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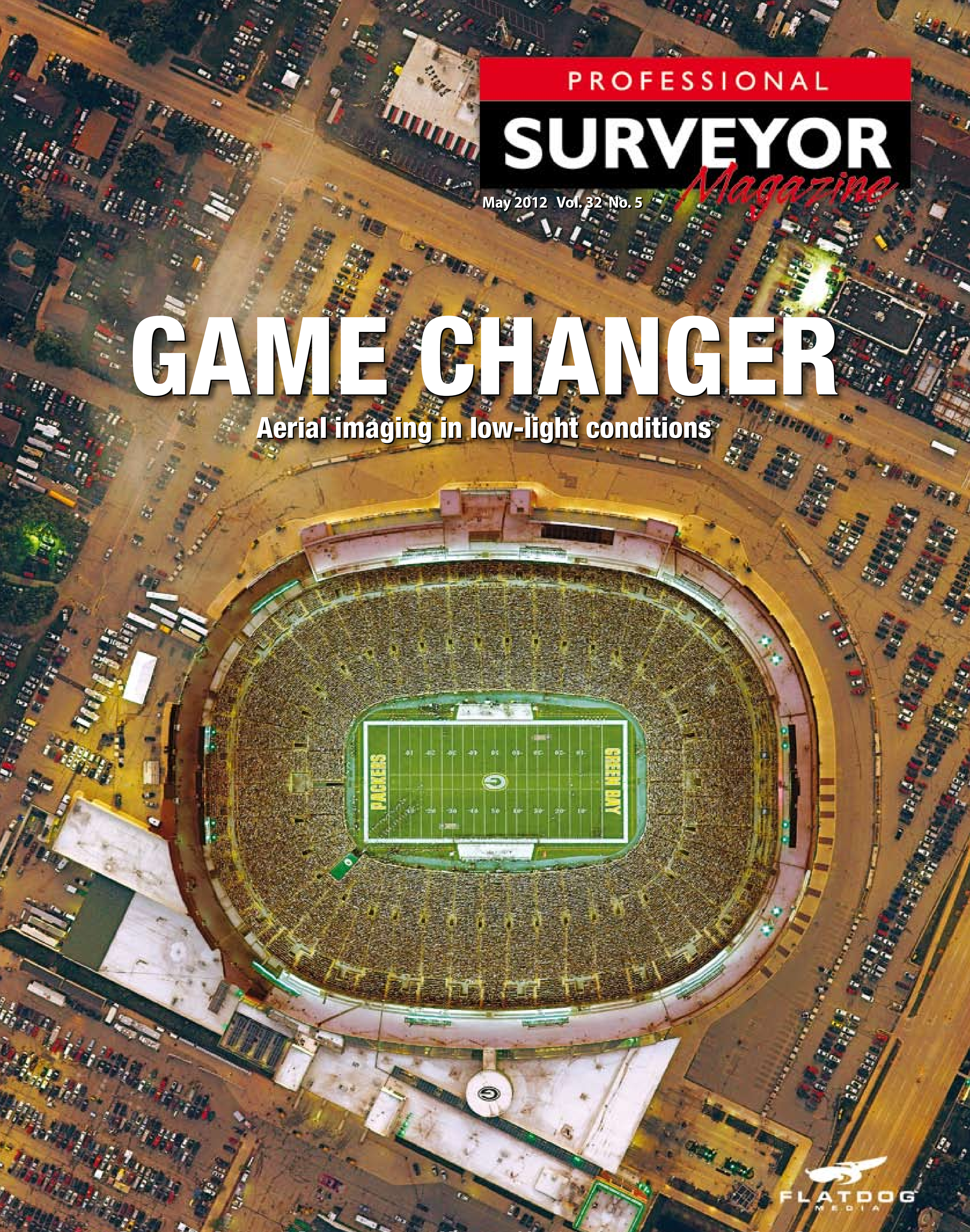
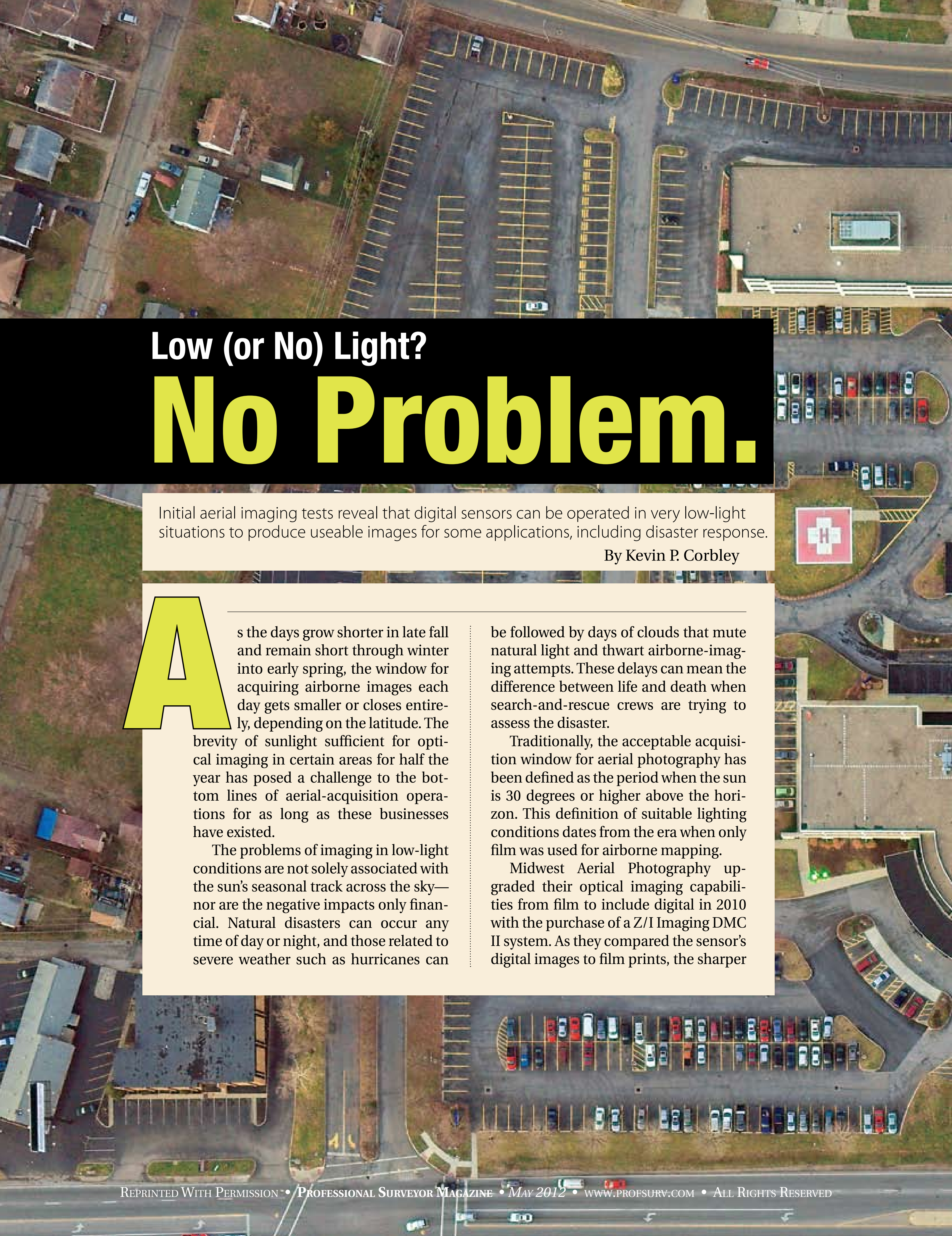
GAME CHANGER

Aerial imaging in low-light conditions





Low (or No) Light? No Problem.

Initial aerial imaging tests reveal that digital sensors can be operated in very low-light situations to produce useable images for some applications, including disaster response.

By Kevin P. Corbley

As the days grow shorter in late fall and remain short through winter into early spring, the window for acquiring airborne images each day gets smaller or closes entirely, depending on the latitude. The brevity of sunlight sufficient for optical imaging in certain areas for half the year has posed a challenge to the bottom lines of aerial-acquisition operations for as long as these businesses have existed.

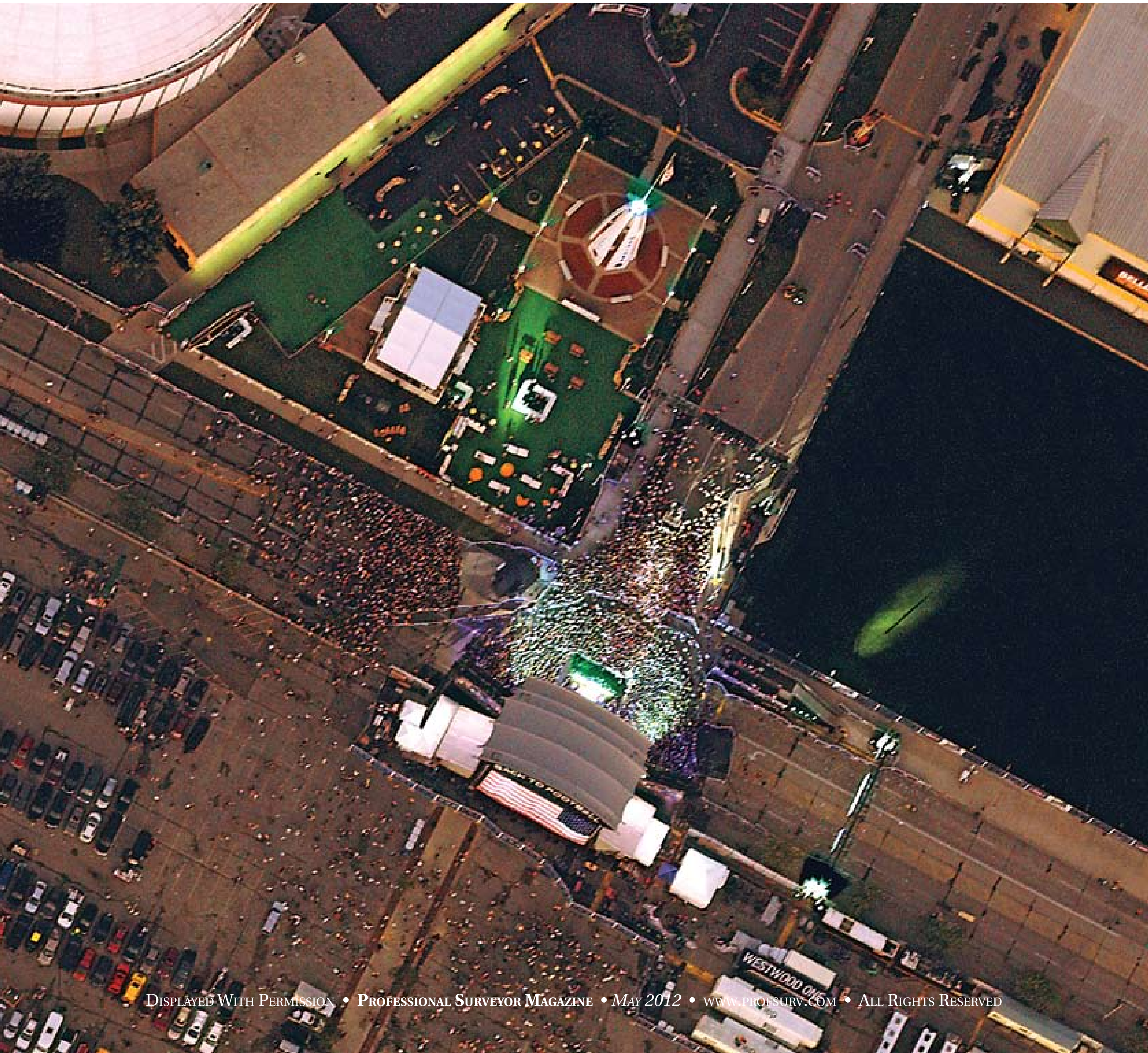
The problems of imaging in low-light conditions are not solely associated with the sun's seasonal track across the sky—nor are the negative impacts only financial. Natural disasters can occur any time of day or night, and those related to severe weather such as hurricanes can be followed by days of clouds that mute natural light and thwart airborne-imaging attempts. These delays can mean the difference between life and death when search-and-rescue crews are trying to assess the disaster.

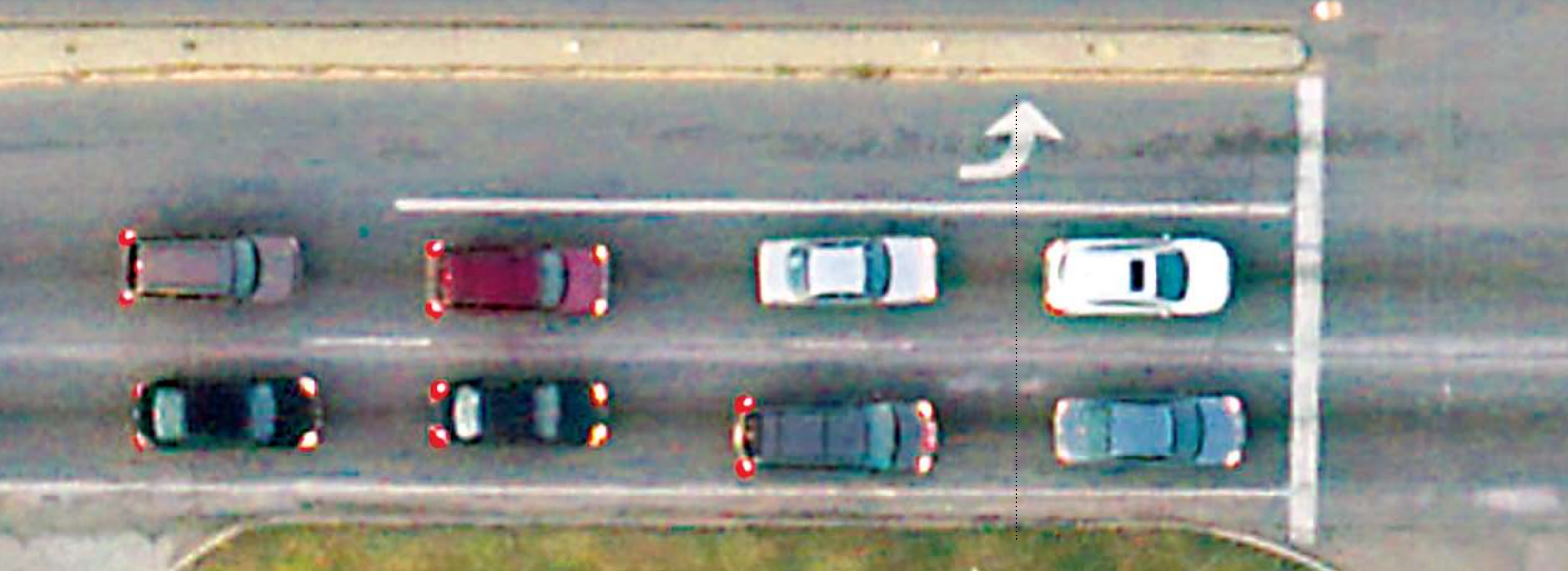
Traditionally, the acceptable acquisition window for aerial photography has been defined as the period when the sun is 30 degrees or higher above the horizon. This definition of suitable lighting conditions dates from the era when only film was used for airborne mapping.

Midwest Aerial Photography upgraded their optical imaging capabilities from film to include digital in 2010 with the purchase of a Z/I Imaging DMC II system. As they compared the sensor's digital images to film prints, the sharper

This image was exposed with a Z/I DMC II 140 digital mapping camera at a 0-degree sun angle (when the sun has just dropped below the horizon). The aircraft altitude was 3,150 feet above ground level, producing a pixel Ground Sampling Distance (GSD) of 3 inches (7.5 cm). The level of detail is stunning considering that this was taken after sunset.

A new world is opening for mapping-imagery acquisition in low light or adverse lighting conditions, especially for disaster response. After a disaster such as a flood, hurricane, earthquake, or chemical spill, the faster the imagery is acquired the more useful it is. And yet weather is usually not ideal immediately after an incident. These new systems provide geospatially accurate and highly detailed imagery previously impossible to generate at this level under low light or adverse lighting conditions. How this technology will be put to use will be determined by those who cannot afford to wait for perfect conditions to acquire detailed geospatial imagery.





Left: This image was exposed at approximately a -3-degree sun angle; the sun is now well below the horizon. However, there is still a bit of glow from the sky providing some illumination of the ground. At this point, artificial lighting begins to be the light source that most brightly illuminates objects. The spillover lighting from the stage in the lower right part of this image clearly illuminates the crowd, but there is enough light to show the hundreds of other individuals not in front of the stage.

Above: At a 0-degree sun angle, artificial lighting begins to show in the imagery, as revealed by the headlights and tail lights on these cars that are stopped at a traffic light.

feature definition and broader dynamic range of the digital data sets were obvious. They then began questioning the conventional wisdom related to acceptable light conditions for flight operations with digital airborne sensors.

It turned out they weren't alone. The Department of Homeland Security (DHS), in cooperation with NASA, was already researching this topic with Innovative Imaging & Research (I2R), a Mississippi company that specializes in calibrating digital cameras. Their joint research came in the wake of several Gulf Coast hurricanes for which FEMA had experienced frustration with the quality of aerial acquisitions taken during the cloudy days that followed the storms.

In 2011, with seed funding from DHS through NASA, Midwest Aerial launched a low-light imaging pilot project in association with I2R and Aerocon Photogrammetric Services of Willoughby, Ohio. The first phase of this pilot involved analyzing images collected just minutes after sunset. While much additional research must be done, the initial results indicate that digital sensors can be operated in very low-light situations to produce useable images for some applications, including disaster response.

Digital Cameras in Low Light

"The duration of suitable acquisition windows is a major concern to Midwest Aerial because our business focuses almost exclusively on airborne image data collection," says Ken Scruggs, Midwest Aerial's president. "Flying is what we do, and we have intentionally built a reputation for deploying aircraft quickly and getting them in the air over the target when our clients specify." Weather is always a factor, of course, but they routinely face the challenge of acquiring imagery in a short time period when ground, climate, or vegetation conditions meet the specific needs of a client application.

For almost 20 years, they operated solely with film cameras, but in 2010 they purchased the first of two Z/I Imaging DMC II-140 sensors as a means of making themselves and their business partners more competitive in the increasing mapping projects that require digital cameras. The DMC II is a large-format frame camera designed specifically for photogrammetric mapping. It captures four-band (R, G, B, NIR) multispectral imagery with high spatial resolution at both large and small mapping scales.

According to Dr. Bob Ryan, vice president and chief technical officer of I2R, the DMC line of digital cameras is well suited for low-light imaging because of a technology called Timed Delayed Integration (TDI), which is a form of Forward Motion Compensation (FMC). This technology shifts pixel value information from one row of pixels to another, which allows the camera shutter to stay open longer at high aircraft speeds and low altitudes without blurring the image. In addition, the DMC II has a relatively large 14-bit radiometric resolution, designed for crisp feature imaging in light conditions ranging from the shadows of deep canyons to the bright white surface of snow-capped mountains.

Shortly after deploying the DMC II, Midwest Aerial began successfully pushing the envelope of the lighting conditions in which it operated. In northern Michigan, for example, they acquired imagery later into the afternoon than they would have dared with film. Likewise, when clients absolutely needed acquisitions in a hurry, they flew under overcast skies and cloudy conditions, which previously would have been impossible with film cameras.

Comparing 2 Views, 2 Lighting Angles

Street | **Woods**

fig. 1
0°

> When using low-light imagery, you will experience shortcomings in identifying some detailed objects and performing some photogrammetric functions. Low light can, nonetheless, be valuable for conditions near sunset or under a heavily overcast sky.

fig. 2
30°

Having confirmed the applicability of the digital mapping camera in some low-light situations, they began wondering how low they could go.

A 0-angle Acquisition

For the 2011 pilot project, they selected a test site six miles northeast of Midwest Aerial headquarters near Columbus, Ohio. They chose the site because it had been surveyed with ground control points during an earlier project. In addition, it contains a mix of land use and land-cover categories including wooded areas, suburban neighborhoods, and a municipal zone with office buildings, stores, and a busy intersection.

From an altitude of 3,200 feet above ground level, they acquired digital imagery over this area at two different sun angles on the same day, once at 30 degrees and again at 0 degrees, just after sunset. Although the DMC II has shutter speeds and other settings that can be adjusted automatically, they opted to run the system in a manual operating mode for consistency from frame to frame. They used the DMC II light-metering system to compute an average light value over the project site and then set the camera to expose all frames at this setting.

After acquisition and image/data processing, they sent the imagery and ABGPS/IMU files to Aerocon Photogrammetric Services for photogrammetric processing. They have worked with Aerocon on numerous projects for which Midwest Aerial typically acquires the imagery and Aerocon performs the photogrammetric processing to generate engineering-scale maps and other derived products. As they would for any other data set, Aerocon ran the DMC II imagery through its Inpho MATCH-AT software for standard aerial triangulation processing without performing any special enhancements.

As planned, Midwest Aerial subjected the test imagery to two different types of examination. First, personnel from the participating firms studied and compared the images with their naked eyes to assess their visual quality. Then Midwest Aerial had Aerocon's experienced photogrammetrists put the images through several automated and manual analyses using digital stereo softcopy workstations and processing software.

Everyone who viewed the two image sets came to a similar conclusion. While the 0-angle imagery is not as crisp around feature edges, the information content is remarkable. Nearly all large features that can be identified in the sunlight imagery can also be seen in the 0-degree sun-angle images. Even small features, such as manhole covers and parking lot stripes, are easily visible on open ground. Among the surprises was the ease with which the colors of vehicles and pavement striping could be distinguished.

A distinct difference in visual quality occurs in wooded areas where the ground and features are difficult to discern. Also, the woods have a reddish cast, and moving vehicles are more distorted, although still recognizable, in the 0-degree sun-angle images. Even in developed neighborhoods, it was difficult to see ground features under large deciduous trees. In open areas around street intersections, the absence of shadows in the sunset image (**Figure 1**) makes it almost impossible to see vertical items such as small posts and signs. The same features from the 30-degree-sun-angle images allow for easier identification with the addition of shadows (**Figure 2**).

Bill Faunce, certified photogrammetrist and Aerocon's production manager, best expressed Midwest's consensus on the value of the 0-degree sun-angle images when he said, "I would use this imagery in a heartbeat if I had an emergency response situation [after sunset] where I had to map a train derailment, bridge collapse, or other disaster … we could make good, useful maps from this."

Another unexpected observation from the 0-degree sun-angle imagery was the clarity of features in non-natural light. Illumination from light poles in parking lots and light emitted from store fronts made vehicles and pavement markings as easy to see and identify as they were in the daylight images.

Photogrammetric Analysis

In the second phase of analysis, the images were turned over to Aerocon's photogrammetrists to determine if they could accomplish a common mapping application. Specifically, their objective was to try to produce one-foot contour maps from both data sets. This meant the photogrammetrists would have to measure surface elevations to generate accurate digital terrain models (DTMs) from the 0-degree sun-angle imagery and compare them against the surface generated from the 30-degree sun-angle surface.

Again, the results were surprising. "We could accurately measure horizontal positions [in the 0-angle images], but the vertical error was greater than what we typically get for digital imagery," said Faunce. "That being said, the overall accuracy is still pretty good."

Next, the Aerocon technicians analyzed the 0-degree sun-angle images with the DAT/EM Summit Evolution workstation to determine if feature extraction could be performed through compilation. This is where the fuzziness of feature edges posed a problem especially for finding small features. While objects such as manhole covers on flat, open ground were easy to extract, curbs were more difficult to discern. The most difficult to see due to lack of shadowing were the vertical signs and posts noted earlier. Even when these could be identified, their horizontal position was difficult to map accurately.

In general, the compilers found the 0-degree sun-angle imagery to be hard on their eyes because of the softness and blurriness of lines and feature edges. They confirmed what was also noticed with the naked eye: ground detail was lost beneath the trees in the wooded portion of the scene.

Next Steps

The most important conclusion drawn from this pilot project is that visually useful imagery can be acquired with a DMC II digital camera at sunset or sunrise with 0-degree-sun angles. Although the orthorectified imagery may not meet mapping specifications for digital data sets collected under normal daylight conditions, the quality is noteworthy and compares to similar film photography. For many applications, this will provide sufficient information that can't be provided as quickly through any other means but airborne imaging.

"When you have a disaster like a hurricane, you don't necessarily need orthophotos of the quality required for a high-precision engineering project," said I2R's Ryan. "You just need to know if a road is blocked, a building is standing, or an area is flooded."

Midwest Aerial plans to continue studying low-light digital image collection. In future missions, they plan to analyze images collected at varying sun angles between 0 and 30 degrees to see how they compare in quality and information content to standard daylight images. In addition, Midwest plans to experiment with manual settings on the DMC II to determine whether the sharpness of low-light imagery can be improved. They believe they have just scratched the surface of the potential for low-light imaging in a variety of existing and new applications that will be limited only by our imaginations.

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