Aerial Infrafed Thermography

Linking thermal mapping results to CAD and GIS systems.

By Gregory R. Stockton

WHEN YOU NEED A THERMAL IMAGE of an area, aerial IR (infrared) thermography is superior to ground-based infrared in applications where a straight-down and large-area view is needed and where large areas and long distances must be covered in a limited amount of time. Most aerial IR imaging is performed at night because daylight solar radiation tends to adversely affect the imagery. Applications of aerial IR thermography include roof moisture surveys, environmental impact surveys, animal counts, wide area thermal mapping, landfill fire examination, underground steam system surveys, electrical power line surveys, and search and rescue operations.

Equipment and Crew

Aircraft and infrared imager. Thermographers perform aerial IR imaging from helicopters and airplanes, each of which has advantages and disadvantages. Light airplanes are less expensive to operate and ferry speeds are higher, allowing more work to be accomplished in a night. On one hand, helicopters are more maneuverable over a target and can get closer to the ground. On the other, they suffer from more vibration problems, take more time to move between targets, and are very expensive to operate. In either case, you need a reliable, well-maintained aircraft and an imager (figure 1) capable of the resolution required for the intended task. Working from a light airplane, where imaging altitudes are higher, requires a larger detector. You should know the needed GRE (ground resolution element), the size of one pixel on the ground, before you select an imager. It's always better to have more pixels, although larger lenses can help if some signal strength degradation is acceptable. No matter which system your thermographer uses, the imager must be fixed-mounted. Dangling a handheld IR camera out the open window of an aircraft does not produce professional results.

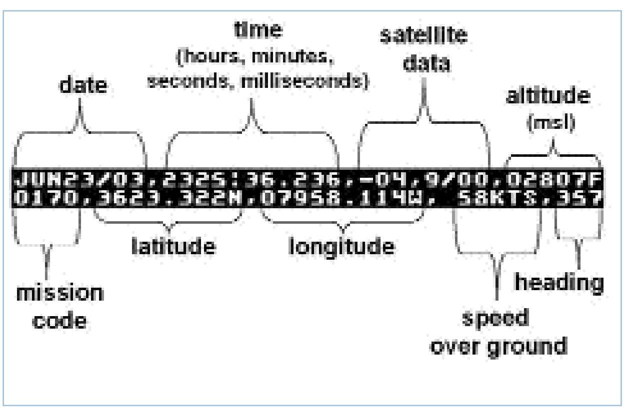

Figure 2. Using a video encoder, you can make your operation more efficient and safer. Note each number offers specific information.

Figure 1. Whether using a helicopter or an airplane, your thermographer needs a fixed-mounted large-format infrared imager.

Recording equipment. The type of IR imager used dictates how images are recorded and saved. Modern IR cameras offer a variety of storage media, but all must be within reach or have remote controls so that the thermographer can move the camera, adjust lenses, and save images. No matter what type of imager or storage medium, there should always be a videotaped record of all the raw IR imaging. Often the image passes by before it can be saved on a flashcard. If the thermographer's attention is turned away from the screen for a second, important images can be lost. It's also a good idea to record the audio from the communication system to narrate the video. Tapes are inexpensive, and digital videotape is best. It's important to have a good monitor with a screen large enough to see the infrared details of the job being performed.

Navigational aids. Precise navigation is important in any aircraft and particularly so in nighttime aerial IR operations. The longer a crew spends finding and imaging a particular target, the higher the cost and less work that can be done that night. Also, air traffic control authorities may limit time over a target due to other air traffic in the vicinity, such as commercial air carriers in and out of a hub airport. Add the fact that the pilot may be unfamiliar with the area and it's dark outside, and GPS (global positioning system) becomes a necessity. Combining the GPS data with a mobile mapping program on a computer and a VED (video encoder-decoder) that encodes and displays the video signal makes the operation safer and more efficient (figure 2).

Your thermographer can use GPS to find targets and plan routes, and it's extremely valuable during post-flight to process the encoded and displayed information such as latitude and longitude, altitude, date, time, and speed.

Secure equipment. Make sure that all equipment in the aircraft is secure. Nothing should obstruct the view of the instruments or interfere with the controls of the aircraft. All wires should be labeled, shielded from electromagnetic interference, and out of the way.

Aircrew. Nighttime infrared imaging is not a job for amateur pilots or airsick-prone equipment operators. I'm referring to those pilots without a lot of experience flying at night with IR imaging devices and those who don't fly for a living. Aerial IR thermography is about flying low, slow, and maneuvering without much room for recovery in the middle of the night—making it a job for professional aviators only.

Back on the ground. The office equipment you need to analyze imagery and produce reports includes a computer workstation complete with digital photographic and thermographic imaging peripherals for handling infrared images and daylight photographs. These should be capable of producing high-quality reports. You also need specialized video capture, image processing, CAD, and mapping software to produce drawings and specialized parts of the final report. Finally, a high-quality printer is needed to create the report.

Applications for Aerial IR Thermography

Animal counts. Used primarily by government agencies, aerial IR thermography is far more accurate than any other

Figure 3. The hot spot in the center of this infrared image is a subsurface fire in a landfill.

method for finding and counting warm-blooded animals. Deer population density information is used to monitor and control the deer population on city, county, state, and federal lands. Counting animals on the ground over large areas may seem easy, but it can be difficult.

Environmental and weather conditions must be right, and flight planning and navigation must be precise. Thermographers must consider factors such as topography, forest growth, target size, and animal behavior so that the study area is effectively and efficiently covered using a flight pattern or grid and altitude that allows the aerial IR thermographer to find the animals and accurately identify and count them.

Figure 4. With infrared thermography, thermographers can see where liquids run into streams, lakes, and rivers. Here is stormwater drainage system flowing into a creek.

Underground geothermal imaging. When a road or building complex is planned, you can fly the site to see if any geothermal activity is present at the surface.

Surface and subsurface fires. The U.S. Forest Service uses aerial infrared imaging to monitor forest fires. This information can be sent immediately to those in charge of controlling fire lines. Subsurface fires can also be monitored using aerial infrared thermography.

Because underground landfill fires can be hazardous to the surrounding environment, knowing where, how many, and their extent is useful to those in charge of containing and extinguishing them (figure 3, p. 48). More and more fire departments are purchasing IR imagers for ground-based fighting of structural fires. Aerial IR can be especially helpful when large single-story buildings are on fire. Though smoke may come out in one place, the hottest part of the fire may be in another spot. Aerial IR can also check for hot spots in peat, coal, and wood chip piles that can combust spontaneously.

Native American trails. Where ancient Native American trails cross the desert, the land is compacted. By using nighttime aerial infrared imaging the aerial infrared thermographer can see this higher density differentiated from the lower density soil adjacent to the trails.

Electrical power line surveys. High-voltage electrical transmission lines can be imaged from an airplane, although helicopters are better suited for this application. Even with modern IR imagers, it's impossible to measure exact temperatures from one-quarter of a mile away, so all anomalies must be compared to adjacent like-loaded components and if warranted, re-inspected by a ground crew.

Because they are smaller, lower to the ground, and run through populated areas, electrical distribution lines are difficult to see against all the thermal clutter on the ground such as trees, street lights, people, and animals. These facts make the IR inspection of electrical distribution lines a job for ground-based IR thermographers.

Pipelines. For the same reasons that electrical distribution lines are difficult to follow, pipelines are also difficult to survey. Trees, shrubs, brush, and water often cover the pipeline. Types of pipelines that can benefit from an aerial infrared inspection include petroleum, natural gas, hot water, and steam.

Environmental impact surveys. When a liquid is introduced into a body of water such as an ocean, river, stream, and lake, the two can be differentiated through the use of high-resolution thermal imaging because the temperatures are almost always different. Often you can follow these liquids to their source. Some of the uses for this application are detecting illegal dumping and discharge, tracking pollution such as waste spills and oil spills, monitoring effluents from storm drains (figure 4) and sewage treatment plant discharges, managing heated water from power plant cooling towers, measuring the amount of

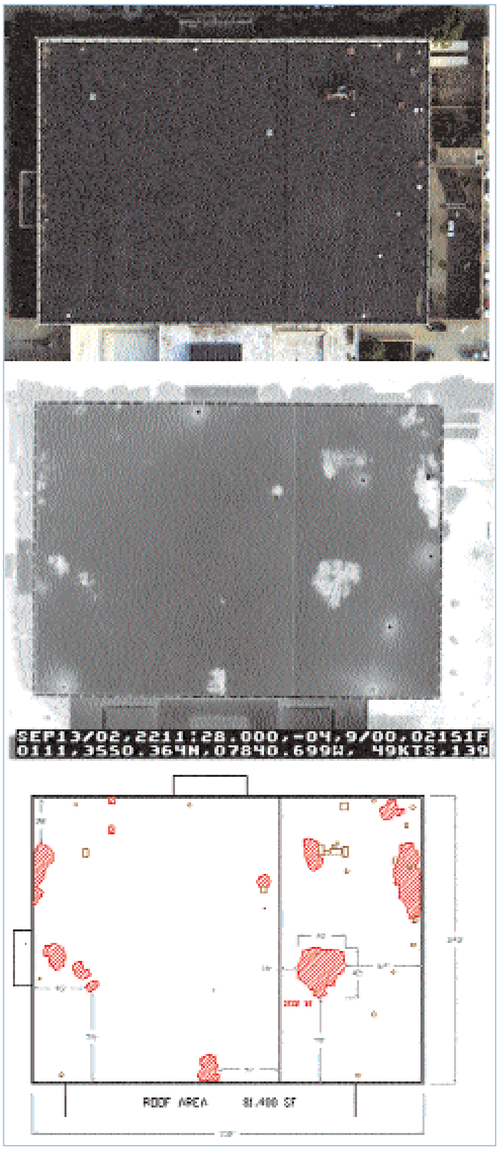

Figure 5. The top image shows a photograph of a flat roof, the middle a thermograph, and the bottom, a CAD drawing of the same roof.

fresh water from ground sources that is introduced into an estuary, and monitoring ground water seepage into rivers, streams, and lakes.

Surveillance, search and rescue. The military, law enforcement agencies, and border patrol officers have used ground-based IR thermography for years for surveillance purposes. In the past few years, aircraft with IR imagers have been used. Now, UAVs (unmanned aerial vehicles) with IR imagers are being tested by the Bureau of Customs and Border Protection to patrol U.S. borders. However, it takes an average of five people to operate a UAV, so it's still expensive.

SAR (search and rescue) operations are often rush jobs where conditions are less than ideal. Aerial IR SAR is better than ground-based SAR in most instances, but it's still overrated. People targets don't want to be seen or may be hard to detect because they're disabled, unable to move to a visible area, or trying to maintain the warmth of their body by insulating themselves. The key is to narrow the search area and image out the side of the aircraft instead of straight down.

Roof moisture surveying. No application is better suited for aerial IR than the predictive maintenance activity known as roof moisture surveys. The ravages of sun, wind, rain, snow, hail, ice, chemicals, leaks, and time eventually cause every flat or low-sloped roof to fail. Roof problems manifest themselves in two ways: leakage and entrained water contamination.

Leakage is pretty simple, although the leak inside the building rarely reflects the exact spot on the roof where there is a hole or tears in the membrane. Because most types of insulation absorb a certain amount of water, it's harder to find the entrained water contamination because the roof may not actually show a leak until the insulation has absorbed all the water that it can hold.

Owners can use one of three nondestructive tools to find subsurface moisture: nuclear gauges that count neutrons, capacitance meters to measure resistance, and infrared, which shows heat patterns. Both nuclear gauges and capacitance meters allow a technician to take a sample reading on a 5' X 5', 10' X 10', or 20' X 20' grid on the roof. When plotted on a roof plan, these measurements are used to extrapolate where the water is. They work marginally on roofs that don't gain or lose much solar energy and therefore don't lend themselves to IR.

IR is the preferred method for roof moisture surveying. During the day, the sun radiates energy onto the roof into the roof substrate, and then at night, the roof radiates the heat back into outer space. This is known as radiational cooling. Higher mass (wet) areas absorb and dissipate heat at a different rate than the lower mass (dry) areas —they radiate heat for a longer period of time at night because they take longer to cool. IR cameras can detect these sources of heat and see the higher mass (wet areas) during this window of uneven heat dissipation.

An infrared roof moisture survey allows a building owner to assess the condition of a roof at all stages of its service life (figure 5, p. 51). Aerial IR imagery is far more useful than on-roof IR imagery because the images are at plan view (straight down), which enables the accurate marking of wet areas on CAD drawings and because large areas can be seen all in one image. Even the slightest nuances of temperatures can be traced to the source and outlined. IR images of the roof, no matter how spectacular, are only signatures of heat. There are many causes of heat (or apparent heat) on a roof. This is why professional verification from roof consultants is so important. The aerial IR report should be reviewed and the printed data taken on the roof to aid in visual, destructive, and other nondestructive testing.

Underground steam system surveys. Even from high altitudes, steam line inspections are one of the easiest applications for aerial IR thermographers (figure 6). Thermal contrast between active steam lines and the surrounding ground are usually good. The reason for conducting these surveys is to detect and locate leaks. This works also for high temperature hot water systems.

An Example of Aerial IR Combined with CAD and GIS

Annually, Stockton Infrared's AITscan Division performs hundreds of aerial IR surveys for various commercial, industrial, institutional, and governmental customers. Many of these clients have large facilities and campuses. We are developing a system to add to our deliverables the option of a single IR image and a single visual image, where each of the single images is mosaicked into one seamless file. Ideally, these single image files will help us work more efficiently on creating a single CAD file as well. One image file will be more manageable for our clients then a series of files. It will also be easier for them to make visual assessments by looking at the imagery across the entire area of interest (full scene). The reports could be three large-format drawings: visual, infrared, and CAD.

Currently we use digitally video-captured IR images, but we can also capture 14-bit full dynamic range images directly to a computer hard drive. This gives us greater flexibility during postprocessing and optimization of the images. Also, temperatures can be measured pixel-by-pixel. These images can then be made into a composite image. Instead of printing multiple images of, say, a large building roof or a steam distribution system, why not print one big image? The same concept applies to a three-story building, a tall smokestack, or giant boiler.

The problem in any imaging endeavor is resolution. We can fly high above a building or steam system and get imagery of a large roof or campus in one image, and we often do for reference purposes. But the GRE is unacceptable from far distances. To make a high-resolution image, we must mosaic many high-resolution images. This may seem a simple, albeit time-consuming task, because software is available off-the-shelf for pasting photographs together.

The problem is that these software products are designed to work with large color photographs that contain much more image information than IR images do. Also, slight variations in altitude and the optical characteristics of the IR cameras make the task beyond the capability of the software. So we must first capture and correct the images, then paste them together by hand. To add even more difficulty, some of our customers want orthorectified and georeferenced images. We currently use GPS to navigate to targets and collect the imagery. However, the exact geo-location may be inaccurate because the GPS records a signal once per second, but the plane

Figure 6. This infrared image shows a leak in a university steam system slightly above the center of the image.

moves as much as one hundred feet per second.

The AITscan Division wants to not only create a single seamless image, but also provide correctly georeferenced images to our clients—especially those who use GIS to maintain their facilities. A georeferenced image could easily be brought into the client's GIS database. The client could then interpret additional information from the images and combine them with other information to get an overall visual impression of the areas of interest. We are developing a prototype GIS database for our clients and potential clients to show how their data can be integrated with other data sets. This database will be georeferenced and will include relative facilities management information, such as thermal steam survey imagery, thermal roof survey imagery, aerial photographic imagery (color and panchromatic digital photography), CAD drawings that outline the features of interest, links to Stockton Infrared's written reports, and other related information such as roads, buildings, electrical distribution, original and edited supply and return carrier pipe layouts, and other utilities within the area of interest. It could also include digital elevation model data, digital orthophotography, or any other imagery/layouts.

A Commercial Future

Aerial infrared thermography has a military past and a commercial future. With improvements in camera quality (IR and visual), methodology, platform and software, aerial infrared thermography, and aerial infrared reports are becoming better and more usable everyday. ■

*Gregory R. Stockton is president of Stockton Infrared Thermographic Services (***www.stocktoninfrared.com***). based in Randleman, North Carolina. Its aerial division, AITscan (***www.aitscan.com***), operates ten aircraft from coast to coast. Greg has twenty-five years' experience in the construction industry, specializing in facilities construction, maintenance, and energy-related technologies. He has performed infrared thermography since 1989 and has published fourteen white papers and many articles on infrared thermography.*

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