band that sees mostly atmosphere."

Worldwide search identifies new calibration sites

A research team led by imaging engineer Larry Leigh completed the first worldwide search for new calibration sites through a partnership with Google Earth.

The one-year project was made possible through a $46,000 Google Earth Engine research award. Leigh is the first SDSU researcher to receive this grant.

"We've always wanted to do an exhaustive search of the entire planet," Leigh said. However, not all of the images are readily available through U.S. Geological Survey Earth Resources Observation and Science (EROS) Center in Baltic, and the intensive computational process is beyond the capacity of the image processing laboratory.

Through this collaboration, Leigh and his team of three graduate students have direct access to the Google archives that include EROS images and the computing power to compile the images via Google Earth Engine and its cloud computing capabilities.

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Identifying new PICS

The primary project goal is to identify pseudo-invariant calibration sites (PICS)–remote places, such as deserts and dry lake beds, where the surface properties, and therefore the reflectance, do not change over time. The stability of these sites eliminates the need to revisit the site each time the satellite sensors are calibrated.

To identify PICS in the United States, Leigh and his team have produced a composite image containing 60,000 Landsat 8 images from July 2013 to December 2015. It took the 5,000-node cluster at Google approximately 9 hours to compile the image at a degraded 900-meter, rather than the full 30-meter, pixel resolution.

Using what Leigh referred to as "the old-fashioned way," this nationwide map would have required downloading 150 terabytes of data, which is more than the lab's current capacity of around 110 terabytes.

Scanning planet

Using nine spectral bands from Landsat 8, the team produced what Leigh called "our first-ever PICS global survey." The global image, degraded to a 300-meter resolution, took nearly 350 hours to produce.

"This output will be analyzed to generate a whole new list of PICS," he added. However, he noted, Landsat 8 has only been in orbit a little more than three years.

"The next step will be to run the Landsat 5 archive," Leigh said, which contains nearly 30 years of data—from March 1984 until June 2013. This will allow the researchers to evaluate the longevity of these new PICS and possibly use these sites to calibrate data from past Landsat missions.

Expanding use of sites

After these new sites are thoroughly characterized, Leigh said, "they can be used as routine calibration sites, thus increasing our frequency of observation and improving our ability to detect calibration drift in a much shorter time period."

Most satellites are calibrated on a somewhat irregular basis. However, the discovery of more sites may make daily calibration possible, he noted. Dennis Helder, head of the SDSU Image Processing Laboratory and associate dean for research, hopes that the success of this project will lead to further collaboration between the two entities.

With Google venturing into the satellite business by purchasing Skybox Imaging in 2014, Helder anticipates that these new sites may one day be used to calibrate sensors on Google-owned satellites.

Precision ag group to develop predictive model for **white mold** in soybeans

Dark lesions on these soybean stems are signs of white mold, which is caused by Sclerotinia sclerotiorum. The fungal disease develops when high humidity and moisture are combined with warm temperatures.

A partnership between the Jerome J. Lohr College of Engineering and the College of Agriculture and Biological Sciences will turn the vast data-generation capabilities of precision agriculture into information that can drive decision-making in the field.

"The Precision Ag Initiative addresses what we think the next big issue on the planet will be—food and water," said associate dean for research Dennis Helder, pointing to a world population that now exceeds 7 billion. Building upon their strong and growing partnership, the two colleges are developing the expertise and programs needed to fully utilize agricultural and climate data to help producers.

Helder sees the university as uniquely positioned to capitalize on the concept of site-specific crop management to improve sustainability and increase production.

Daniel Scholl, director of the South Dakota Agricultural Experiment Station and interim dean for the College of Agriculture and Biological Sciences, agreed: "It fits right into our land-grant mission."

College of Agriculture and Biological Sciences scientists determine which field and climatological data should be used and computer scientists and statistical analysts in the Jerome J. Lohr College of Engineering capture and process that data, Helder explained.

"Our key focus is turning that data into information, such as the likelihood of disease occurrence," he said. A producer can then act upon that information.

"We're building up our expertise to support this type of activity," Helder added.

Predicting disease occurrence

The research group's first project is developing a predictive model for white mold in soybeans. To do this, the researchers are working with SST Software, a company that provides data management tools to producers in 23 countries and has one of the largest agricultural databases in the Midwest.

"This disease is hard to predict," Scholl said. "It doesn't happen all of the time under all conditions, so it's a good candidate for semi real-time cues that there is a high enough risk of it occurring to justify pre-emptive fungicide treatment."

SDSU Extension pathologist Emmanuel Byamukama, who leads the white mold pathology research team, said, "Because the disease develops midseason, it is often not detected early enough to apply fungicide. A predictive model will give producers information about when and where the disease risk is likely to be high.

To develop the model, the researchers will use historical data from field sites where white mold occurred and then, based on these parameters, identify areas in the state with similar conditions that have increased risk for disease development during the 2017 growing season.

Retrieving and converting data

"My job is to find out what the ag people need to know and then retrieve that data from SST's archive," said computer science professor Sung Shin. The site-specific information can include yield, soil type and condition, fertilizer and pesticide application, tillage practices, rate of disease occurrence, seed variety and row spacing.

In addition, scouting data from producers or technicians in the field will be part of the mix, according to SST Software Western Corn Belt account manager Scott Cogdill. Producers who enroll in the study will enter the observations into SST Software's database as they survey fields for signs of white mold and give the company permission to share their stored datasets with SDSU researchers. Cogdill's goal is to gather data on about 5,000 acres of soybeans.

Shin will work with SST Software to gain access to enrolled producers' datasets, which the computer scientists will download through Amazon Web Service.

"Retrieval and conversion are the two keywords with this big data project," Shin noted. The computer scientists must convert the SST data into a form that the statistical modeling team, led by assistant mathematics and statistics professor Gary Hatfield, can use.

In addition, Shin will retrieve historical satellite datasets to identify conditions at specific locations where white mold infestations occurred. Furthermore, the researchers will need current satellite images to evaluate conditions statewide and pinpoint areas that have increased risk for disease development this growing season.

Once the statistical analysis is completed, Shin said, "we should convert the output back to SST's desired format—we have to bring it back to them." In terms of decision-making, he anticipated that artificial neural networks, K-means clustering and support-vector machine modeling may be employed.

Developing risk model

"Our objective is to develop a real-time spatial-temporal risk model," said Hatfield, who has experience using geospatial data. One doctoral student is also working on the project.

"We're dealing with lots of variables and observations," he explained. Those variables can be categorical or qualitative, such as soil type or soybean variety, while others are continuous or quantitative, such as row spacing and yield.

Integrating spatial data at different scales—anywhere from 1 meter to 30

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"The Precision Ag Initiative addresses what we think the next big issue on the planet will be—food and water."

—Dennis Helder,
associate dean for research

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CONTINUED FROM PAGE 11

meters or larger—will also be challenging, Hatfield explained. Common vegetation indices, for instance, have a 30-meter scale.

Moisture plays an important role in disease development. Consequently, climate and hydrologic data must be incorporated into the project. Assistant professor Laurent Ahiablame from agricultural and biosystems engineering uses precipitation, temperature and wind speed scenarios as inputs into his predictive model, either the Water Erosion Prediction Project or Hydrus. These results are then integrated into the statisticians' risk model.

In terms of statistical modeling, Hatfield utilizes R programing language, which he said, "provides the latest innovations in modeling techniques for developing an analytical solution to this problem." Because of the large datasets and complexity of the model, processing is done on the university's high-performance computer cluster.

"First, we need to develop the methodology and find out what works," Hatfield said. Once the model is completed, the researchers will compare their predictions with actual disease occurrence. That will then allow them to refine the model.

Lastly, SDSU Extension production economist Tong Wang, who leads the economic team, will do a cost-benefit analysis to determine return on investment for those areas where fungicide is applied to prevent white mold.

Private companies must verify their predictive tools, explained Beth Clarke, director of product development at SST Software. "That's the benefit of working with a university—we have a better chance to be successful."

Clarke sees SST's partnership with SDSU as a long-term relationship that can strengthen the company's relationship with its clients through development of these tools. "Partnerships and collaborations are an integral part of growth. Our partnership with SDSU will provide long-term benefits to the precision agricultural community and SST's customers."

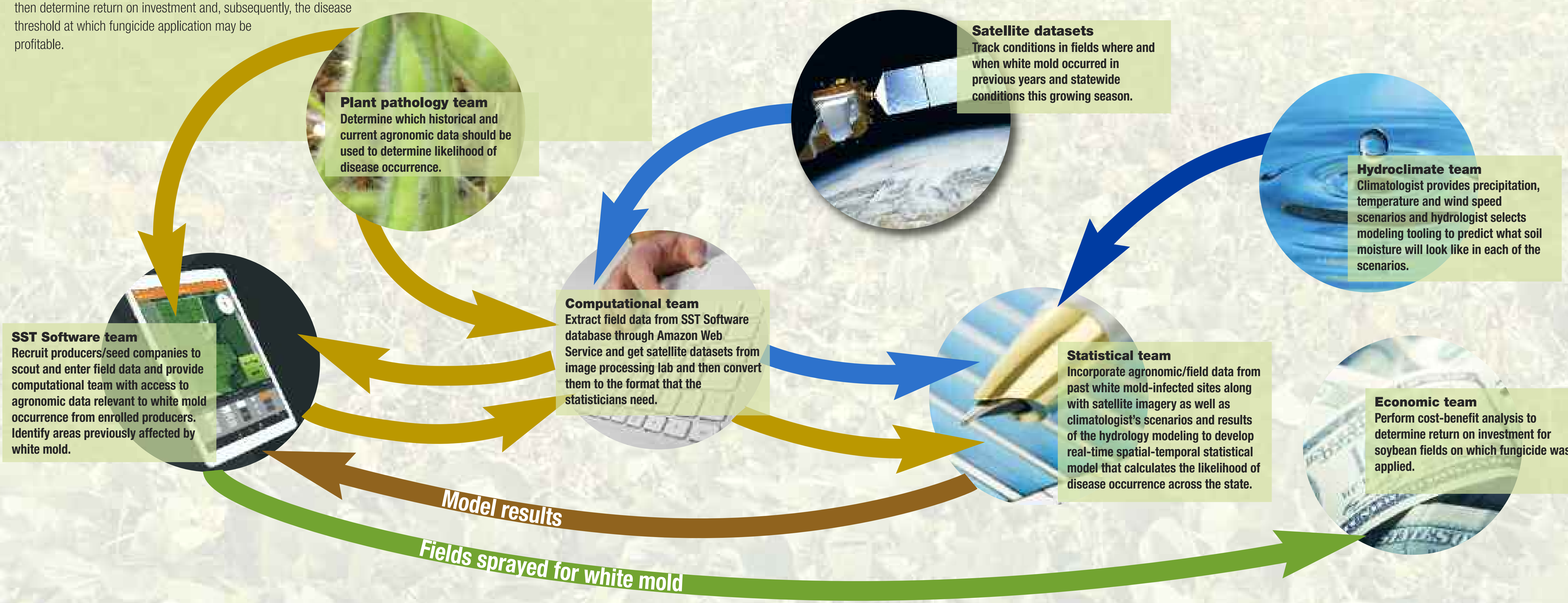
Helder agreed: "We feel this is the wave of the future. SDSU is uniquely positioned to fulfill that role—it's a perfect fit."

Steps to developing predictive model for white mold in soybeans

Based on the conditions that existed within specific fields where white mold developed, researchers are developing a model that uses the current statewide conditions to predict which locations are at increased risk for disease development during the growing season.

First, the plant pathology team determines which agronomic field data were relevant to disease development. Then the computational team will extract field data from enrolled producers through SST Software and satellite geospatial data through the SDSU image processing laboratory. They then will turn that information over to the statistical team which will combine white mold field data with modeling and climate information from the hydroclimate team to develop a real-time spatial-temporal risk model. The predictive model will be completed next summer to coincide with soybean flowering when white mold typically begins to appear. Sharing that information with producers through SST Software will then help producers decide whether to use fungicides in high-risk areas.

Comparing the predictive model and actual disease occurrence for 2017 will then allow the researchers to improve the model for the next growing season. In addition, the economic analysis for selected areas where producers use fungicide will then determine return on investment and, subsequently, the disease threshold at which fungicide application may be profitable.



Computer scientists develop software for new

tumor imaging technology

Patients and their doctors may benefit from a partnership between SDSU computer scientists and a Korean research institute to develop a new method of detecting breast tumors.

The Electronics and Telecommunications Research Institute (ETRI) in Daejeon, South Korea, is perfecting the microwave tomography imaging system. SDSU computer scientists are developing software that will help doctors diagnose and decide on treatment options for breast cancer patients.

Microwave tomography imaging produces a 3-D image using microwaves, rather than X-rays, explained computer science professor Sung Shin. Since 2010, he has been collaborating with ETRI, which holds the patent on the microwave tomography machine. The $500,000 research project supports three graduate students each year.

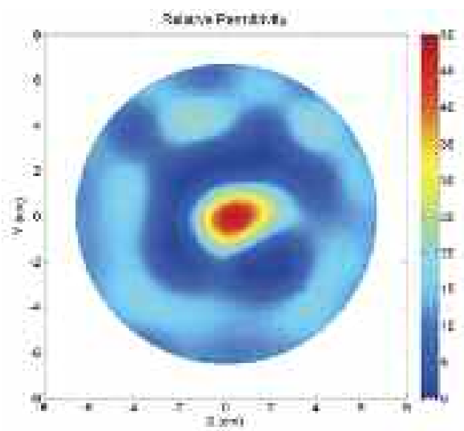
The imaging technique holds promise as a safe method for examining soft tissues, including breasts, lungs, hearts and brains, Shin explained. However, the developers are first targeting breast cancer screening.

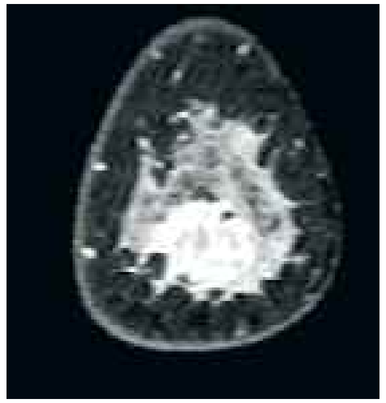
Increasing comfort at lower cost

Microwave tomography has some distinct advantages, Shin pointed out. It may produce better images—particularly in the case of dense tissues—than mammography at a cost that the developers anticipate will be less than magnetic resonance imaging.

Unlike mammography, no compression techniques are necessary. Waves travel through a gel, so the patient simply lies face down on a special bed that allows her to place one breast at a time in the gel.

Each scan takes 5 to 10 minutes, so exposure to microwaves is negligible, according to Shin. Thus, microwave tomography can be a compromise between mammography and MRI.





Software developed by SDSU computer scientists compares the microwave tomography image, left, with the MRI, right, of the same tumor and then extracts the case files of patients with similar tumors. Reviewing the treatments and outcomes from these cases can then help doctors decide on the best plan of action.

To take a microwave tomography image, the patient lies on a special table and places her breast in a compartment filled with gel. The technician then does the scan.

Training algorithms

Shin and his team are developing software that first identifies the tumor on the microwave tomography image and then analyzes its features to determine whether it is more likely to be either benign or malignant. This involves feature extraction, segmentation and classification using machine learning algorithms.

To obtain images of breast tumors, Shin collaborates with Dr. Wu-Kyung Moon, one of South Korea's leading cancer researchers, at Seoul National University. After microwave tomography imaging was approved for use on human subjects in Korea, Shin received data in fall 2012 from the first 15 patients screened using the first-generation 3-megahertz MTI machine, MRI and mammography.

"Based on the MRI images, we know what's malignant in the library," he explained. Utilizing vector machine algorithms and artificial neural networking, Shin and his team "train the software to recognize images that contain malignant characteristics." The image parameters then determine which machine learning method is more accurate.

"The more we train, the more accurate the programing becomes," he noted. This can involve the software examining as many as 100 subregions within the region of interest, where the scan shows abnormalities in the breast tissue.

Identifying similar tumors

The project's second phase is the most difficult, Shin admitted. The software uses what it has learned about the tumor from the MTI scan to select cases from a database of 10,000 MRI images that are similar and then extracts the image along with the patient's case file. This requires the use of decision-making analytics, such as K-means clustering.

Doctors will use the selected cases, which detail what treatments were used and how successful they were at combating the cancer. Based on the patient histories, doctors will then decide on the best plan of action.

"We're still working on this part," said Shin, equating the decision-making process to comparing apples and oranges because MTI and MRI produce different types of images.

Another stark contrast is the number of images available for analysis. "We have thousands of MRI cases, and we already know that some patients died and some were cured," Shin said. However, a limited number of MTI tumor scans are available because the technology is experimental.

In addition, the process is dependent on the image quality that the machine produces, he said.

Improving MTI quality

In 2015, ETRI upgraded its 3-gigahertz system to 6 gigahertz in hopes of improving the quality of the image and sent the SDSU researchers datasets on another 15 patients. Though this added to the number of cases they can use for algorithm training and software development, Shin said, "the machine's resolution is not much better."

As part of the MTI processing, the conductivity measurement numbers must be converted to produce the images, Shin explained. For the 3-gigahertz machine, that took less than five minutes per image. However, he noted, "now it's taking a much longer computational time than expected."

Consequently the ETRI scientists are working to improve the resolution of the 6-gigahertz images and reduce the processing time. "Once they get a reasonable image, we are ready to run with this one." Shin said.

Despite the challenges the partners face, Shin is optimistic about the potential applications of this new imaging technology. He sees the possibility of MTI being used not only to improve the accuracy and reduce the costs of breast cancer screening, but also being applied to different areas of tumor treatment.

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Decision-making analytics help business developers, customers, data centers

What factors do companies use to select data center sites? That's the question assistant professor Yunpeng Pan of mathematics and statistics wants to answer.

"This research is useful to multiple stakeholders," Pan said. First, economic developers seeking to lure data centers to their state can use the decision-making analytical model to identify potential sites. In addition, companies in need of cloud computing services can use the model to search for providers.

Lastly, cloud computing service providers can use the analytical model to identify prime locations for new data centers.

The project was supported by a one-year, $62,038 grant from the South Dakota Board of Regents, in addition to $2,500 from the SDSU Research and Scholarship Committee and $2,500 in matching funds from the Department of Mathematics and Statistics.

Identifying potential users

Those who wish to lure data centers to South Dakota must understand how these sites are selected, Pan explained. "Data centers are not labor intensive; they are capital intensive." Consequently, traditional business recruitment tools, such as employee training, are not effective.

Electricity costs and the availability of renewable energy sources are important, as is the reliability of the power infrastructure and telecommunications capabilities, according to datacenterknowledge.com.

"We can help stakeholders understand the complicated process of how these decisions are being made," Pan said, making what he referred to as "data-driven marketing" possible.

In addition, new companies must set up an online presence, Pan noted. However, selecting the cloud operator and cloud service offering best suited to their needs can be difficult. "It is much harder than finding a cellphone carrier, much more complicated than buying life insurance, because it's often difficult to make an apples-to-apples comparison."

Part of that decision-making depends on quality-of-service measures relevant to specific applications and services, he explained. "Suitable configurations of computing/networking hardware and software are required to achieve good user experience."

For instance, Pan pointed out, productivity applications, video streaming, social media and gaming have different expectations on reliability, security, latency and throughput.

Developing model

Pan has taken a two-pronged approach to developing the predictive model. One graduate student is using remote sensing data from the U.S. Geological Survey Earth Resources Observation and Science (EROS) Center to extract data on all the major data centers in the world.

"This is an automated approach to populating our database," Pan said. Then, a second graduate student, who is fluent in coding and programming, develops algorithms to process that data.

"Our research validates the feasibility and efficacy of employing Landsat 8 satellite imagery to automatically identify and monitor data centers," he said. To do this, they "developed tools based on new image descriptors embodying novel mathematical insights, industrial-strength support vector machine classifiers and a cellular evolutionary algorithm for automated parameter tuning."

In addition, the researchers can identify electrical lines, substations, access roads and wind turbines on the Landsat images. Furthermore, they will try to integrate other data feeds, such as government filings and permits, to validate their image-processing-based data center classification.

Once the model has been fully tested and deployed, Pan said, "site selection optimization will be built on top of this data model." In the end, the model can be used to identify prime locations for new data centers. "Our tool will be very relevant and useful."

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AWARDS

Research Award Winners

Qiao named outstanding researcher for photovoltaics work

Increasing the efficiency of solar cells to 15 percent is the goal that associate electrical engineering professor Qiquan Qiao seeks to accomplish. For his work, Qiao was named the outstanding researcher for the Jerome J. Lohr College of Engineering at the university's 2016 Faculty Celebration of Excellence.

Qiao, who has been at SDSU for nearly 10 years, established a lab devoted to studying organic electronic materials and devices. He and his team are creating a tunneling layer to improve overall photovoltage and photocurrent output of organic solar cells. Another project focuses on building a single photovoltaic unit that will both generate and store energy.

In addition, he is collaborating with professor Muhammad Hassan Sayyad of the Ghulam Ishaq Khan Institute of Engineering Sciences and Technology in Pakistan to develop research on dye-sensitized solar cells and promote renewable energy technologies on a global scale.

Last summer Qiao became the coordinator for the electrical engineering graduate program, which has about 40 master's and 17 doctoral students. This year, he secured more than $1 million in federal funding for photovoltaic research.

This fall he will become the Harold C. Hohbach Endowed Professor in Electrical Engineering. Professor emeritus David Galipeau was the first recipient of the five-year position, which was created in 2011. The investiture ceremony will be Oct. 21.

Neumann earns two early-career awards for forensic science research

Cedric Neumann

Research on statistical models to determine the probability that forensic evidence can be associated with an individual has earned assistant mathematics and statistics professor Cedric Neumann two early-career awards: the Sherwood and Elizabeth Berg Young Scientist Award and the Jerome J. Lohr College of Engineering Young Investigator Award.

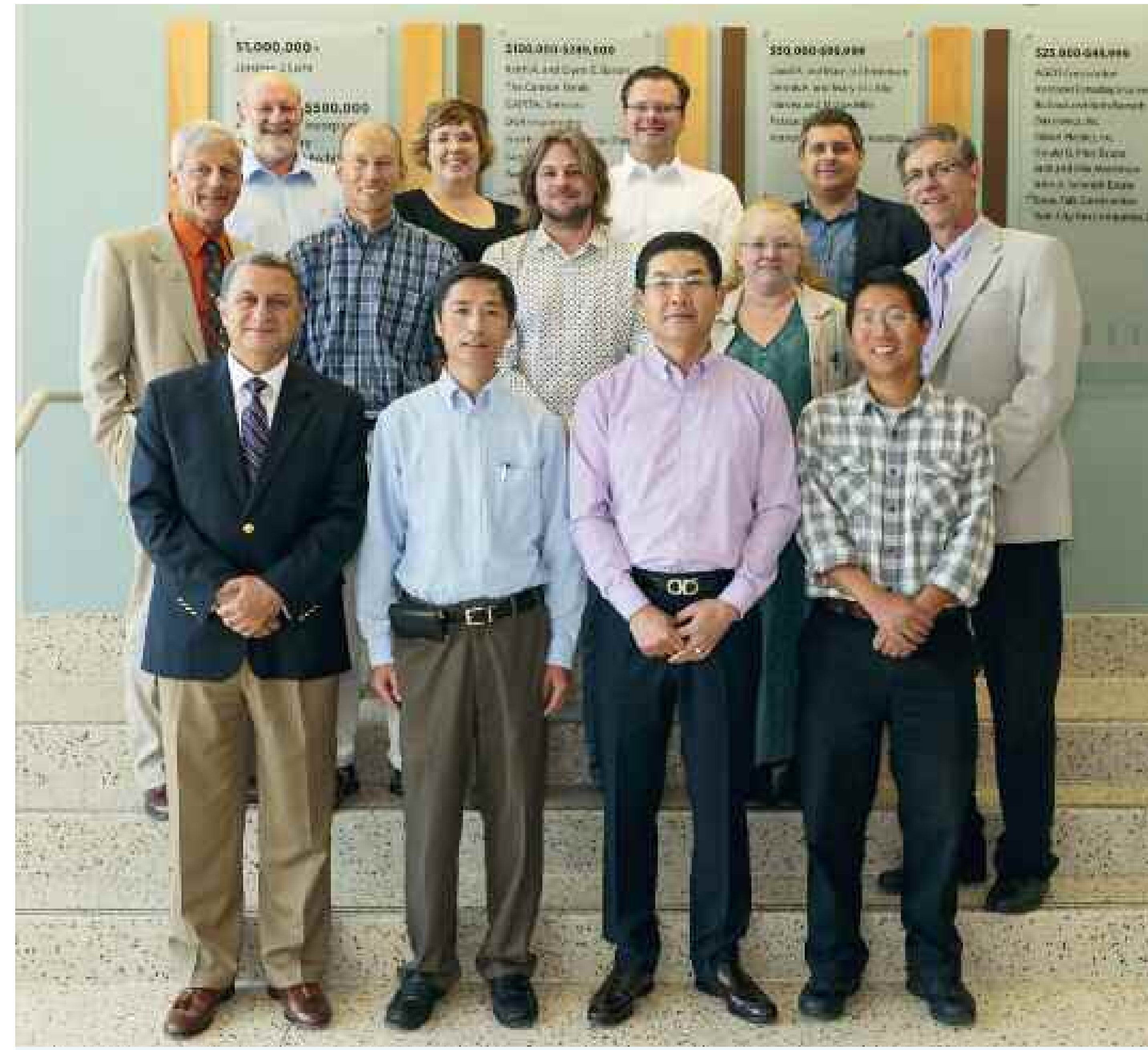
The Swiss native came to SDSU in 2013 after three years teaching and doing research in forensic sciences at Pennsylvania State University. Prior to that, Neumann was scientific manager of the statistics and interpretation research group at the national forensic laboratory of the United Kingdom for five years and developed projects for the U.S. Secret Service for two years.

Neumann and colleague Chris Saunders are developing statistical models designed to determine the probative value for forensic evidence, such as glass shards, fingerprints, bullets and handwriting, through a three-year $780,300 grant from the National Institute of Justice. They are the first SDSU statisticians to receive such a grant.

"There is a strong movement to quantify the probability value of evidence to support the fairness and transparency of the criminal justice system," Neumann said. The goal of the project is to build a solid foundation for determining probability values that will help law enforcement agencies and the court trust the forensic evidence.

"Their work could have a lasting impact on the national criminal justice system," said Kurt Cogswell, who leads the Department of Mathematics and Statistics.

Grantswinship award winners recognized



The Jerome J. Lohr College of Engineering faculty members who secured or had research expenditures of $100,000 or more during the 2015 fiscal year are: first row, from left, Nadim Wehbe, Qi Hua Fan, Sung Shin and Qiquan Qiao; second row, Rich Reid, Ross Abraham, Cedric Neumann, Suzette Burckhard and Dennis Helder; third row, Ken Skorseth, Sharon Vestal, Stephen Gent and Chris Schmit. Not pictured are Jon Puetz, Fereidoon Delfanian and Chris Saunders.

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