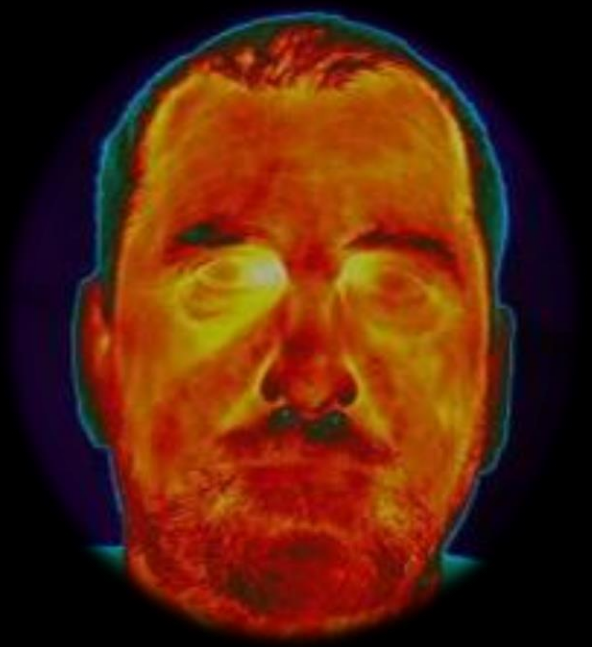
Leak Detection - Aerial Thermal Mapping Reveals Leaks in All Types of Systems ...Get the [Thermal] Picture!



CampusEnergy2017
Greg Stockton

February, 2017

Topics of Discussion

- Abstract
- Thermal Mapping
- Aerial Platforms
- Resolution
- Heating & Cooling Lines
- Liquid Leaks
- Air Leakage
- Oblique Aerial IR Imaging
- 3D Aerial Imaging
- Solar Fields
- Flat Roof Thermography

Abstract

Aerial thermal mapping of your campus every few years will reveal leaks in all types of systems, like steam and condensate return lines, hot water lines, chilled water lines, supply water mains, distribution pipes, storm water drains, building heat loss and moisture leaks into your roofs.

Aerial photographs should be taken every few years as well. They are inexpensive and can be a great asset when discussing future building additions with management, planning utility repairs and improvements, drawing CADs of the facilities and for uses as simple and handy as 'showing' outside contractors where not to park.

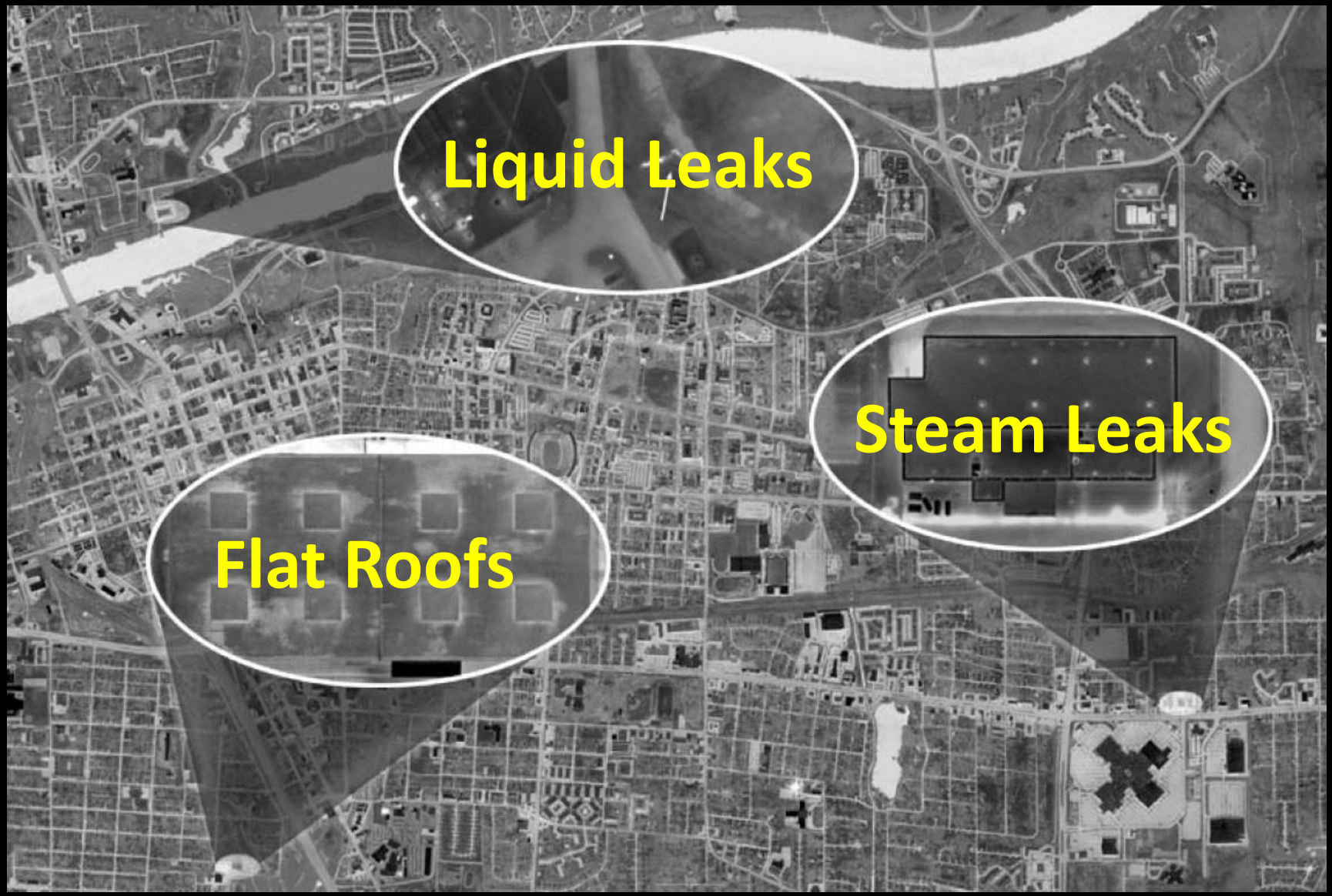
Abstract

The methodology for taking infrared (IR) thermographs is similar in many ways to taking aerial photographs. To collect the data, the aircraft flies over a given area at night with an infrared thermal imager mounted to the airframe and oriented looking straight-down (NADIR) to the ground. Oblique or lower angle shots are taken out the side of the aircraft by pointing the IR camera at the desired angle. The imagery is stored on a computer hard drive and later copied it to a convenient deliverable, such as a DVD. Thermal Imagery is almost always taken at night because the Sun is such a distraction. Obviously, aerial photos are taken during the day because the sun provides brilliant visible light so one can see features on the ground, like buildings, bridges, roads, etc.

Abstract

Once high quality digital thermal and photographic ortho-rectified maps are created, these can be added as layers to existing CAD and GIS systems and to other data sets. By post-processing the imagery, many wasteful conditions can be found and reported. The maps and reports help facility managers keep up with their assets in a very efficient manner. This can be a great tool for managing your assets in general, repair activities and planning budgets.

Thermal Mapping



Get the [Thermal] Picture!

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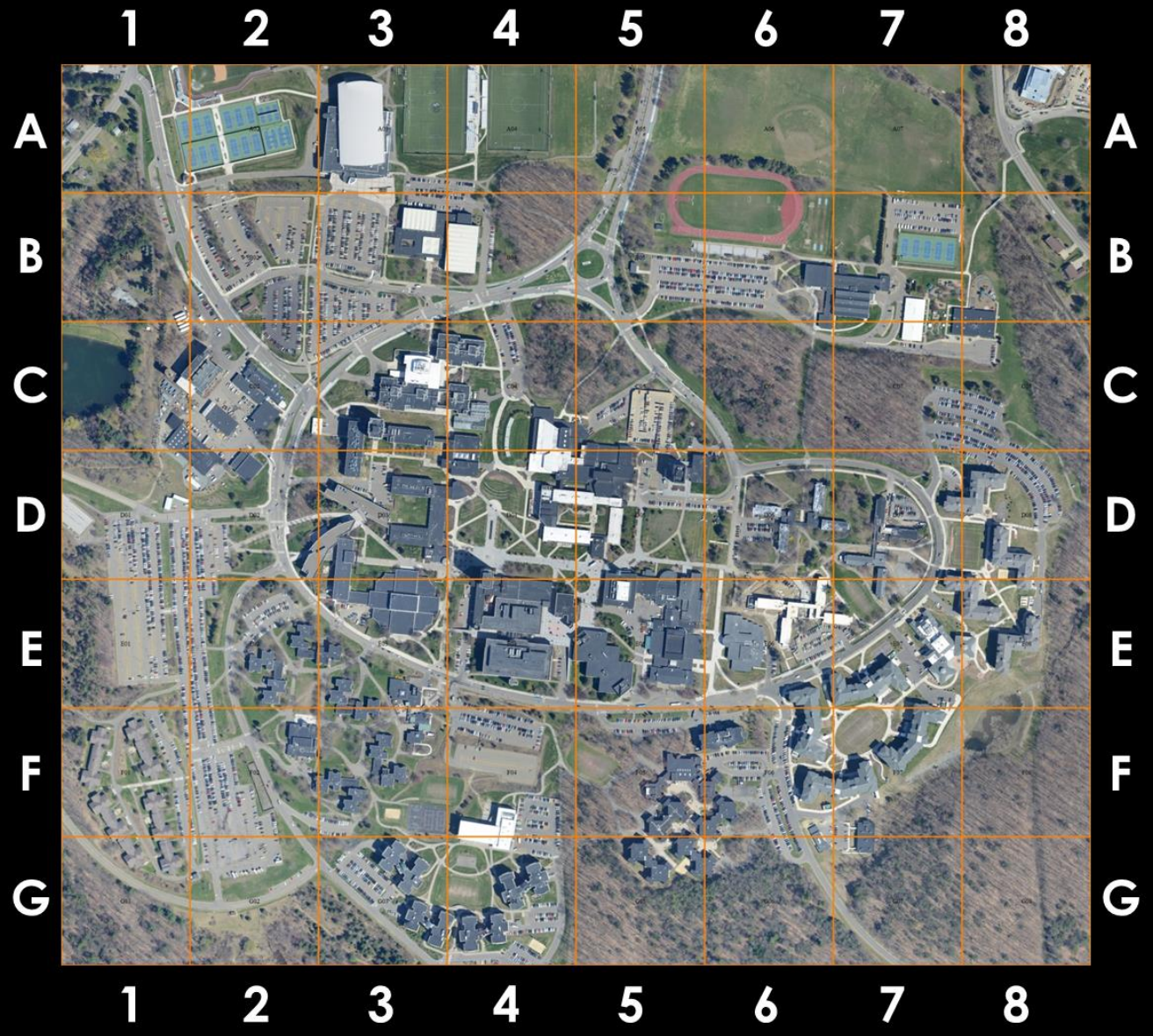
AITSCAN



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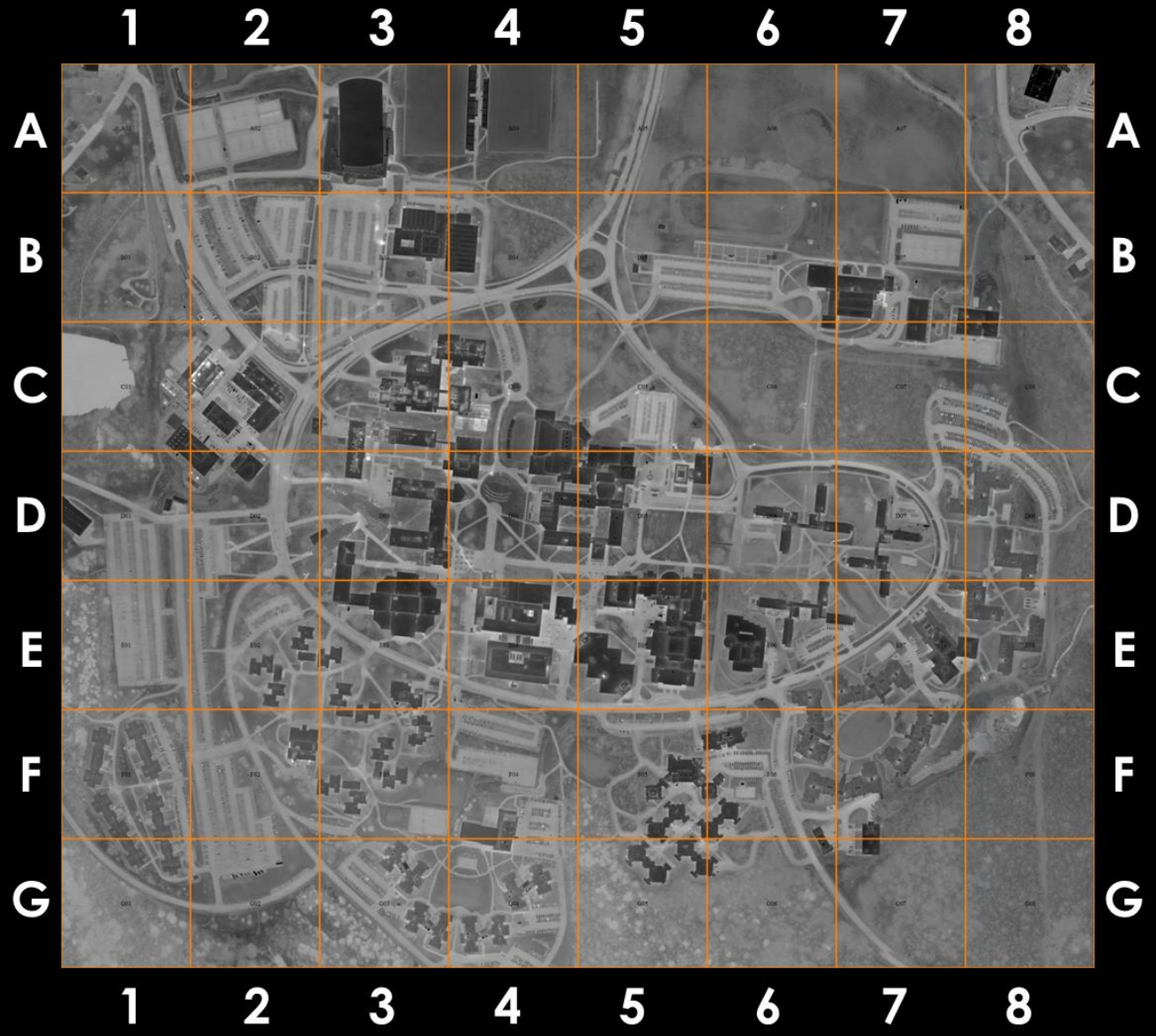

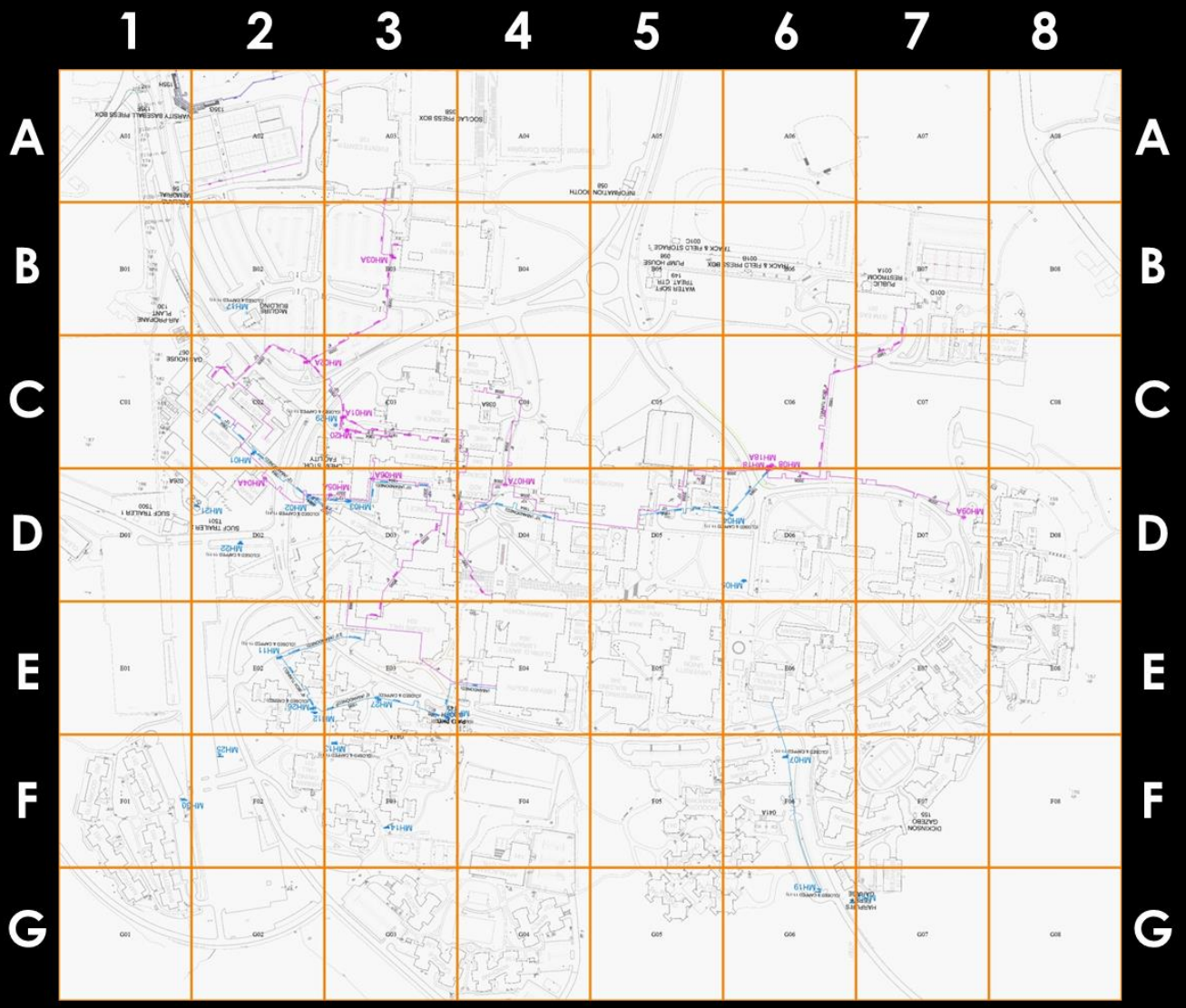
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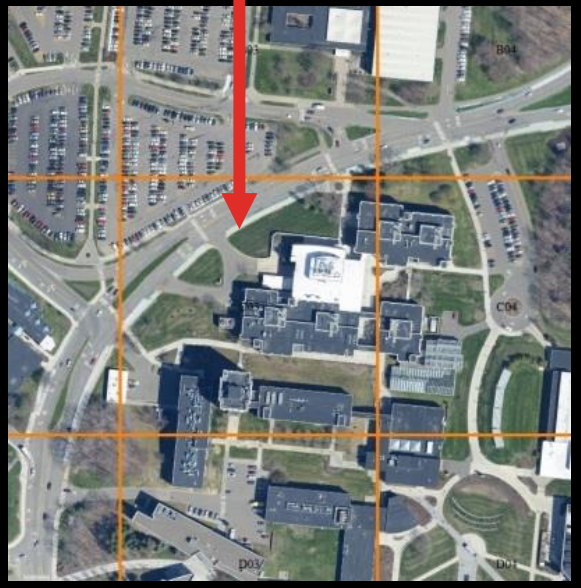
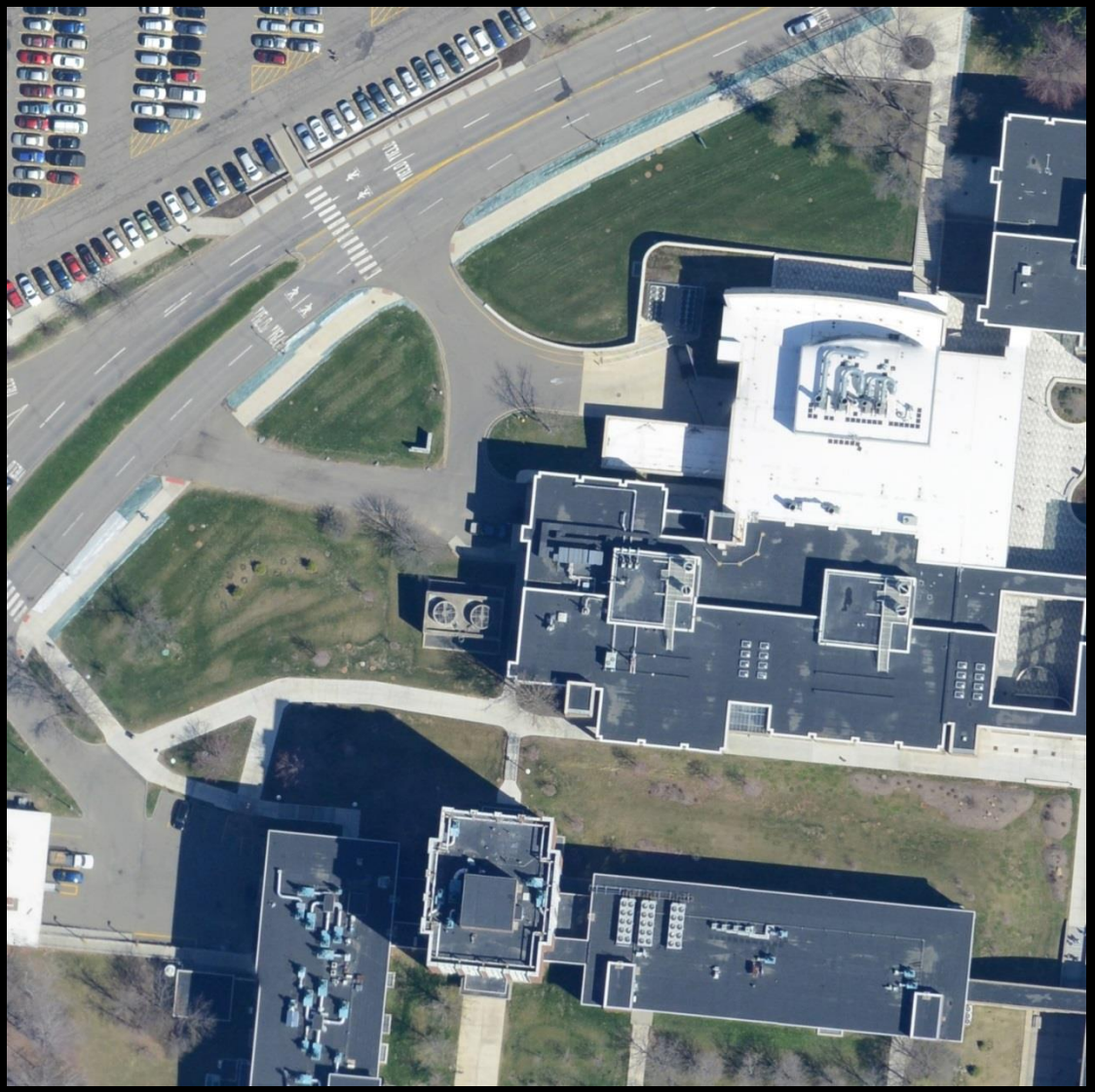
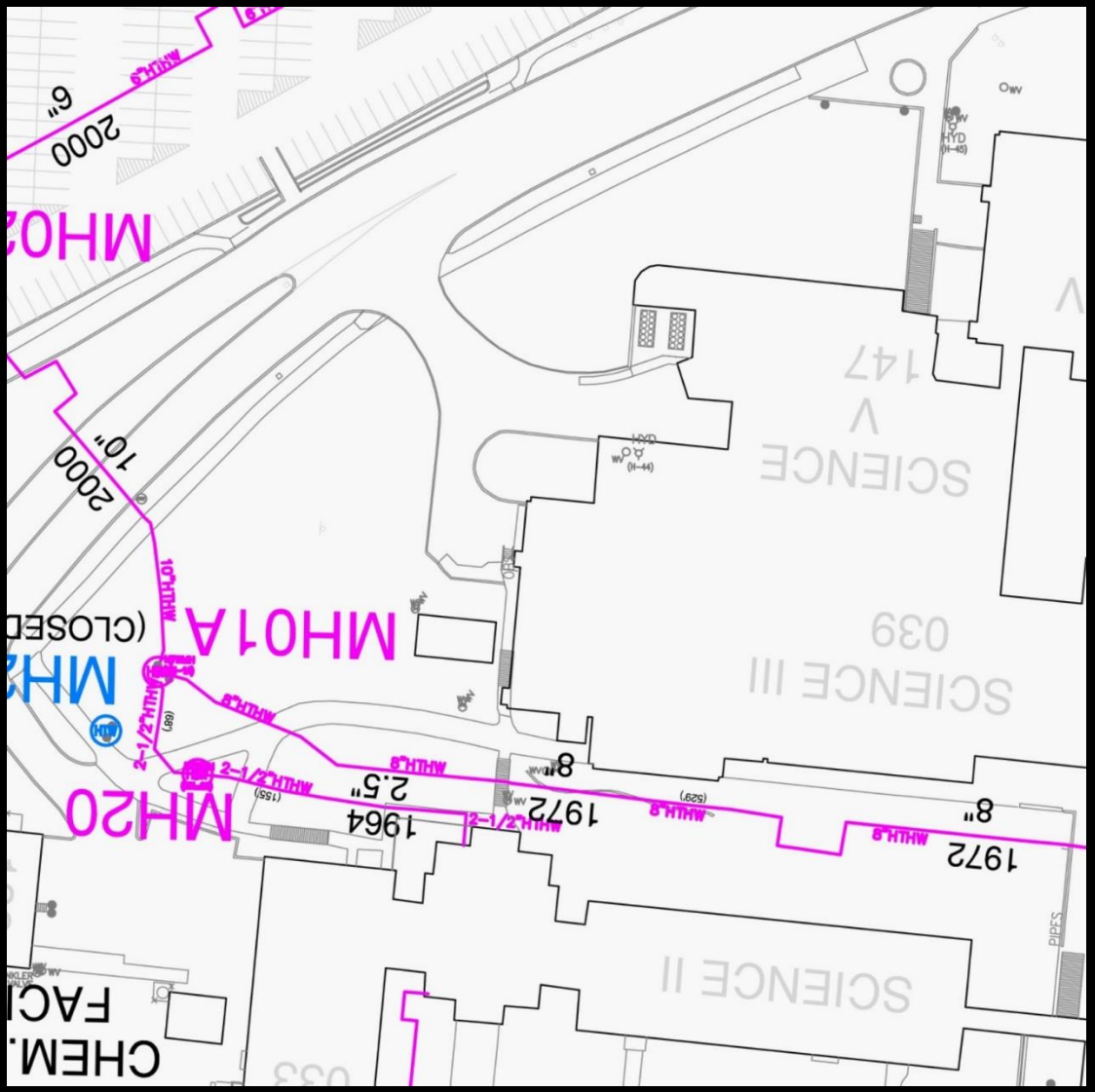




University_C03_1-PIC

Get the [Thermal] Picture!

University_C03_2-IR



University_C03_3-MAP

Aerial Platforms & Imagers

Choose the platform and the imaging system based on what you are trying to accomplish…

- √ Helicopters (rotor-wing)
- √ Airplanes (fixed-wing)
- √ UAVs (rotor-wing and fixed-wing)

All have their advantages and disadvantages…

Helicopters (rotor-wing)

Airplanes (fixed-wing)

UAVs (rotor-wing and fixed-wing)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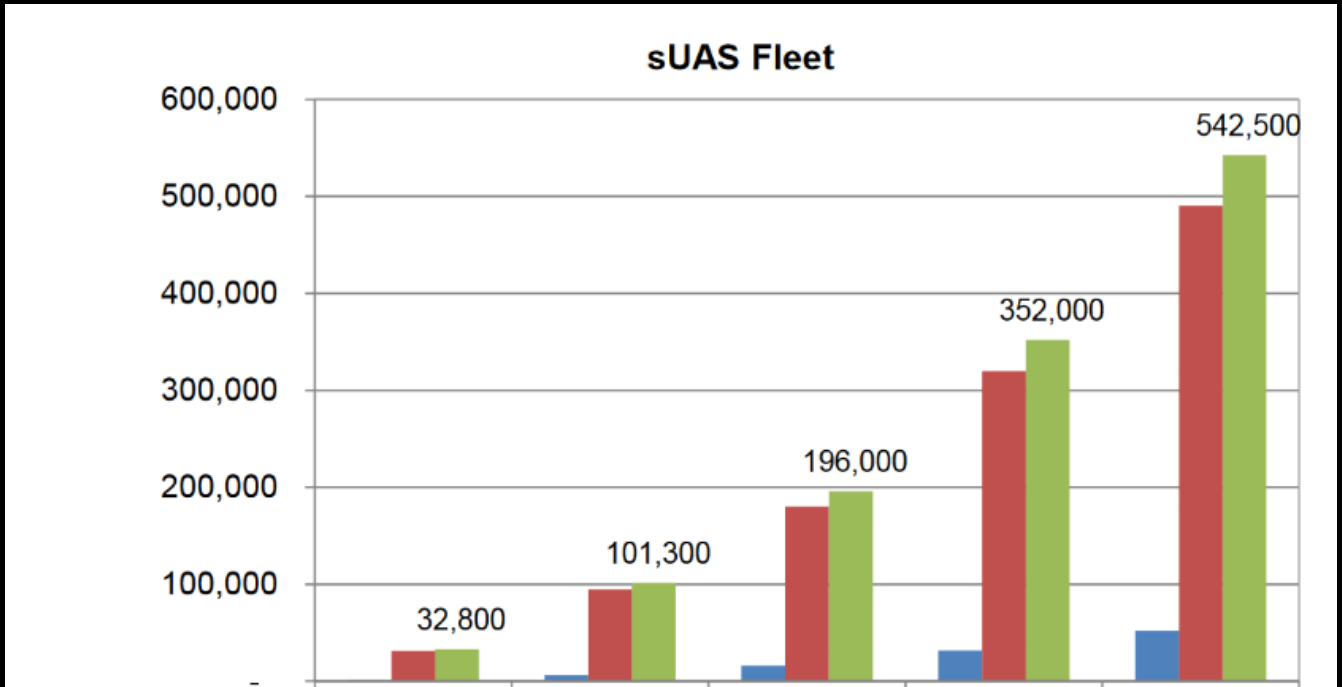
AITSCAN

The total UAS fleet number by 2020 will be 7 million:

- 4.3 million hobbyist
- 2.7 million commercial



	2016	2017	2018	2019	2020
Higher end UAS	1,300	6,300	16,000	32,000	52,000
Lower end UAS	31,500	95,000	180,000	320,000	490,500
Total Fleet	32,800	101,300	196,000	352,000	542,500

https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf

For U.S. citizens, permanent residents, and certain non-citizen U.S. corporations, this document constitutes a Certificate of Registration. For all others, this document represents a recognition of ownership.

For all holders, for all operations other than as a model aircraft under sec. 336 of Pub. L. 112-95, additional safety authority from FAA and economic authority from DOT may be required.

Safety guidelines for flying your unmanned aircraft:

- Fly below 400 feet
- Never fly near other aircraft
- Keep your UAS within visual line of sight
- Keep away from emergency responders
- Never fly over stadiums, sports events or groups of people
- Never fly under the influence of drugs or alcohol
- Never fly within 5 miles of an airport without first contacting air traffic control and airport authorities

Ground Resolution Element (GRE) = 30”

Resolution

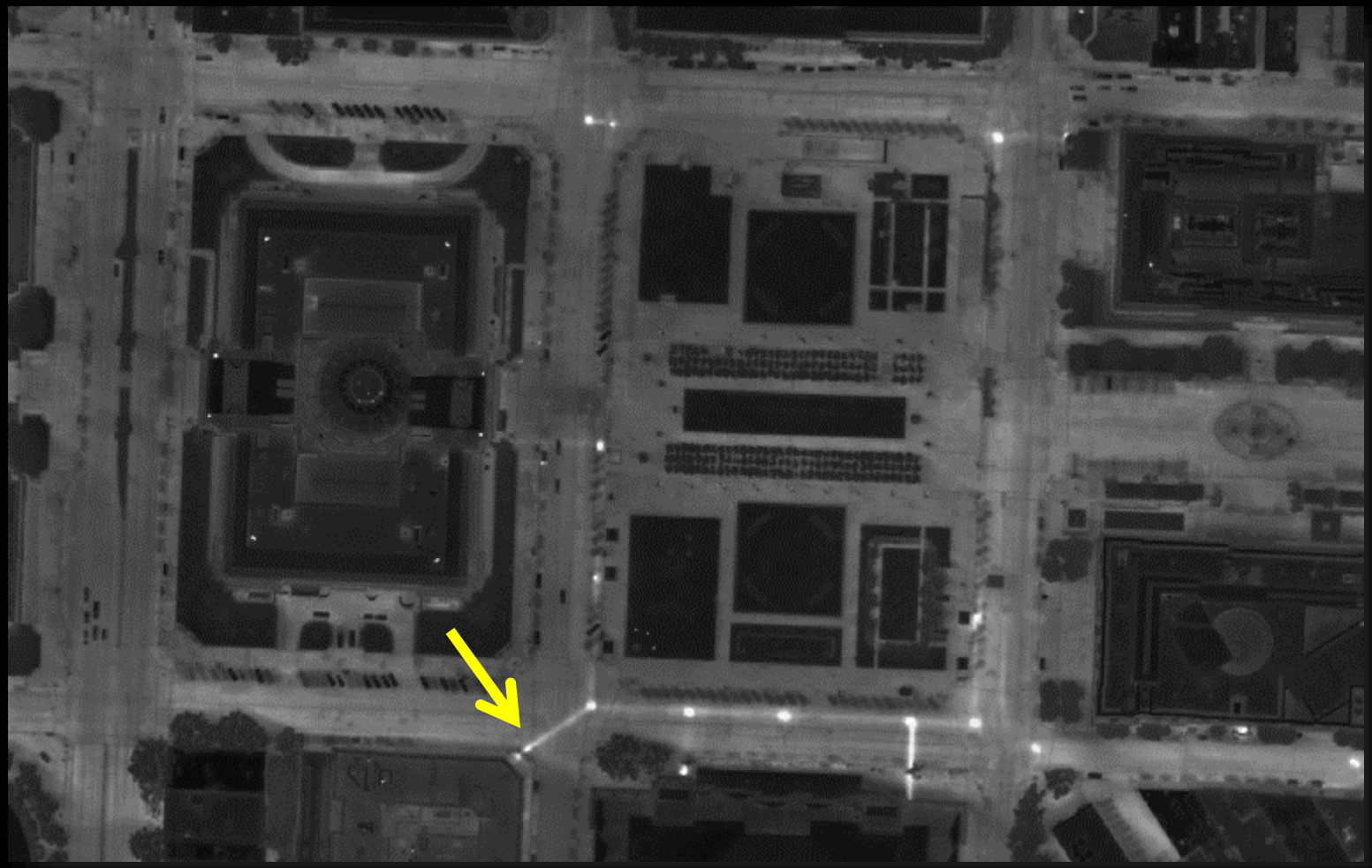
Ground Resolution Element (GRE) = 24”

Resolution

Ground Resolution Element (GRE) = 18”

Resolution

Ground Resolution Element (GRE) = 12”



Resolution

Ground Resolution Element (GRE) = 6”

Resolution

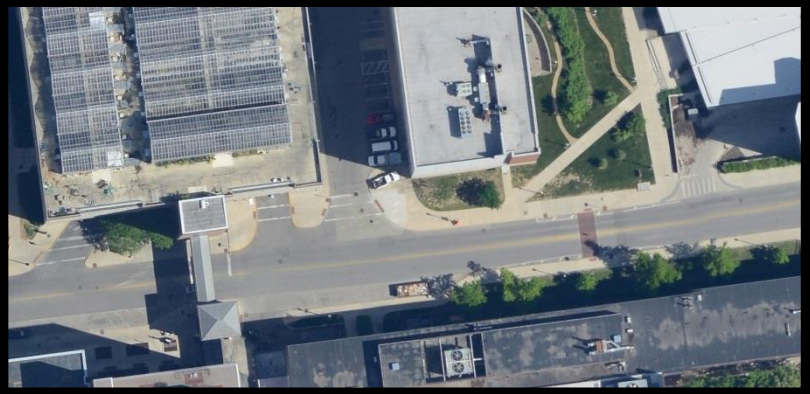
Ground Resolution Element (GRE) = 3”

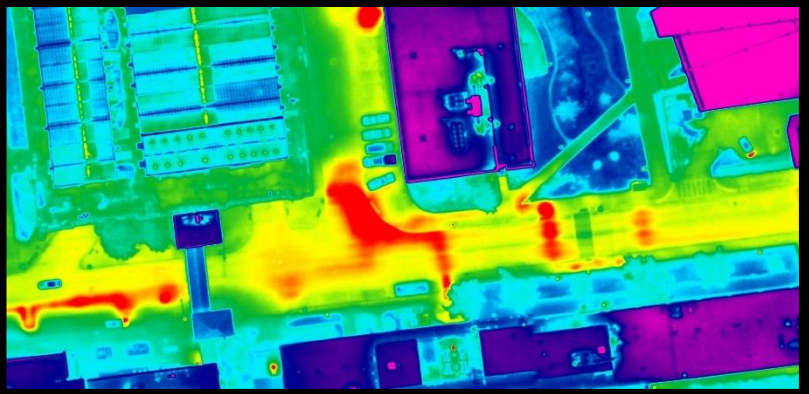
Resolution

Heating Lines

Heating lines in overhead (OH), underground (direct-bury) or in steam tunnel (vaults) are almost always readily visible with infrared imaging, even when no notable problems exist. This is due to the fact that no matter how good the insulation is functioning, there is always some heat loss from the lines which makes its way to the surface.

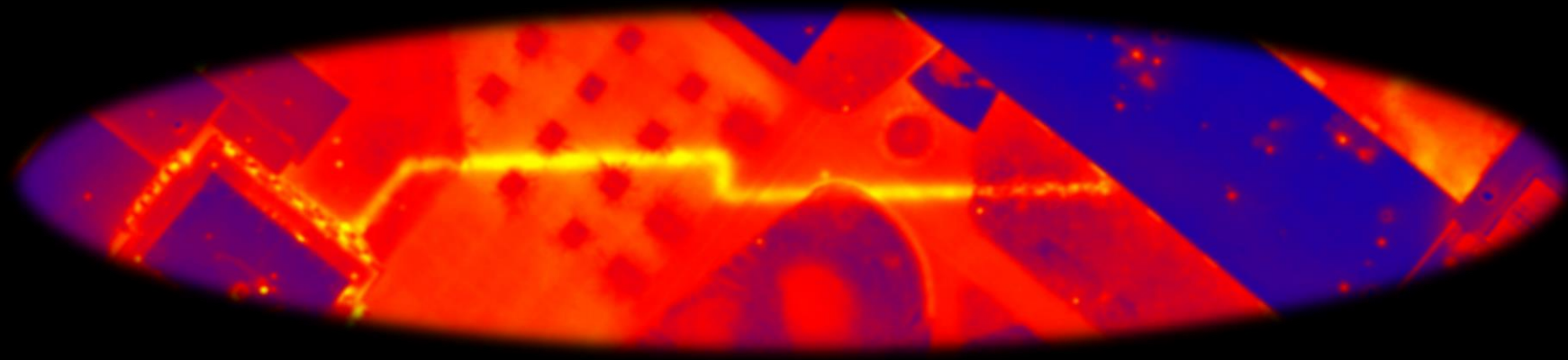
However, some heating lines are not visible through thermal imaging because no heat makes its way to the surface; either because of the depth of the line or the insulative value of the overburden above the line. Generally, these are considered to be in good shape, even if the manholes along these lines are detected.



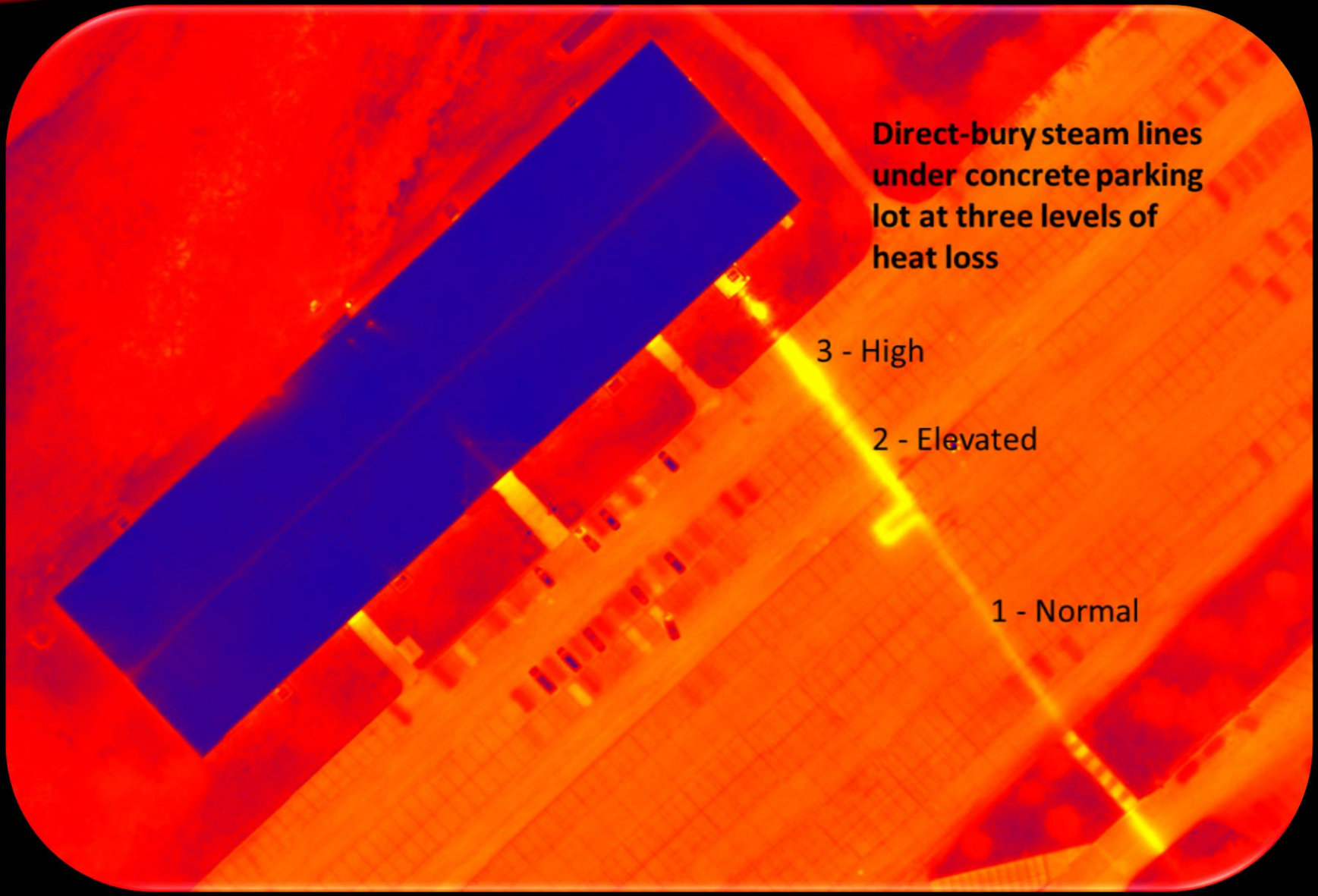


Heating Lines

Problem areas are generally quite evident, having brighter white IR signatures that exceed the norm. Heating line faults normally appear as an overheated area in a line or as a large hotspot in the form of a bulge or balloon along the line. Overheated line faults often occur when the heat escapes into the insulating jacket, saturating the insulation and rendering it largely ineffective. The line will then will begin to transfer heat producing the classic bulge or balloon-like hot area straddling the line. Heating line imagery can be a little misleading, unless one understands and interprets the relative brightness and temperature patterns of a given line correctly. A line that is the same temperature from one end to the other can exhibit a variety of temperature variations. For example, five different apparent temperatures will result from the same temperature line that runs under a grass-covered field, an asphalt parking lot, a concrete loading dock, a gravel-covered area and bare earth pathway.



Heating Lines



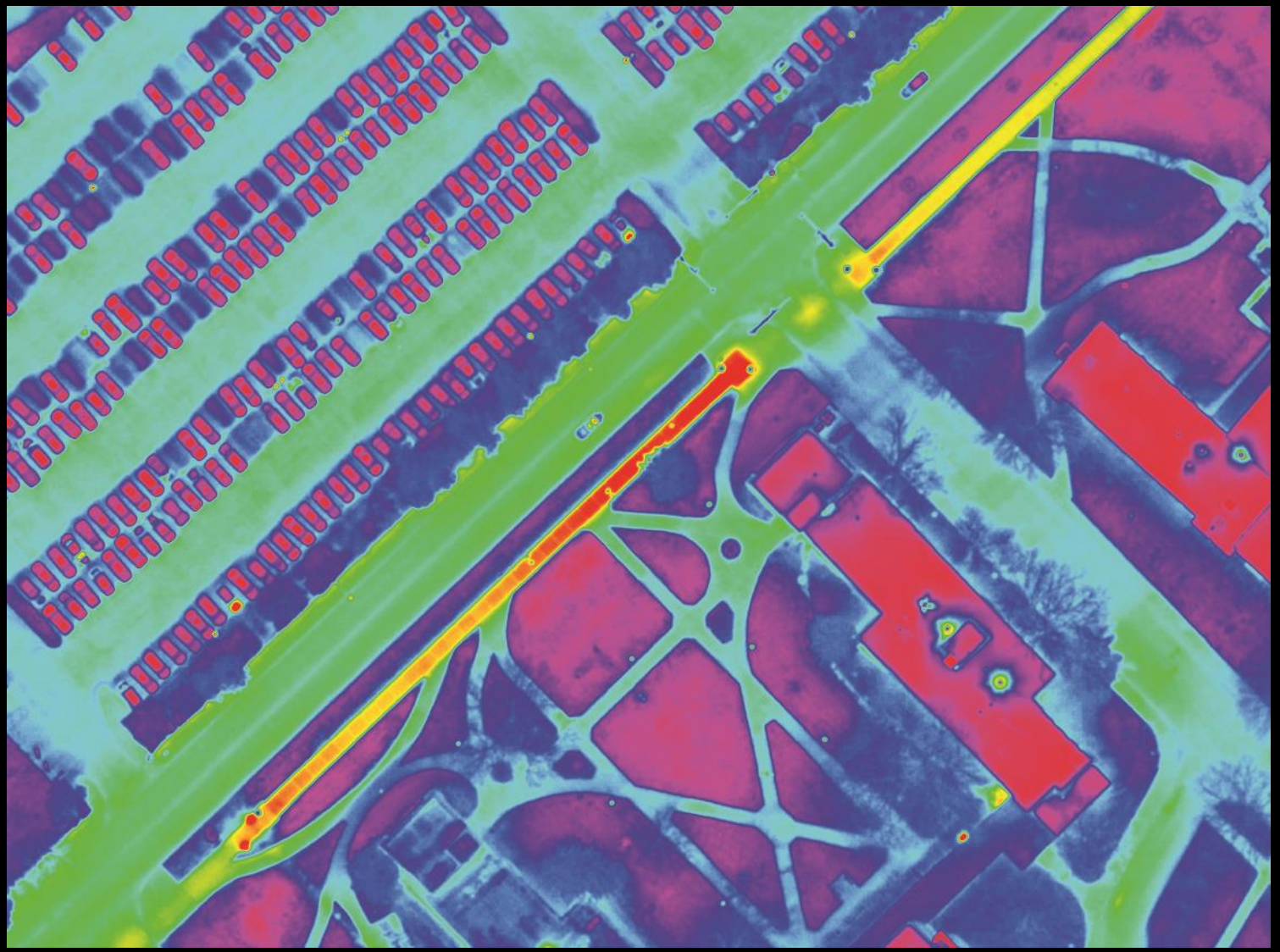
Heating Lines

FALSE

Colorization

Heating Lines

F A L S E



Colorization

Heating Lines

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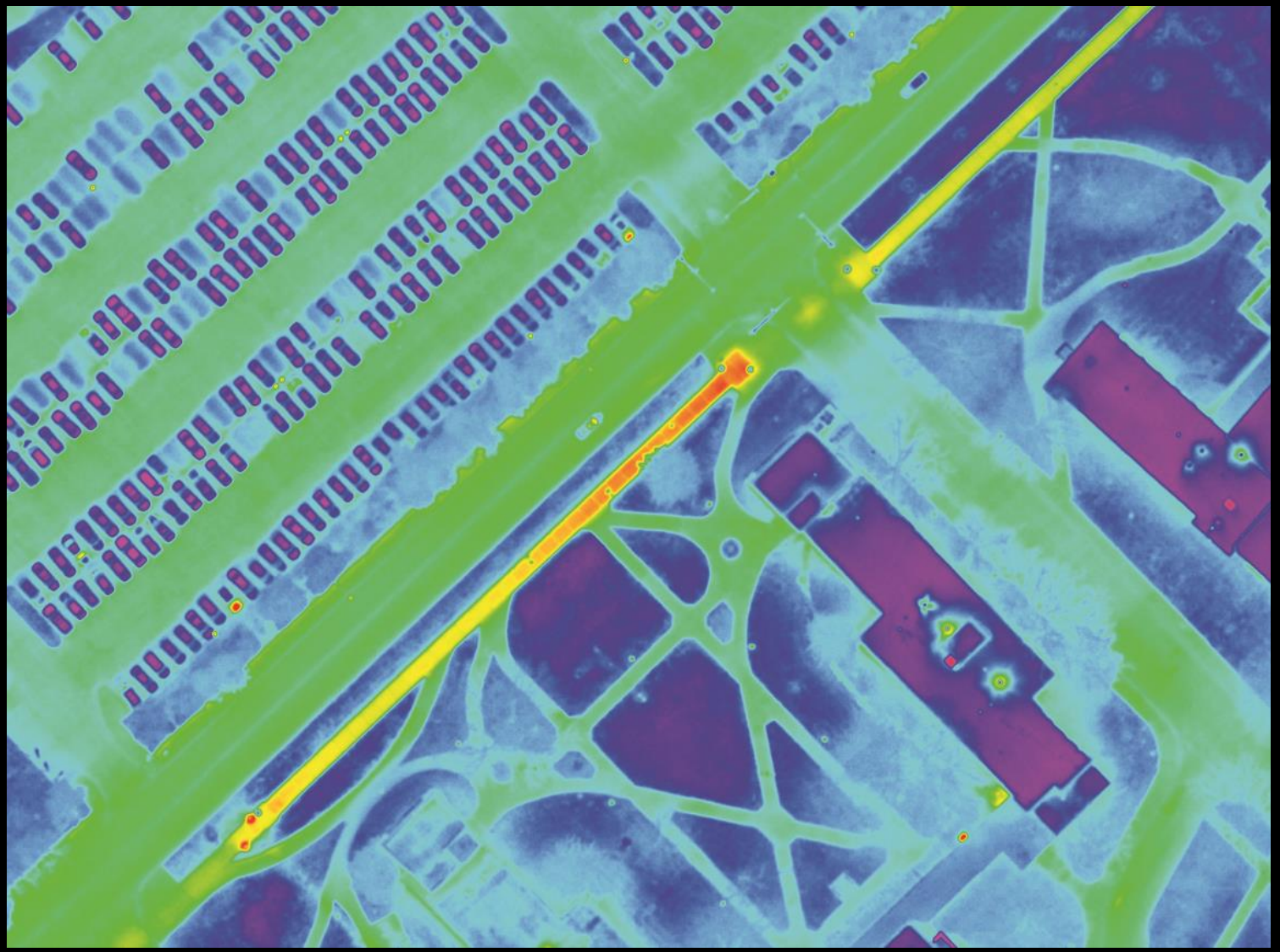


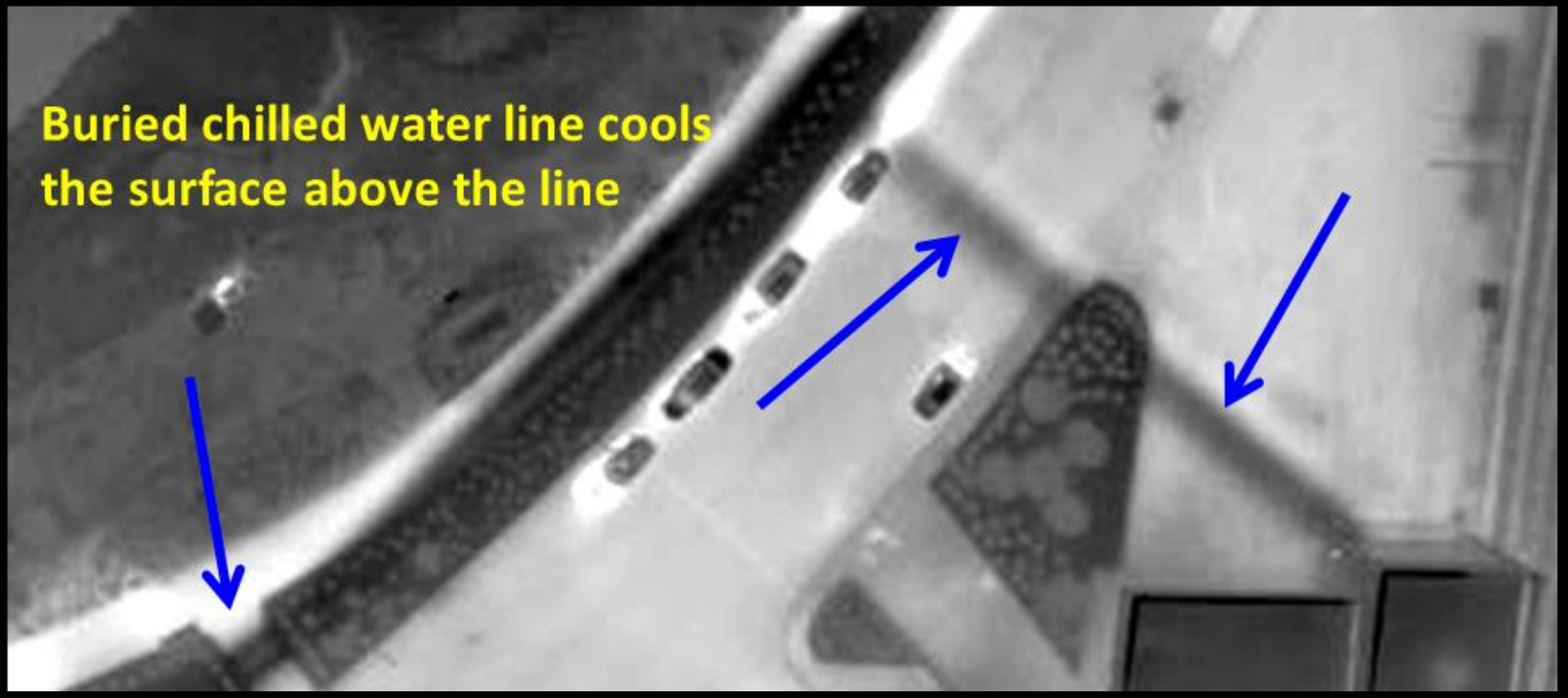
Colorization

Heating Lines

FALSE

Colorization

Chilled water supply (CHWS) and Chilled water return (CHWR) lines are usually cooler than the surface temperature and can be surveyed for thermal loss and leaks as well.



Liquid Leaks

A given area of any waterway will exhibit near homogenous temperature patterns except for areas where another liquid has joined the flow. This flow of liquid typically appears warm as compared to the surface water in a creek, stream, river or lake - particularly during cooler times of the year, due to the relative warmth of the ground a short distance below the surface. Leaks from nearby lines often come to the surface through lateral transfer to a creek, stream, river or lake bed, or to a slope leading down to the surface of the water. These leak areas and the warm plume of liquid joining and flowing downstream with the body of water are visible in the thermal infrared spectrum due to the difference in temperatures of the two liquids.

Late fall, winter and early spring are well suited to this type of inspection because of the cooler water temperatures (ground and surface waters) and because the interference to view by foliage is minimized. Ground water seeps and outfalls of all types are also easily distinguishable for similar reasons.

Liquid Leaks

Leaking sewage collector lines, storm water drain discharges and illegal taps into storm water drainage lines can often be identified by their thermal infrared signatures during certain times of the year. As these sources of pollution leak, seep or empty into creeks, streams, rivers and lakes, their thermal signatures vary from their surroundings and they can be pinpointed accurately from the air. Cool temperatures (lower than 40 degrees F) and dry (no rain in the last 48 hours) conditions are required. As a general rule, the lower the ground surface and the water surface temperatures, the more contrasting the image. outfalls of all types are also easily distinguishable for similar reasons.

Get the [Thermal] Picture!

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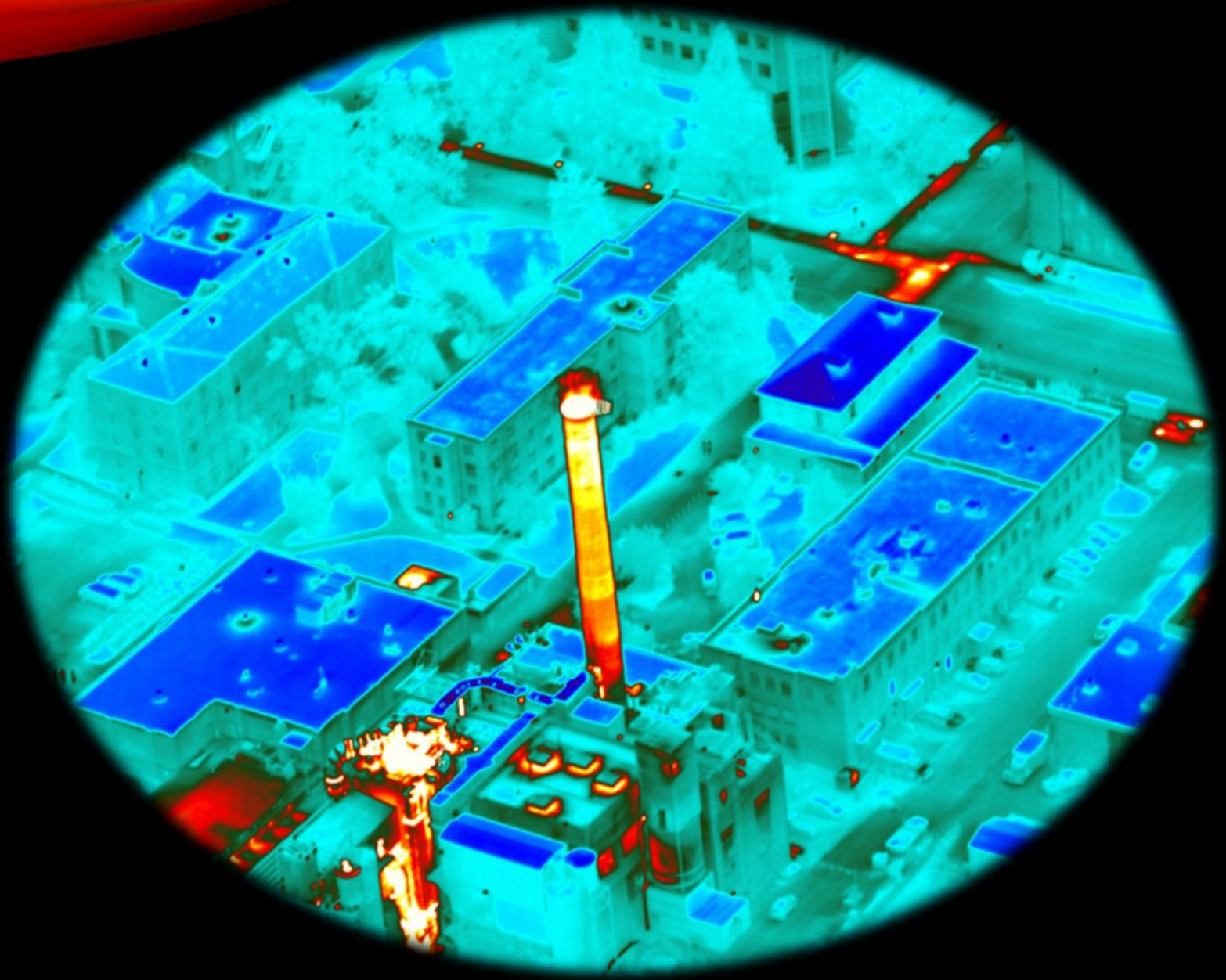
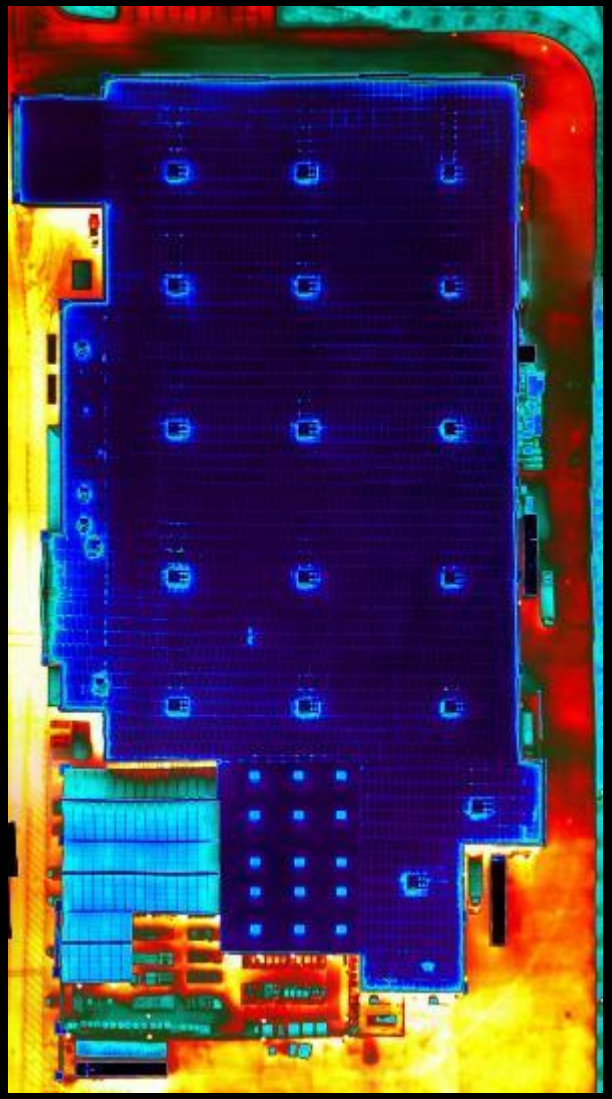
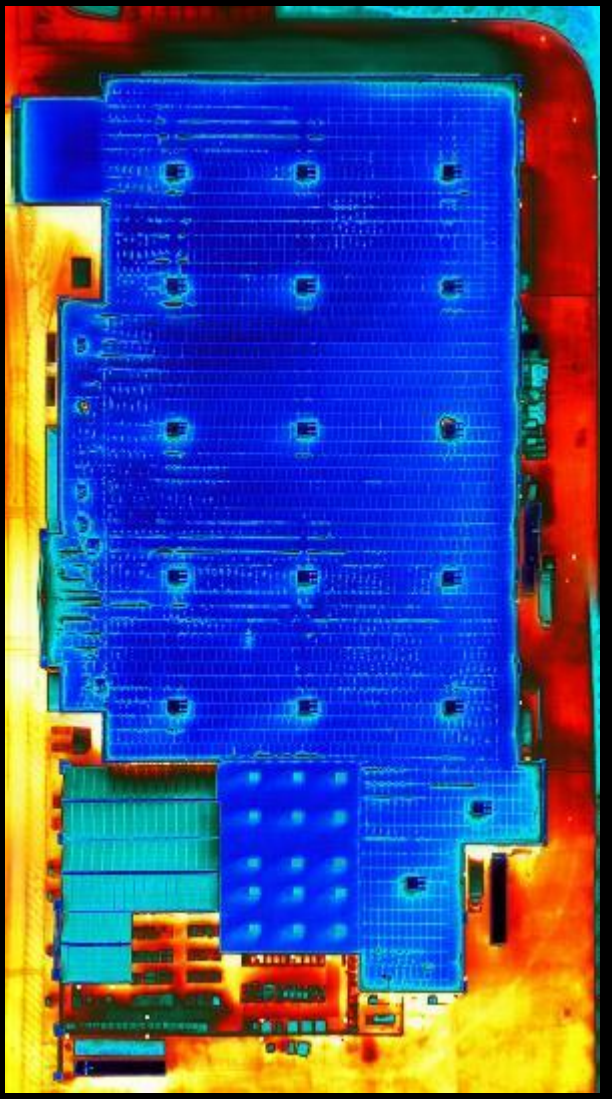


Air Leakage Testing

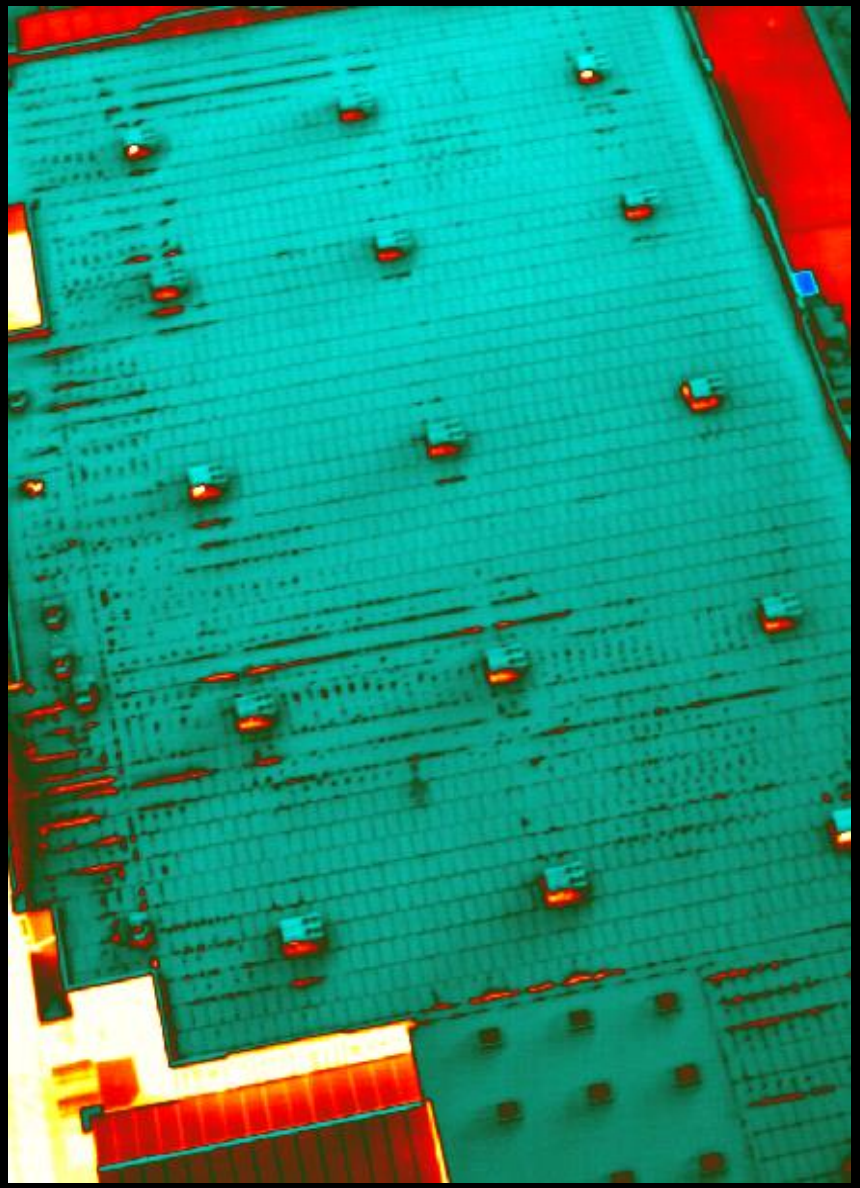


Before Pressurization



After Pressurization

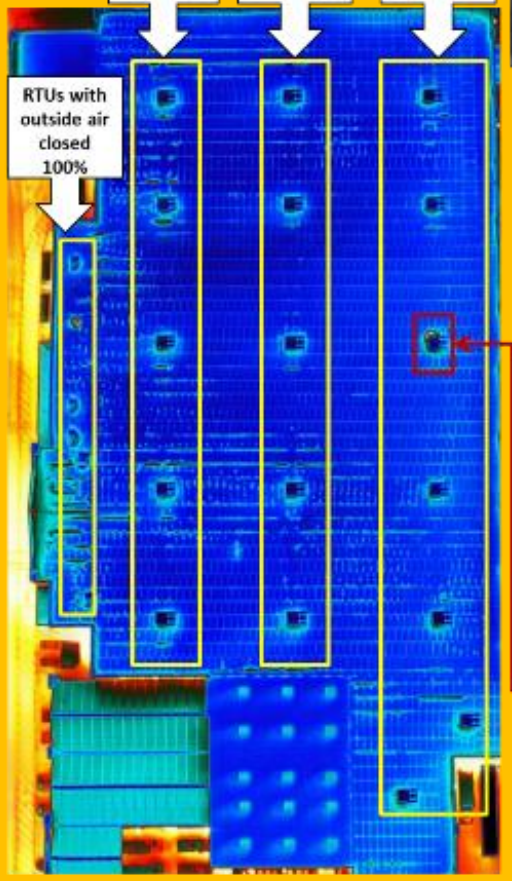
Get the [Thermal] Picture!



During the pressurization testing, ~50,000 CFM was supplied to the building with the procedure described in Reports 2. This raised the building pressure from normal (slightly negative) to .1 inches or ~25 Pascal).

RTU's Operating in Full Economizer during the survey

RTU-6
RTU-7
RTU-8
RTU-9
RTU-10
RTU-16
RTU-17
RTU-19
RTU-20
RTU-21
RTU-22

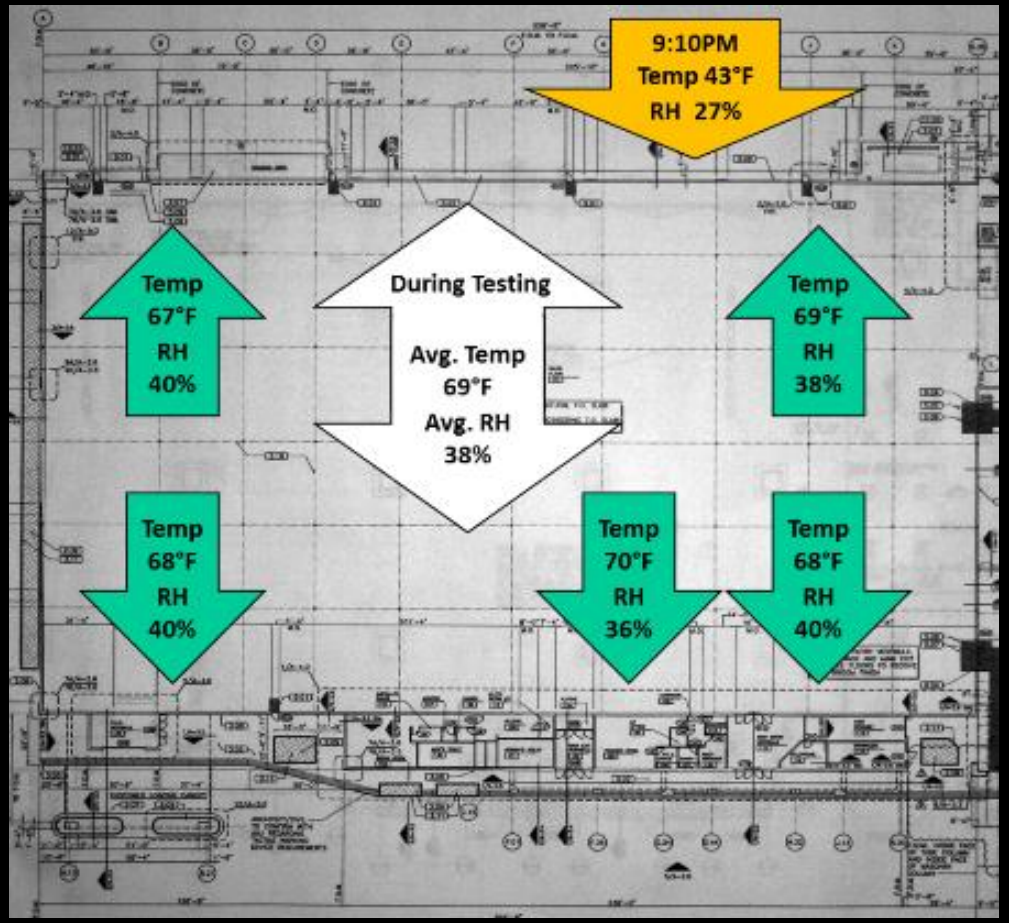


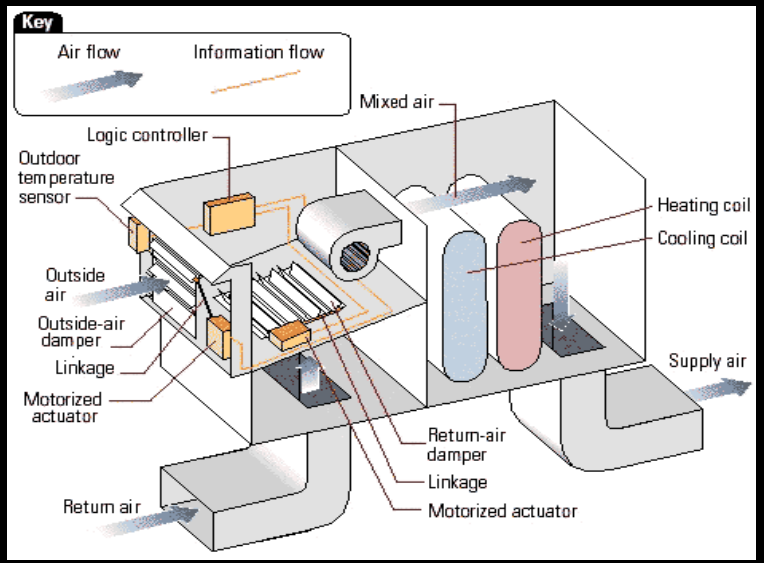
RTU's Operating in Normal during the survey

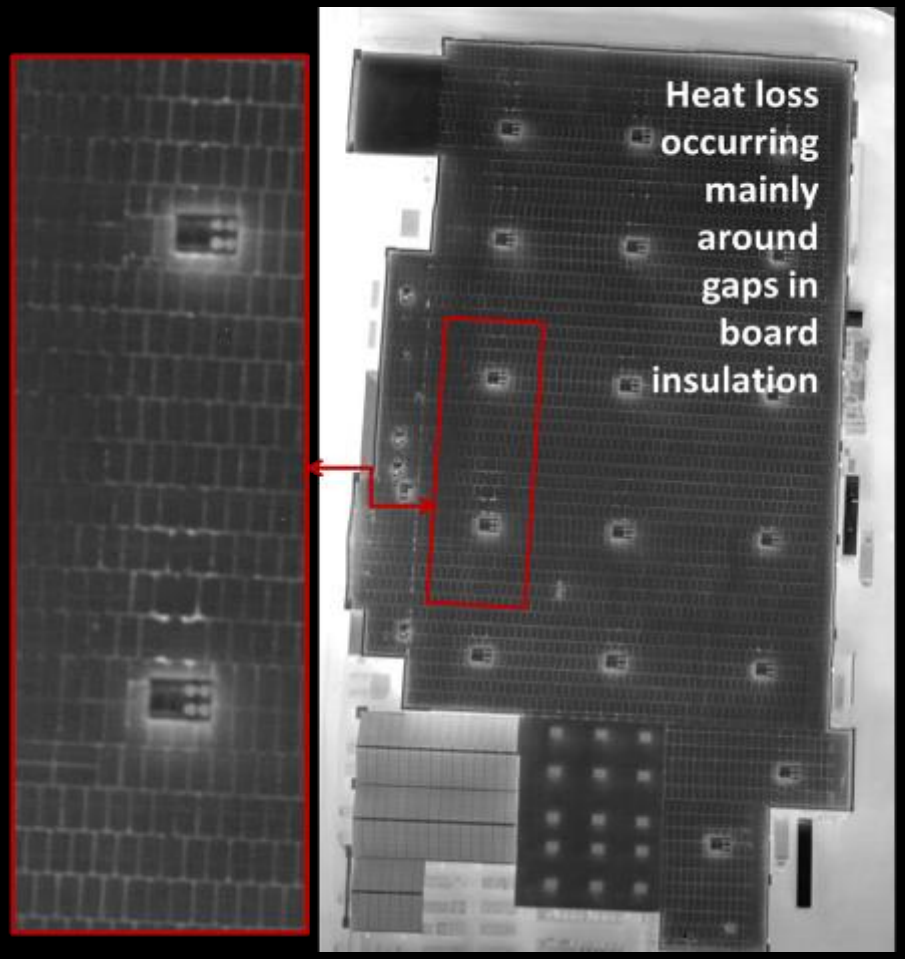
RTU-15
RTU-14
RTU-13
RTU-12
RTU-11
RTU-5
RTU-4
RTU-3
RTU-2
RTU-1

RTU -18
Not Operational

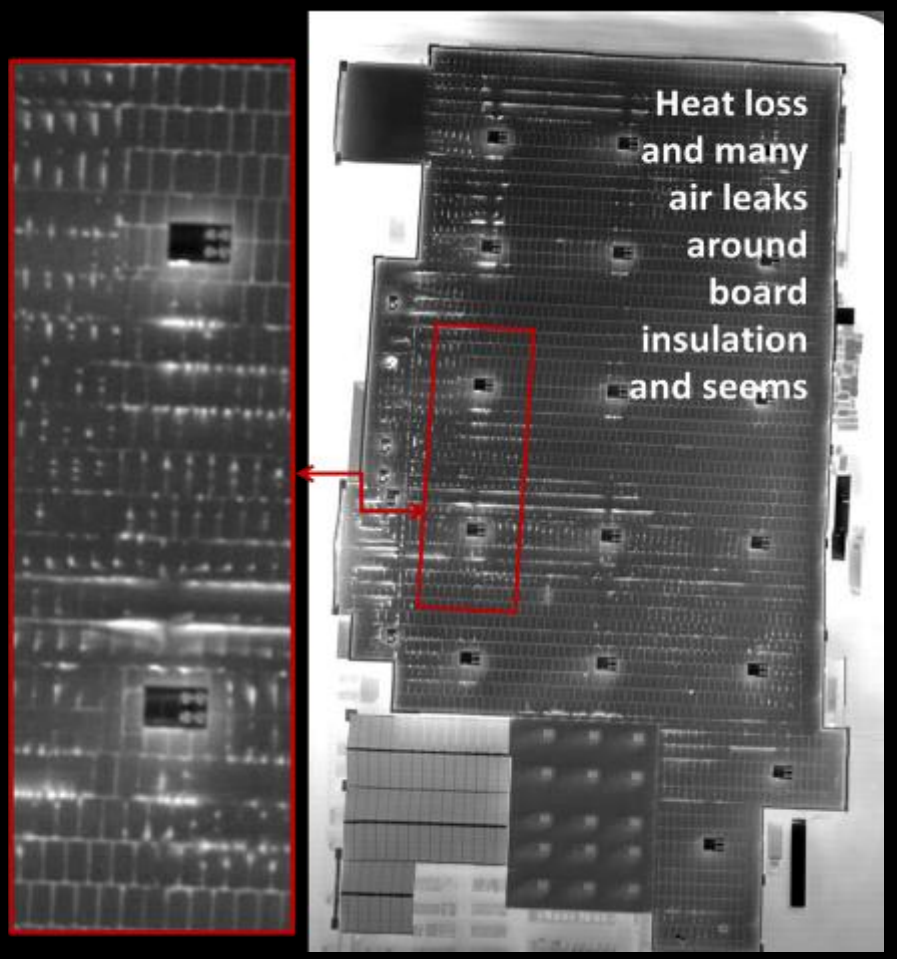
Get the [Thermal] Picture!





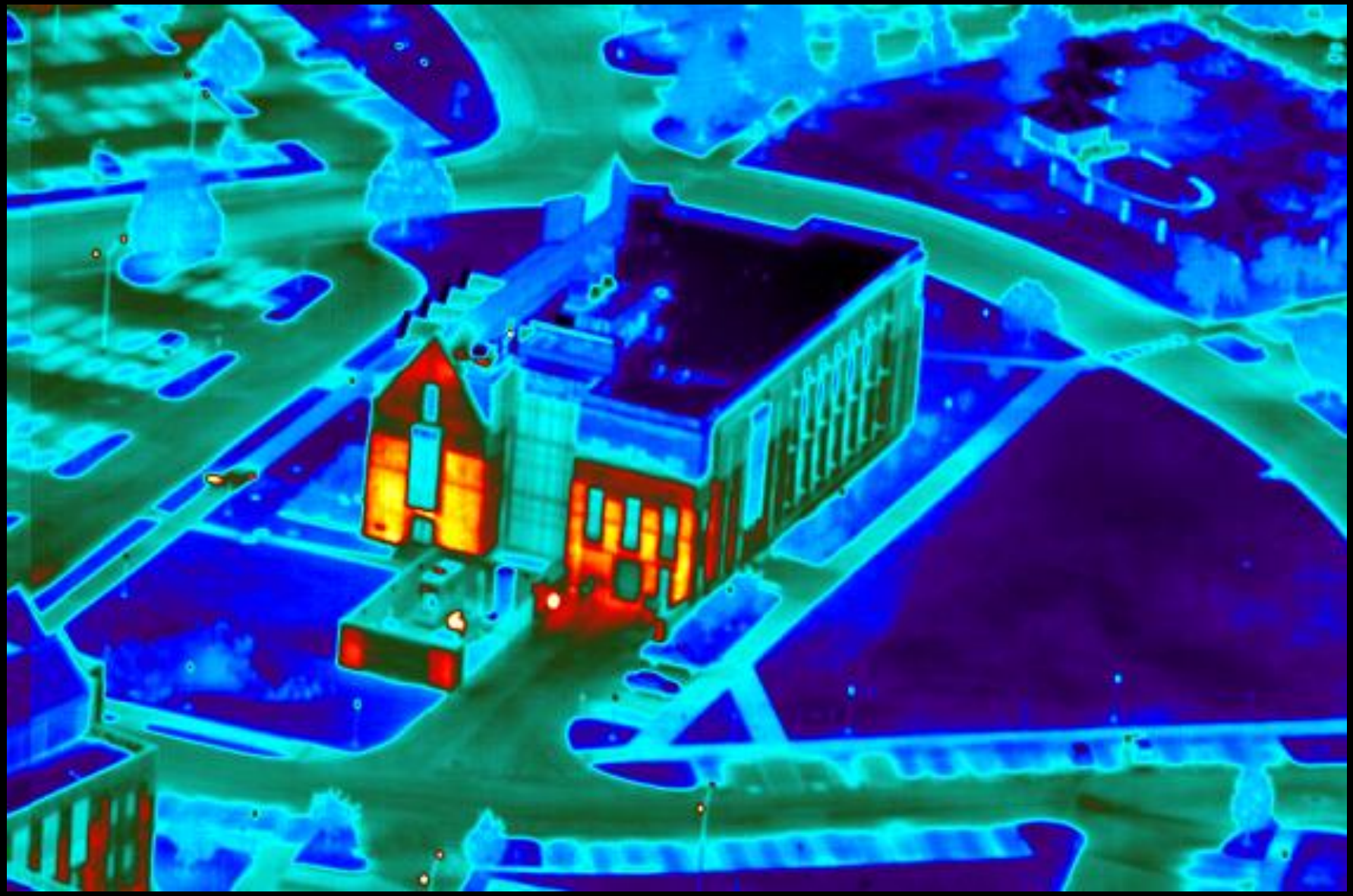


Before Pressurization

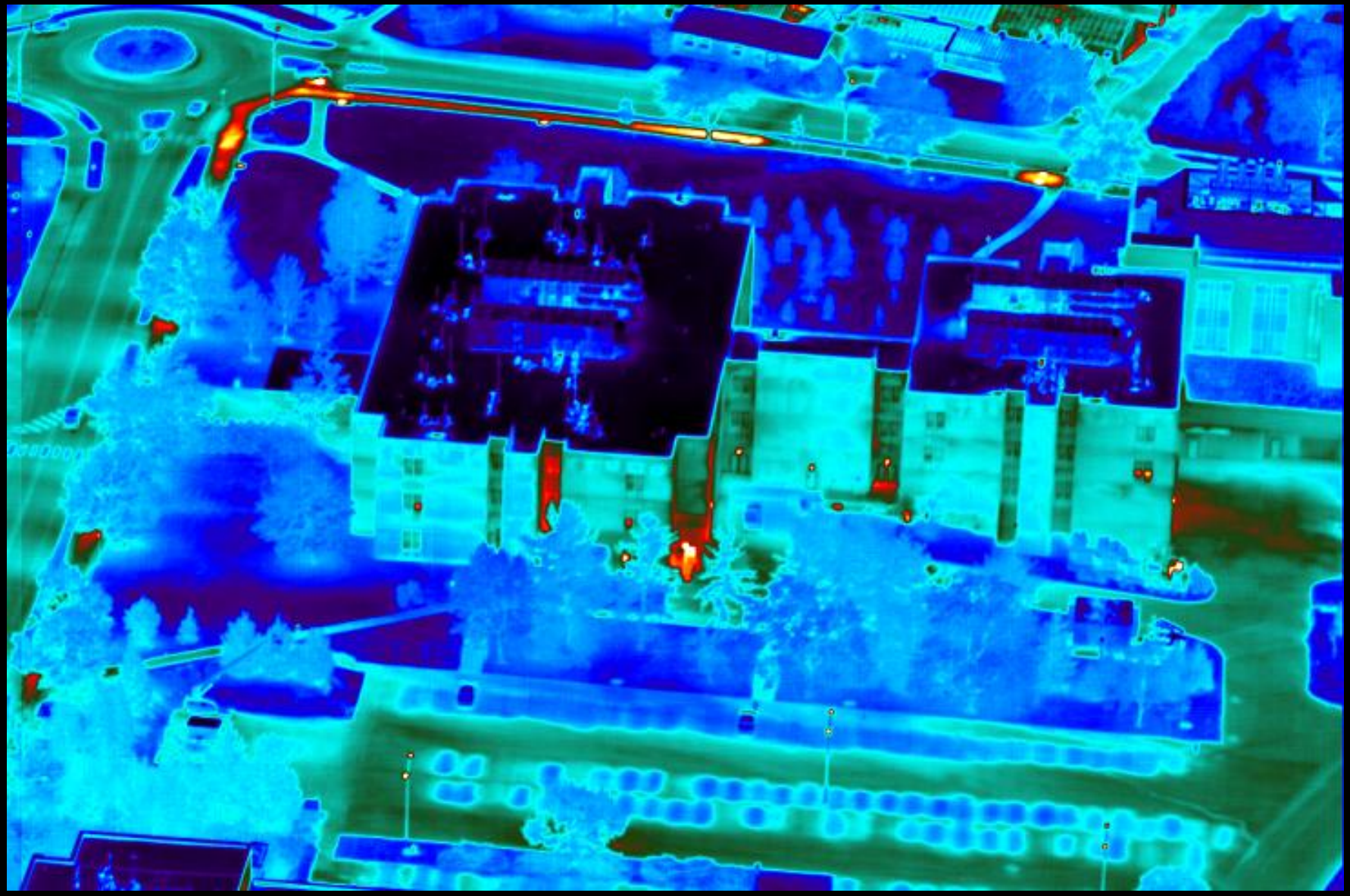


After Pressurization

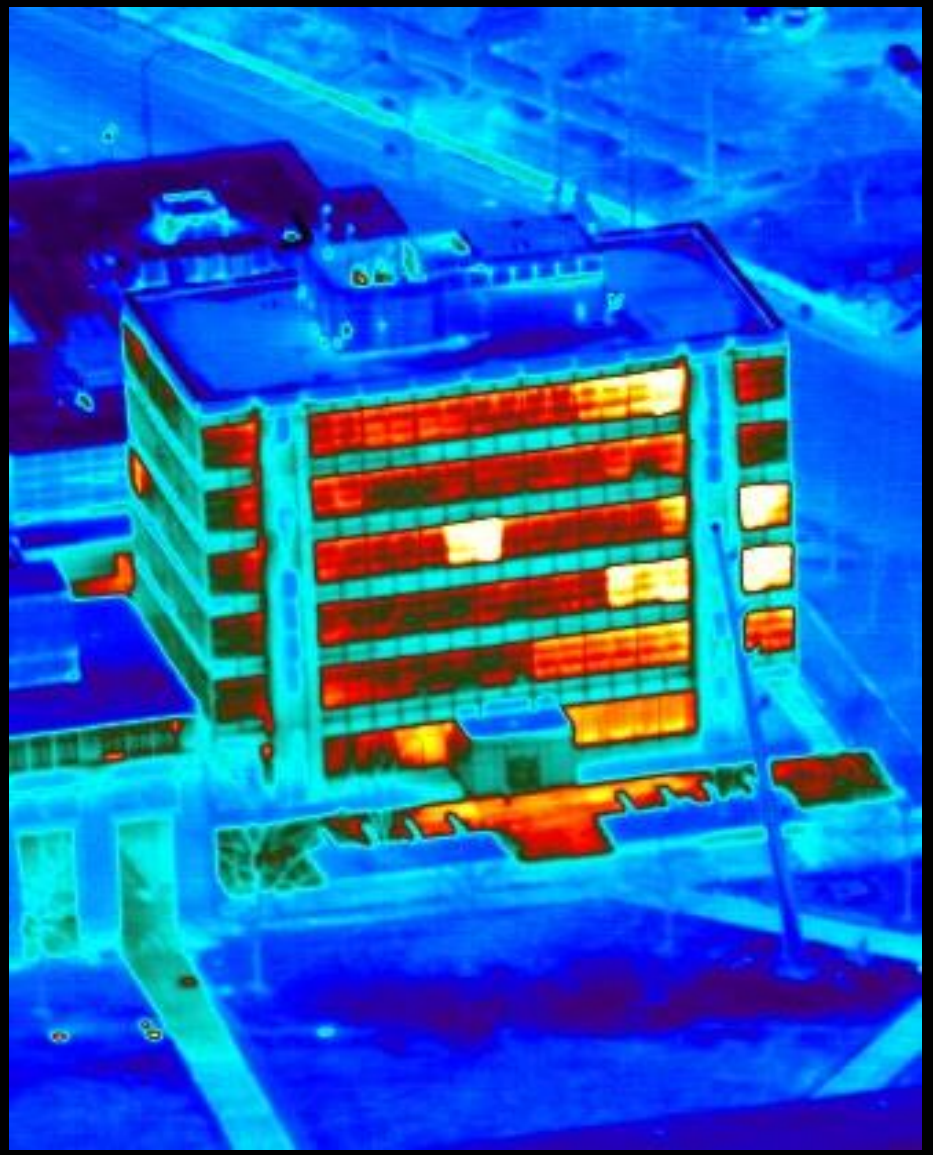
Oblique Aerial IR Imaging

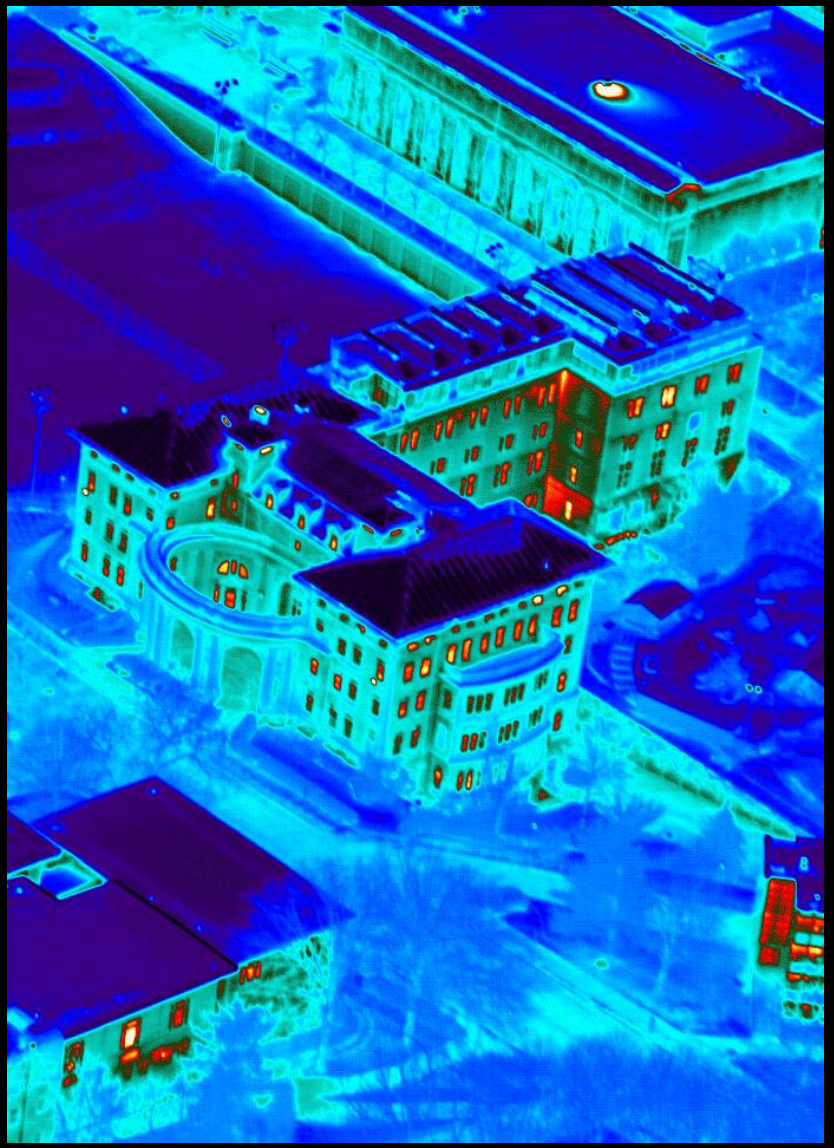


Oblique Aerial IR Imaging

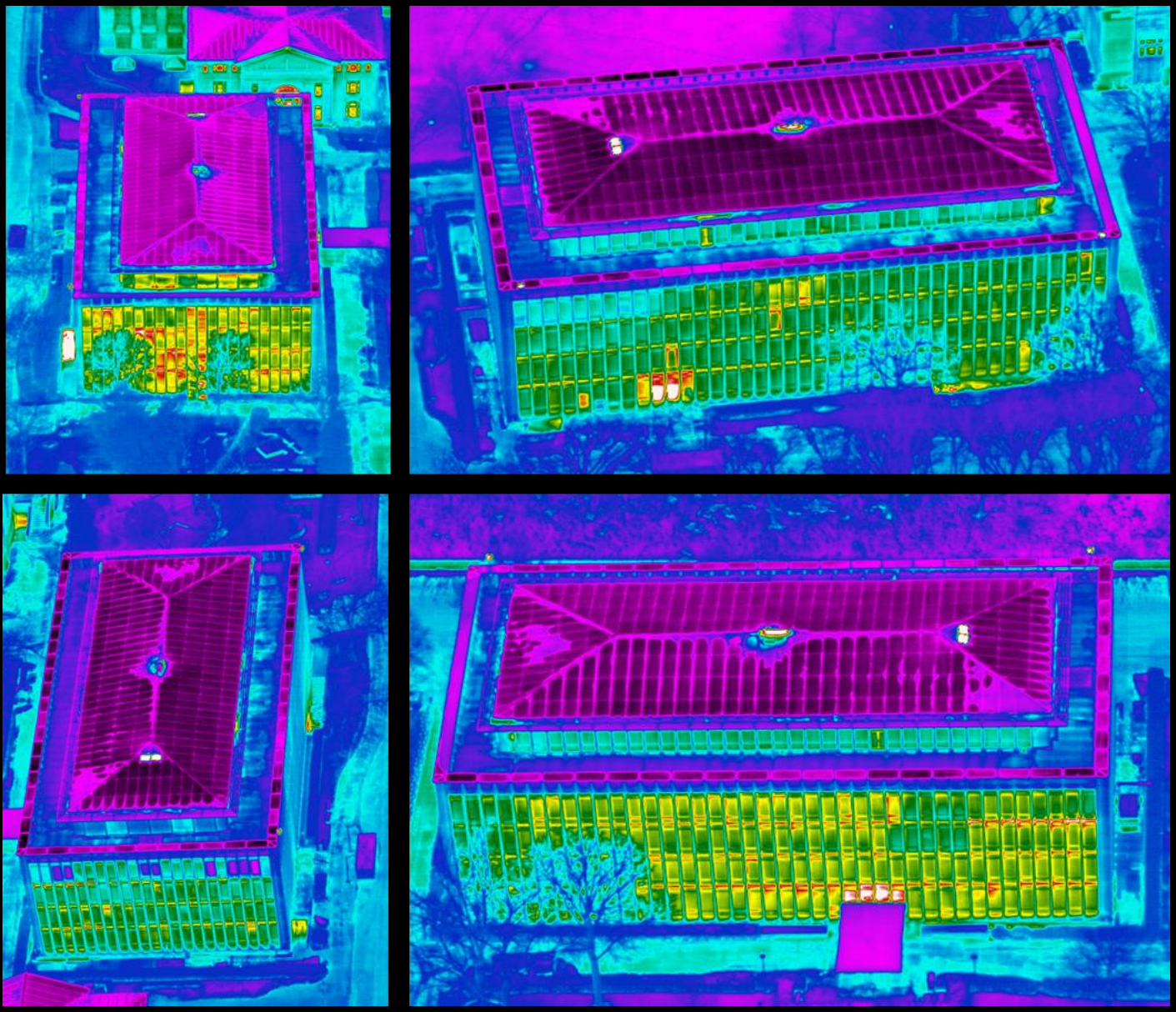


Oblique Aerial IR Imaging

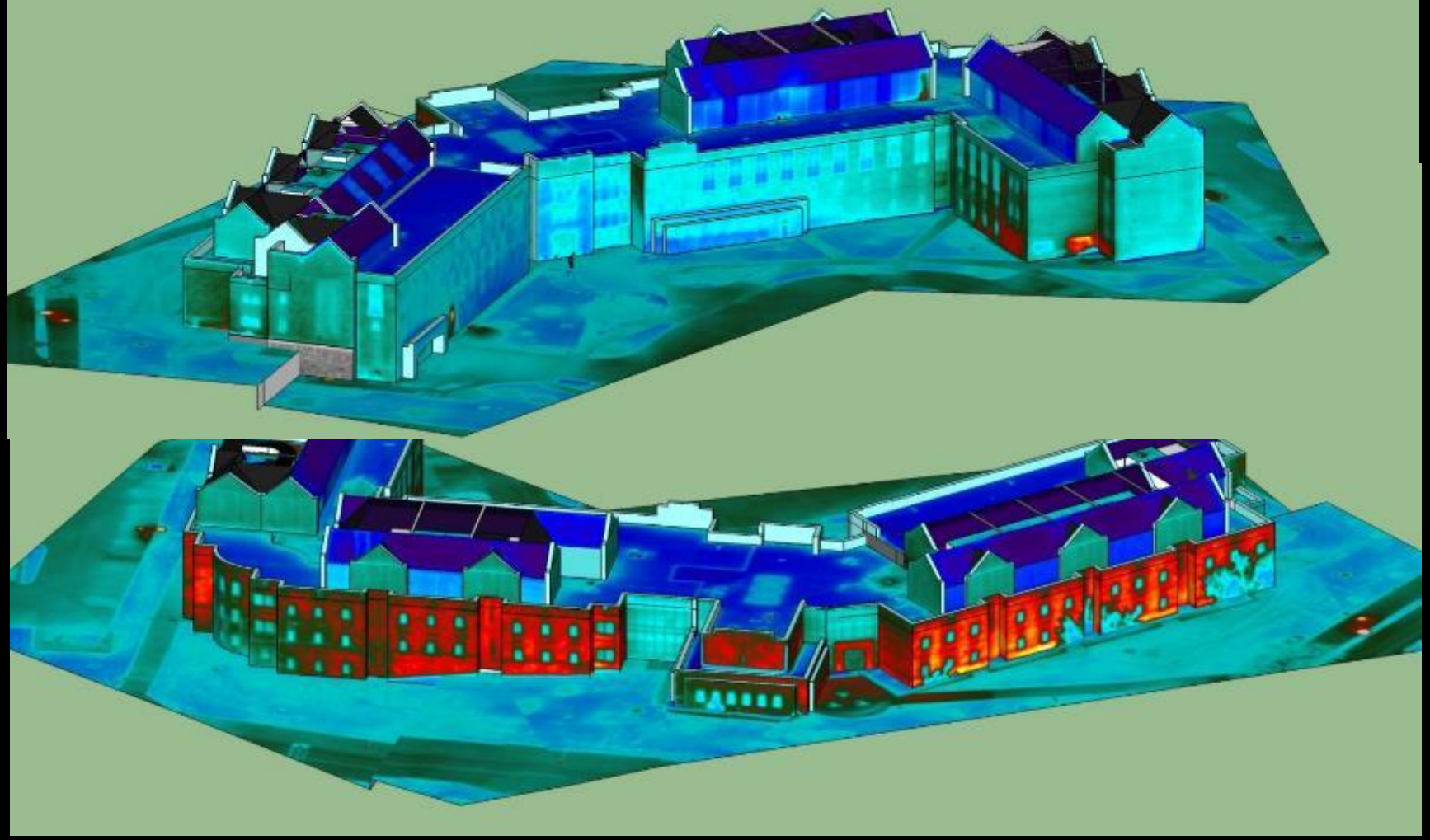




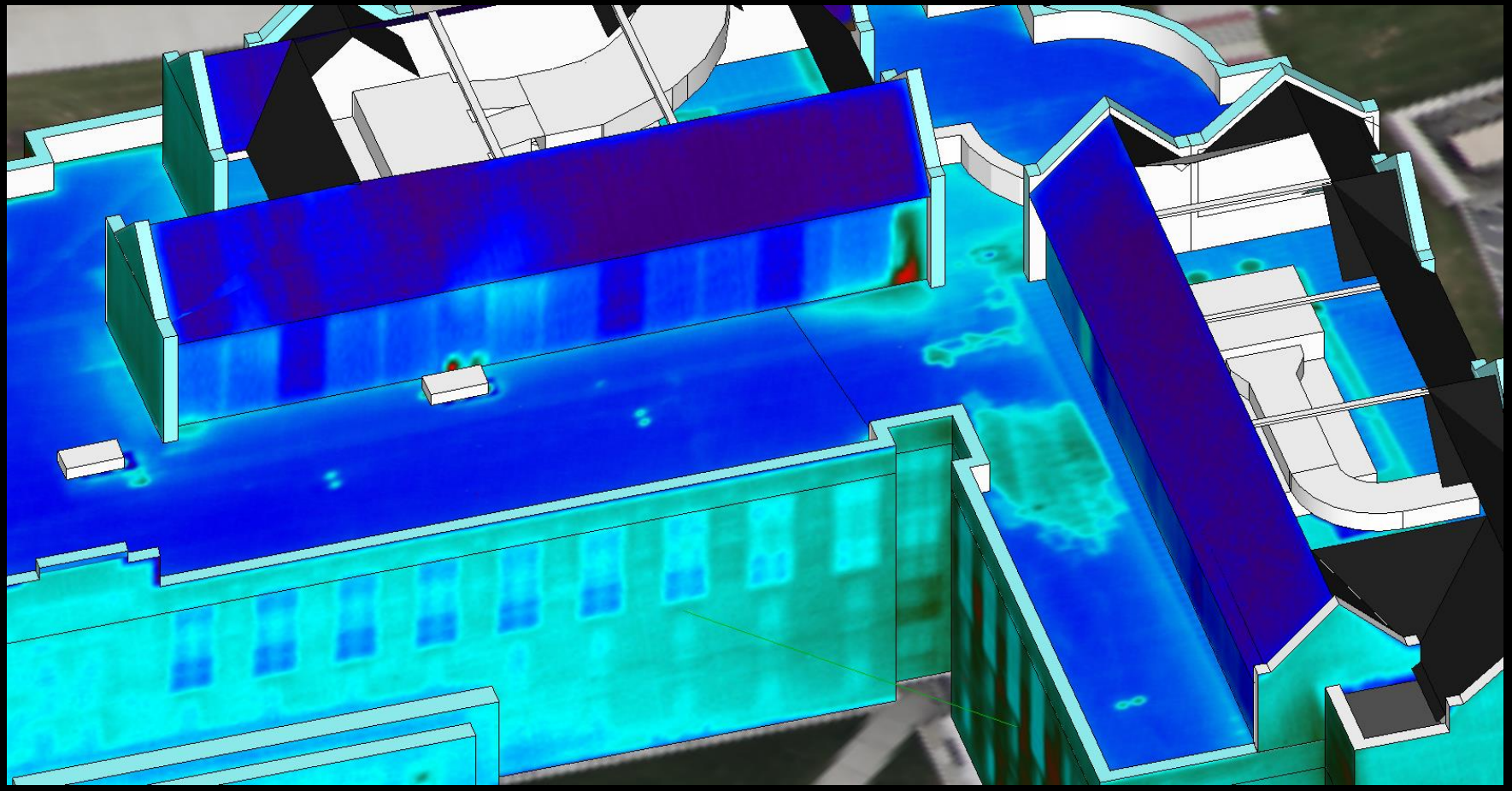
Four-sided Oblique Aerial IR Imaging



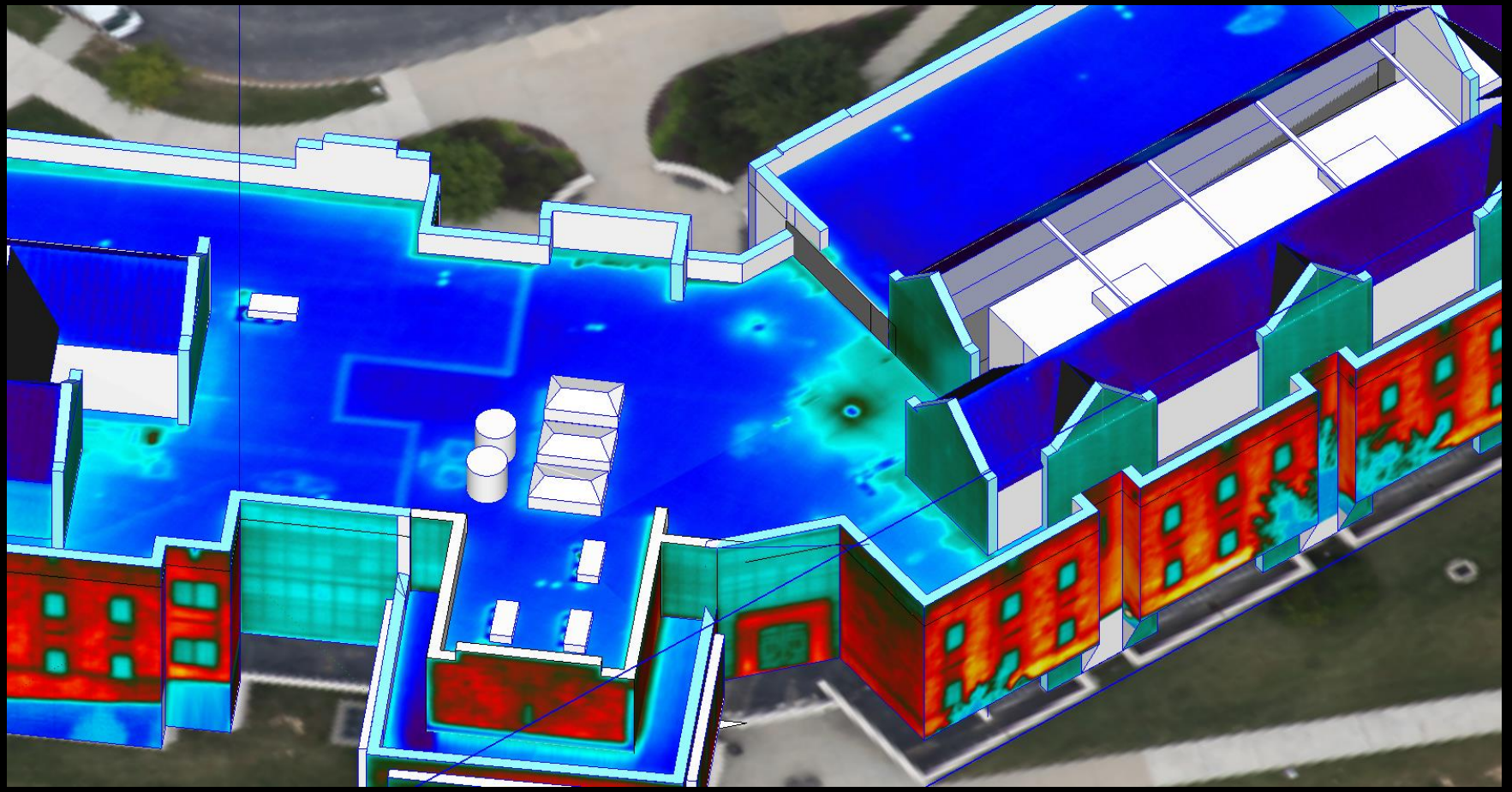
NADIR & Oblique IR Imaging Required for 3D Imaging



NADIR & Oblique IR Imaging Required for 3D Imaging



NADIR & Oblique IR Imaging Required for 3D Imaging



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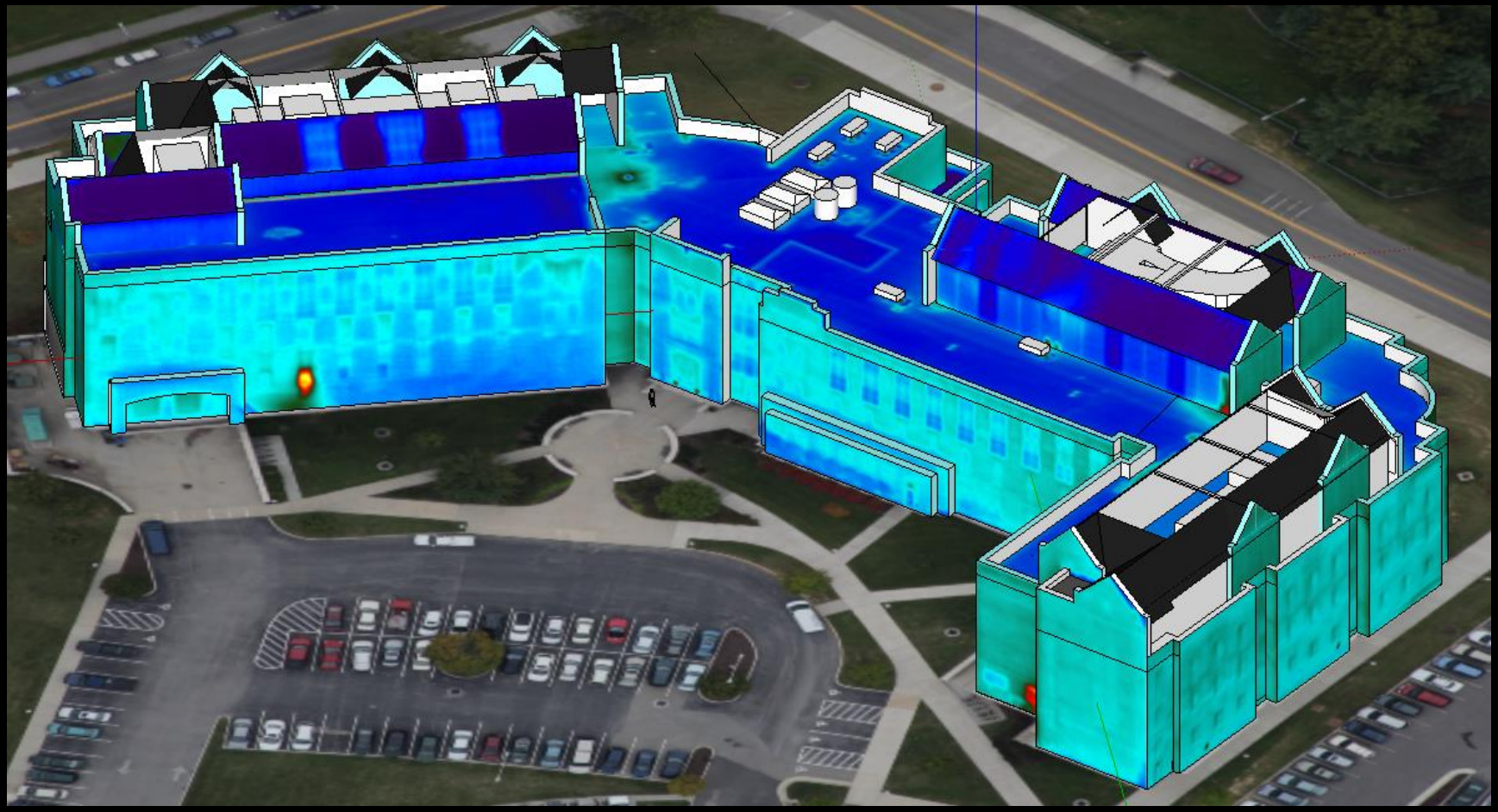
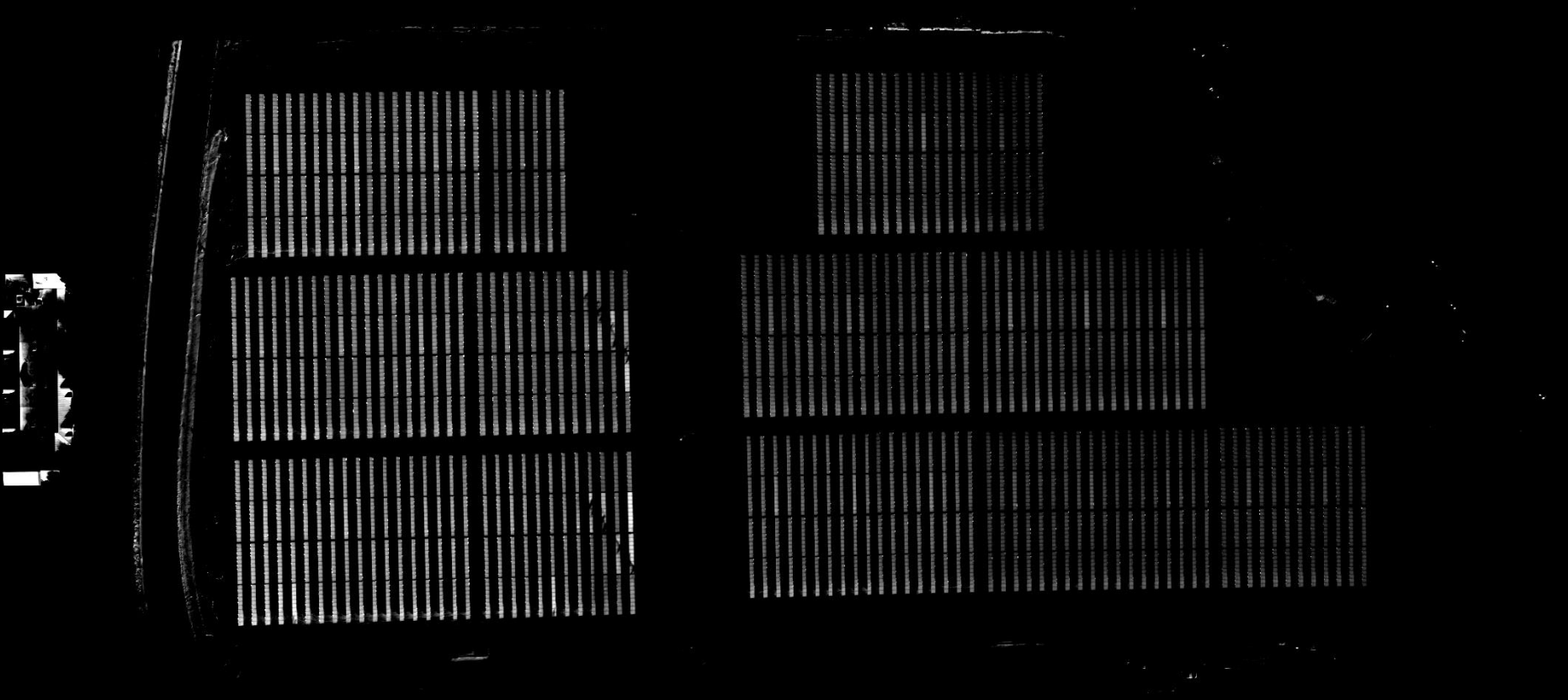
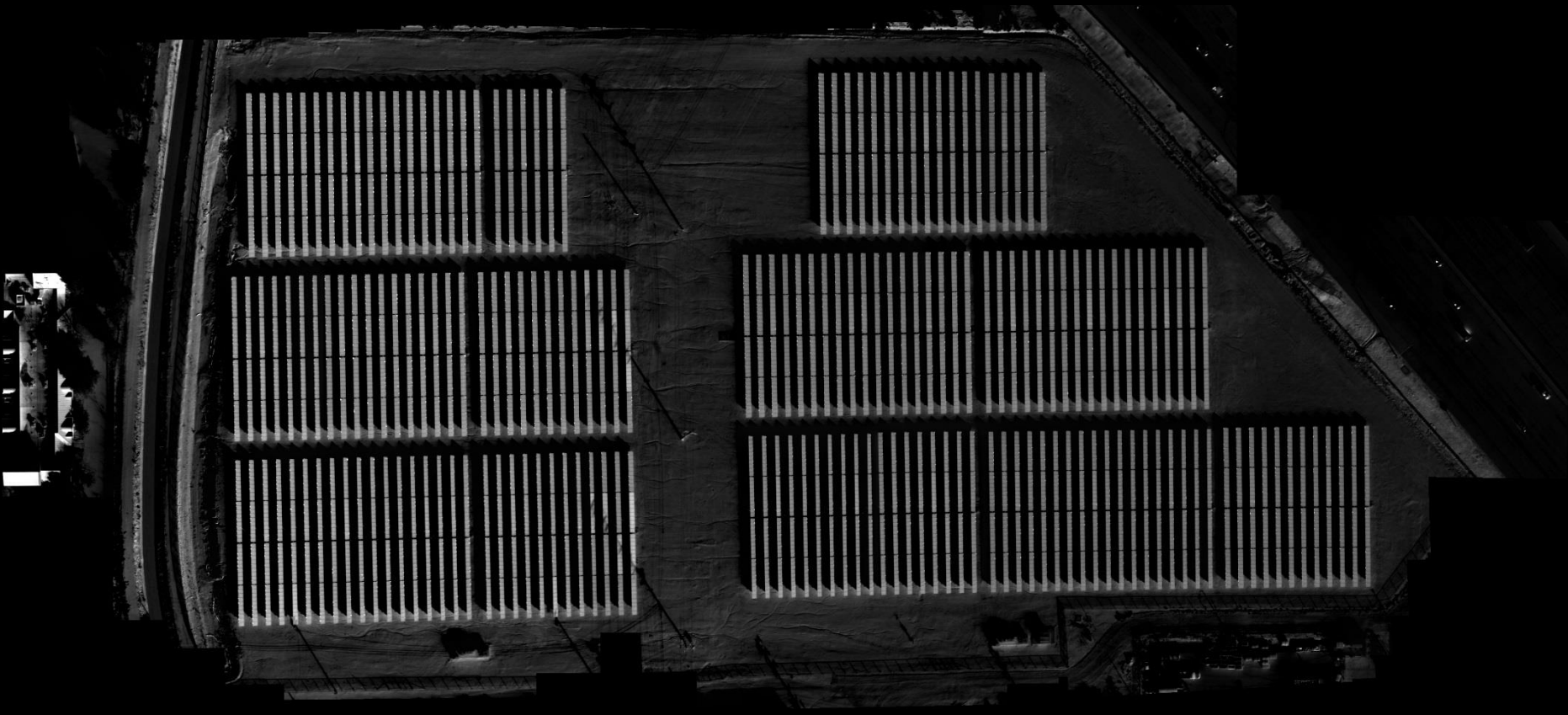


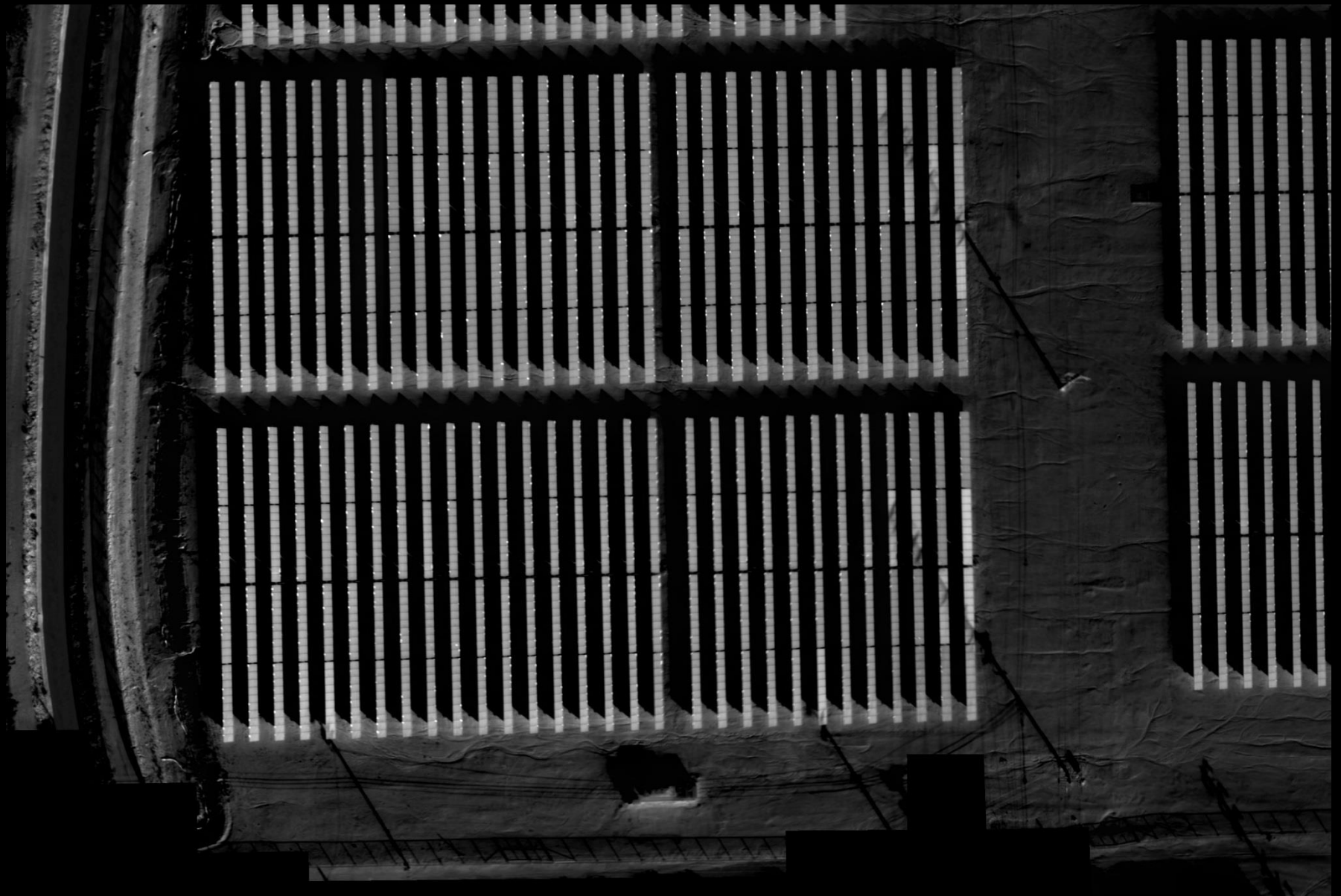
Sol-IR



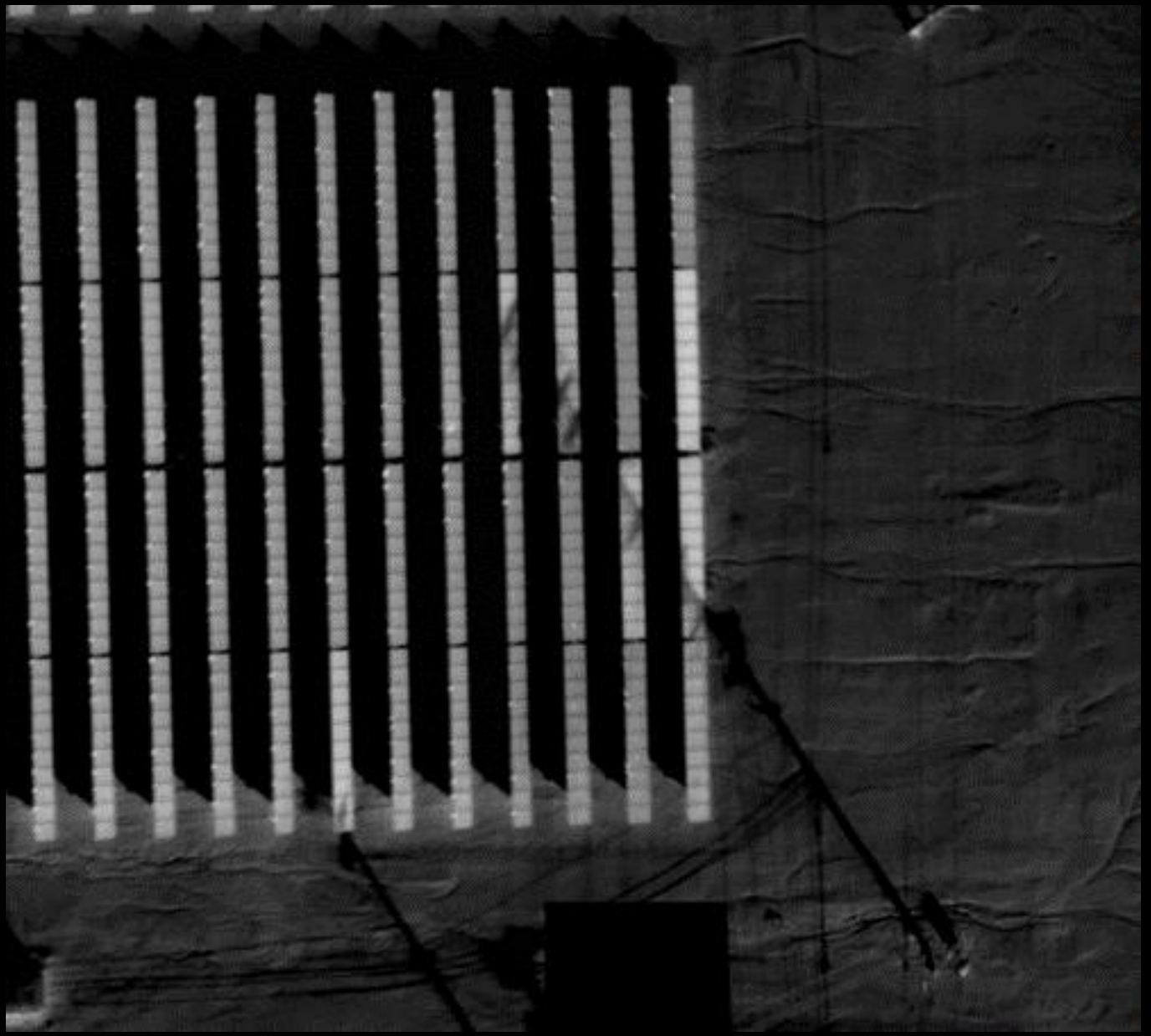
Sol-IR



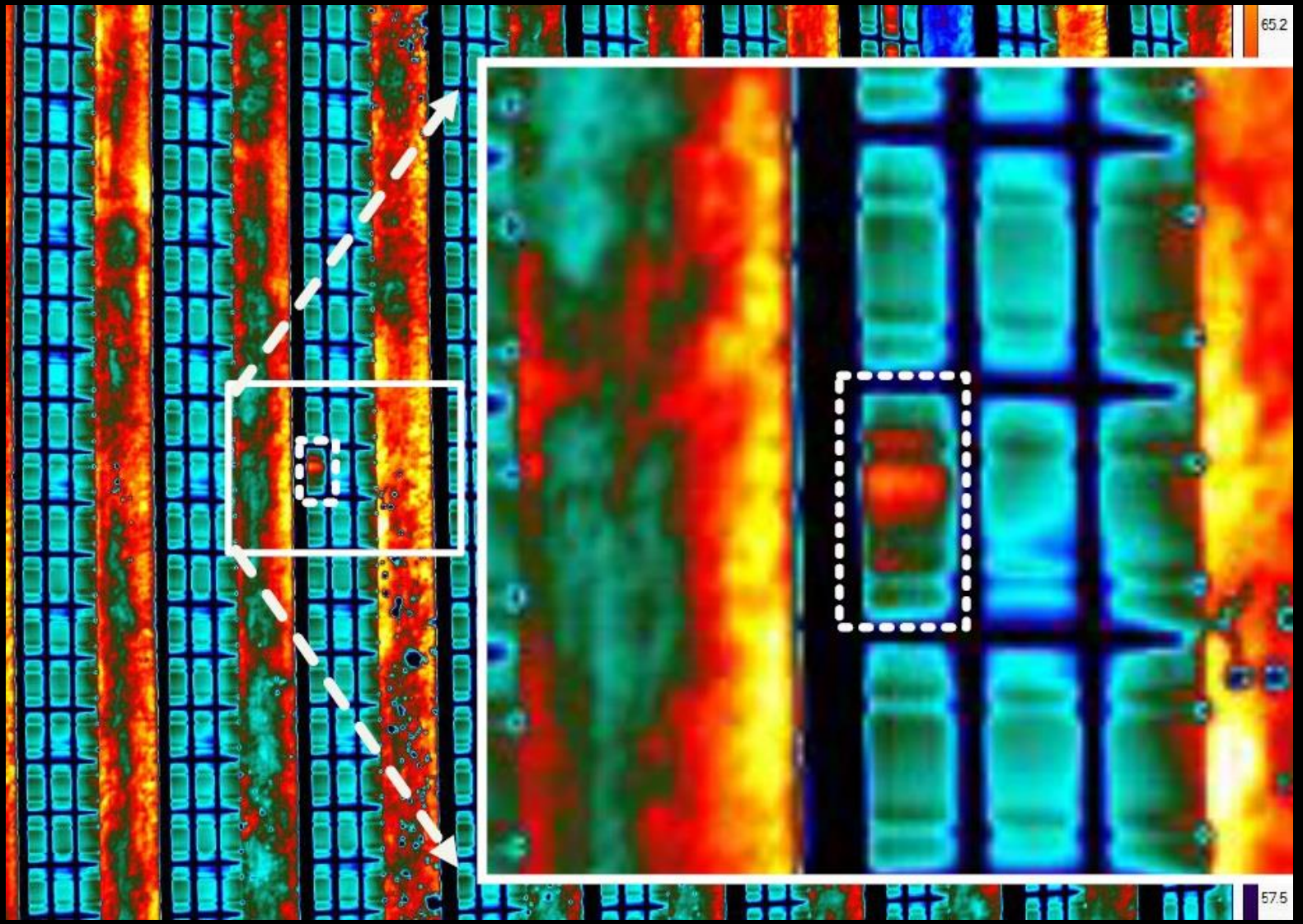
Sol-IR



Sol-IR

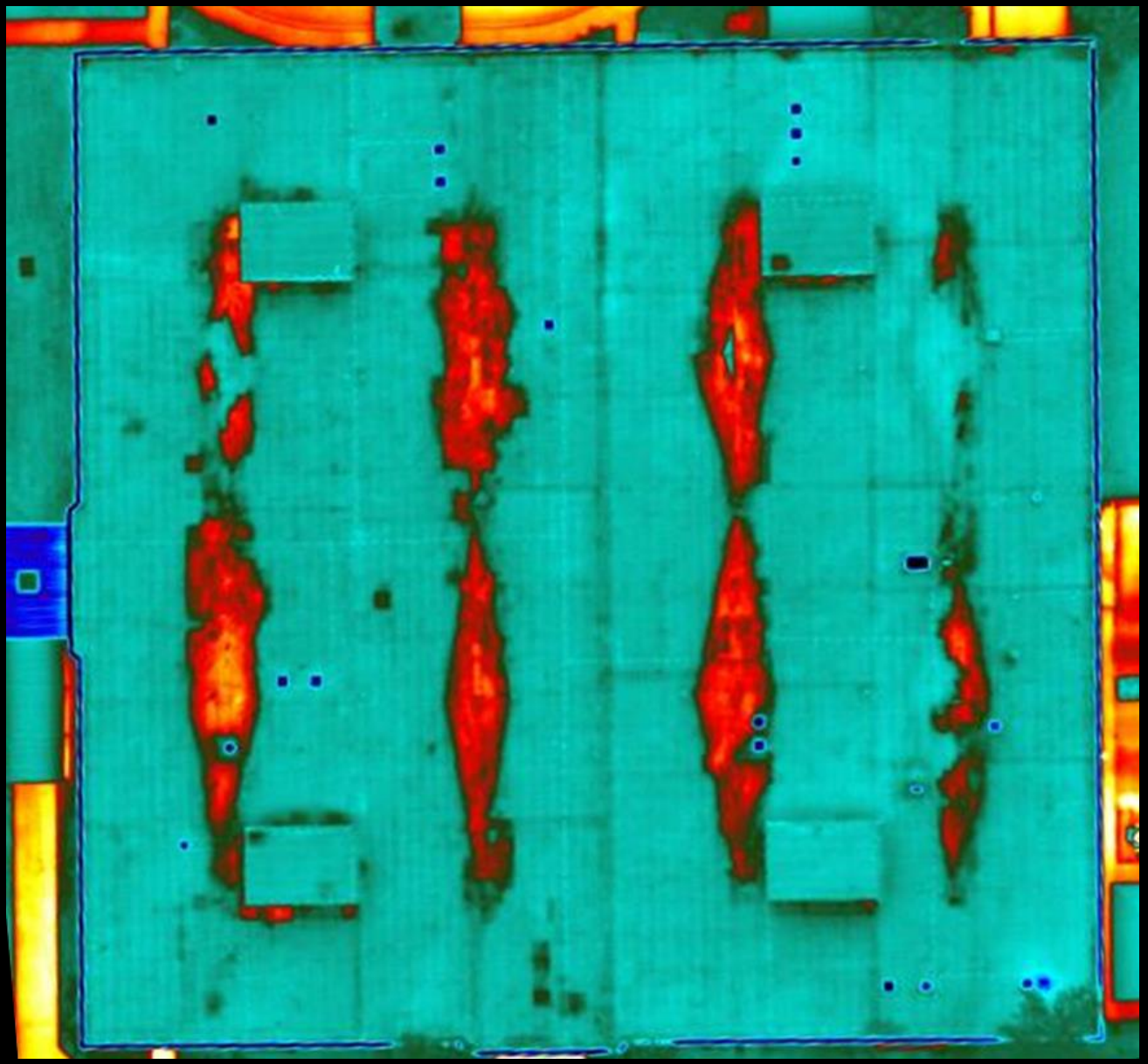


Sol-IR

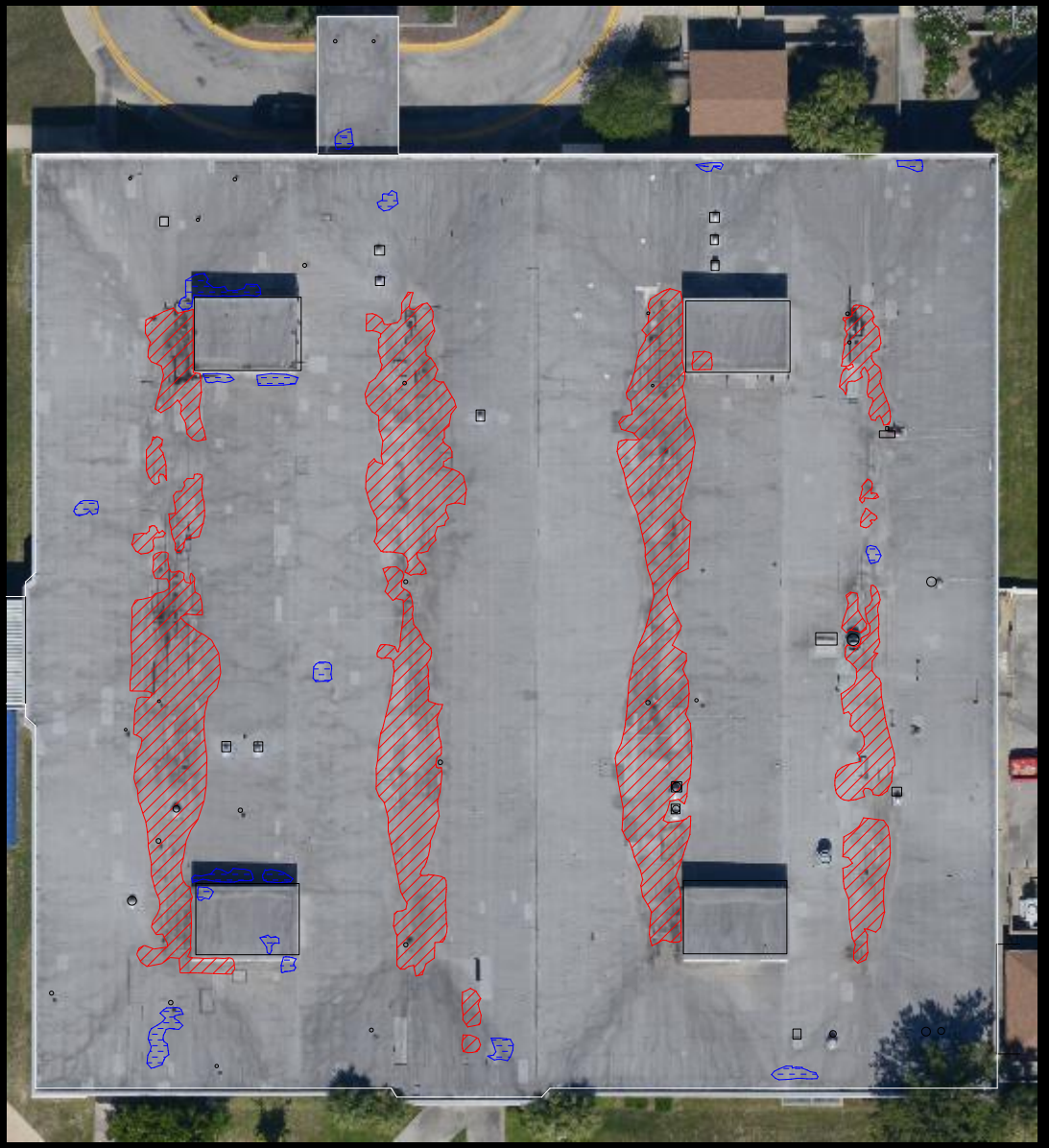


Flat & Low-Sloped Roofs

IR Finds Subsurface Wet Insulation



Wet insulation can be mapped and removed surgically…



Purpose

What makes roof moisture surveying so valuable to the owner of a roof? Of course, cost-savings:

95+% of all roofing materials that are removed are dry

- Best practice condition monitoring (PM) for roof maintenance
- Salvage the thermal value of the existing undamaged insulation
- Avoid costly tear-off expense in labor to R&R wet insulation
- Avoid cost to bury perfectly good insulation in a landfill
- Save time: recover is faster vs. tear-off and replacement
- Minimize risk of leaks and consequential damage
- It is “Green” not to throw away perfectly good materials

Waterproofing problems manifest in two ways:

- Leakage
- Entrained moisture contamination

NDT is not leak detection!

Leakage is pretty simple, although the leak inside the building rarely directly relates to the exact spot on the roof, since the water flows down the slope of the roof to a spot that is not sealed and into the building at that point. Most leaks [on the roof] occur where the waterproofing is not sealed or where a penetration through the roof that is not sealed. Since most types of roof systems absorb some amount of water, it is harder to find the exact spot of water contamination in the insulation because it may not leak into the building until it has absorbed all the water it can hold.

Two Methods of testing roofs for moisture:

1. Destructive Testing
   - Pin type meters
   - Core Sampling

2. Non-Destructive Testing
   - Nuclear Density Gauges
   - Dielectric Capacitance Meters
   - Thermal Infrared Cameras

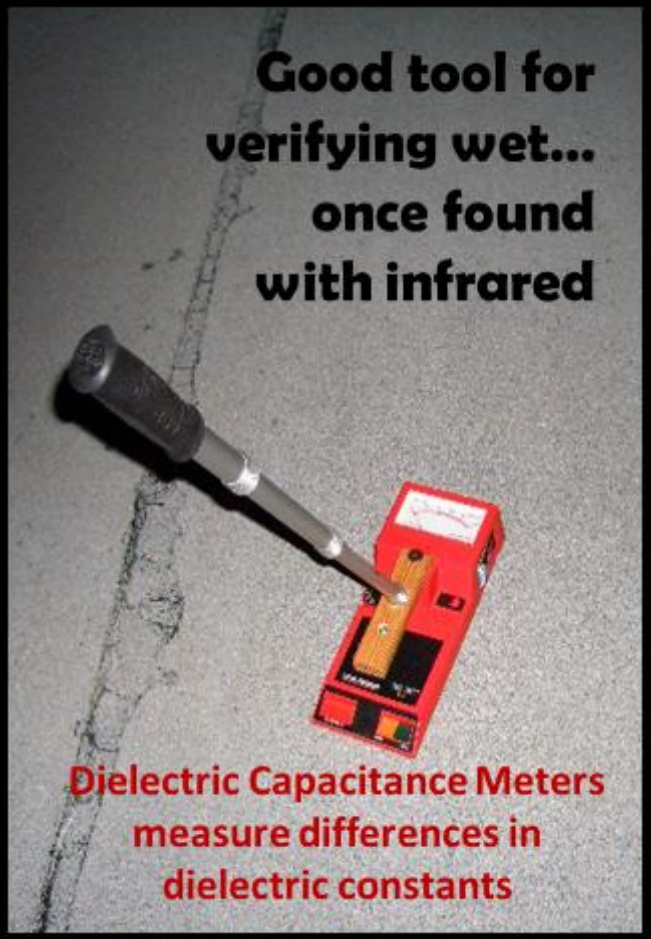
Destructive Testing
Pin type

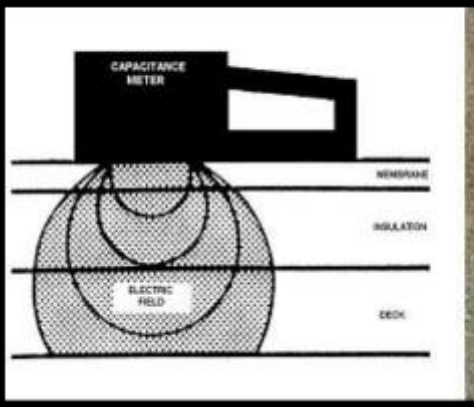
Destructive Testing
Core Sampling

Non-Destructive Testing – Three Devices

- **Nuclear Density Gauges**
  – which count slowed neutrons
- **Dielectric Capacitance Meters**
  – which measures differences in dielectric constants
- **Thermal Infrared Cameras**
  – which measure heat differences

Non-Destructive Testing – Capacitance





Non-Destructive Testing – Nuclear

Nuclear Density Gauges count slowed neutrons

Non-Destructive Testing – Meter Surveys

- Both nuclear gauges and capacitance meters are used to take spot readings on either a 20'x20' or 10'x10' or 5'x5' grid on the roof.
- These measurements are used to extrapolate where the water is from the readings obtained from the gauge.
- Notwithstanding false or inaccurate readings, the sample of the roof is tiny, given the amount of readings and associated labor.

Infrared is always better because you are getting 100% coverage of the roof…

5,000 SF Roof Area

80 SF wet
5 spots
0 found
65 reads
10' x 10' Grid

Metering takes 2-3 hours to find ZERO wet areas

Infrared

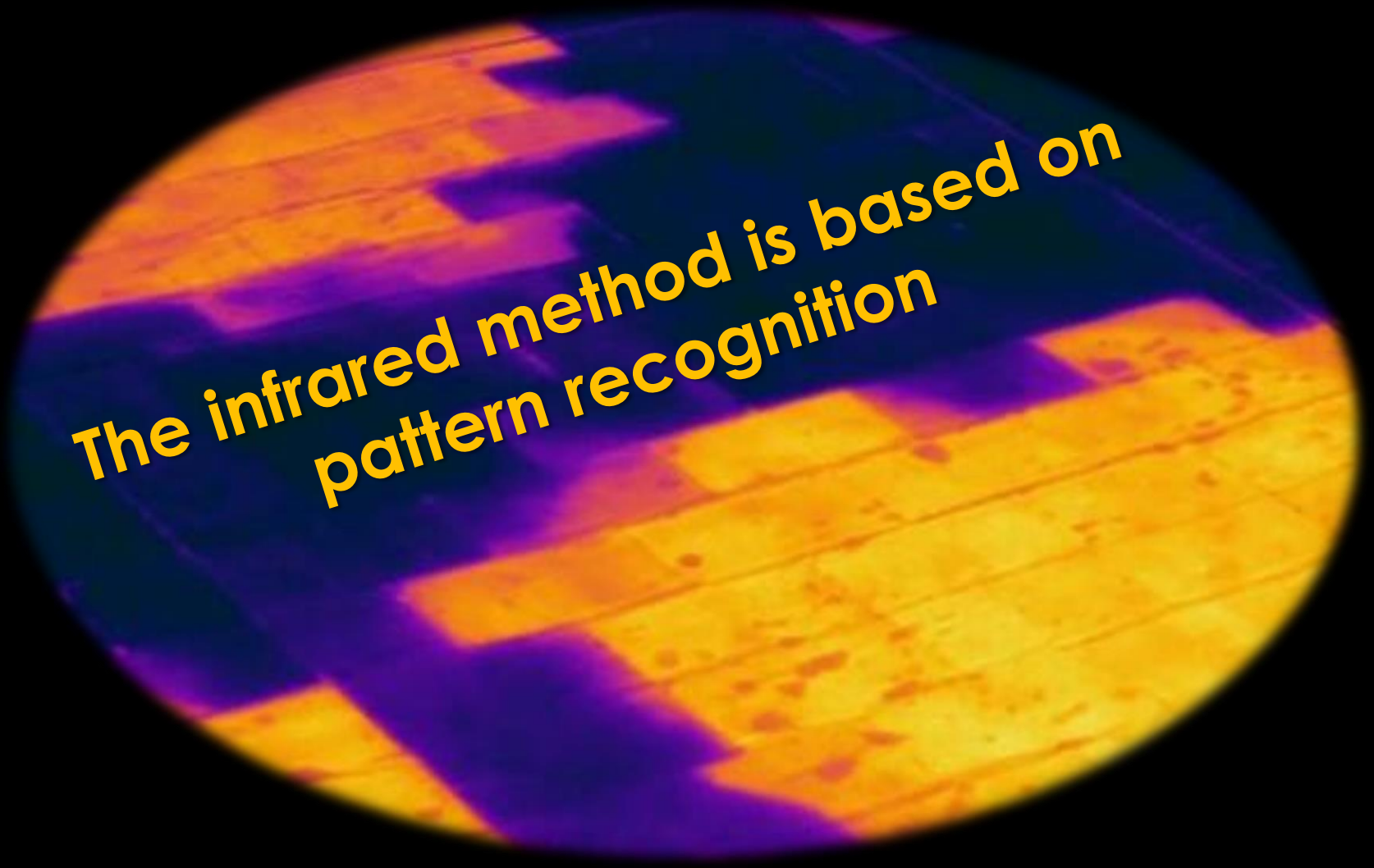
Four methods to accomplish IR Roof Moisture Surveys:

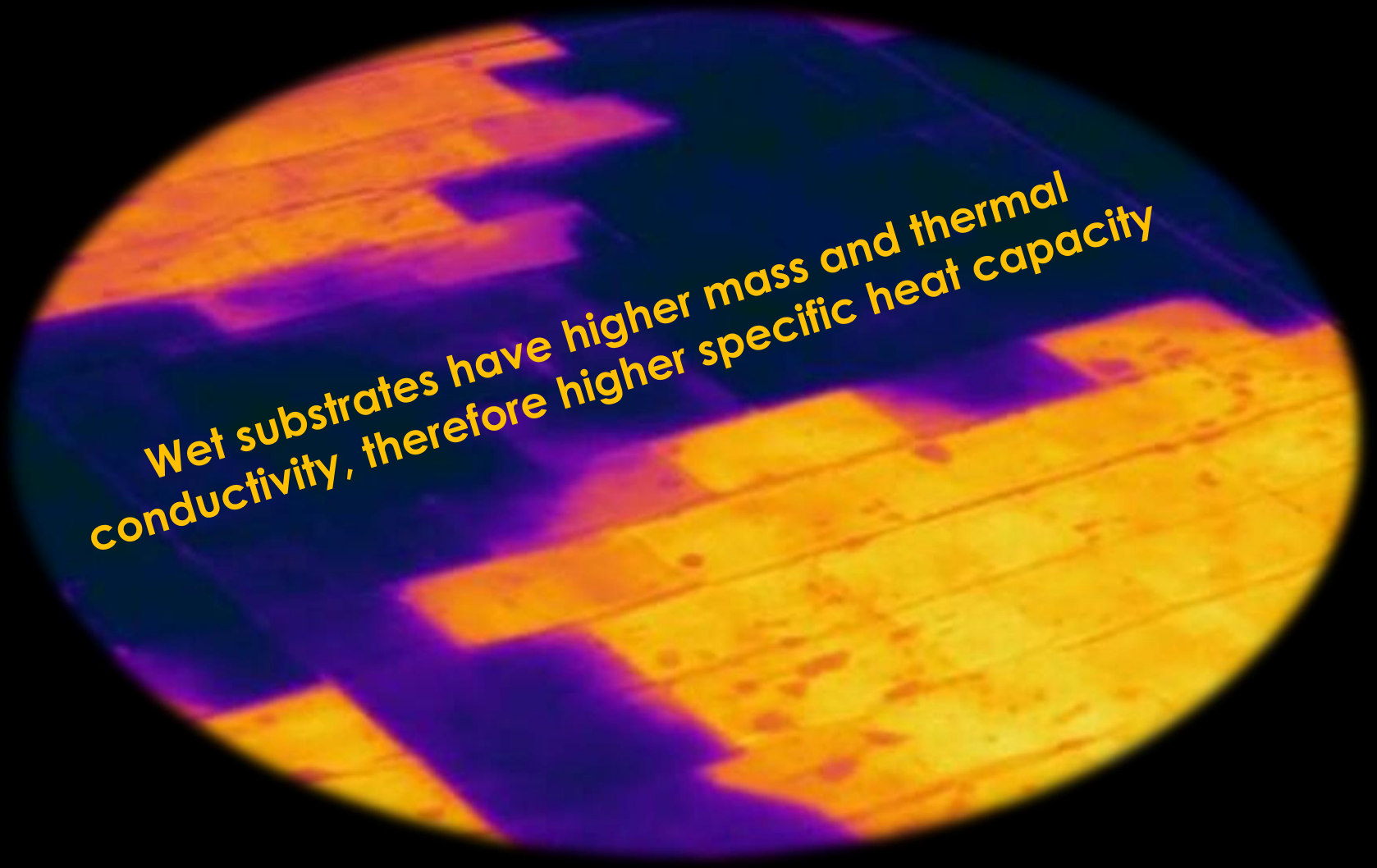
- Under-Roof **Infrared Roof Moisture Surveys**
- On-Roof **Infrared Roof Moisture Surveys**
- Elevated Vantage Point **Infrared Roof Moisture Surveys**
- Aerial **Infrared Roof Moisture Surveys**

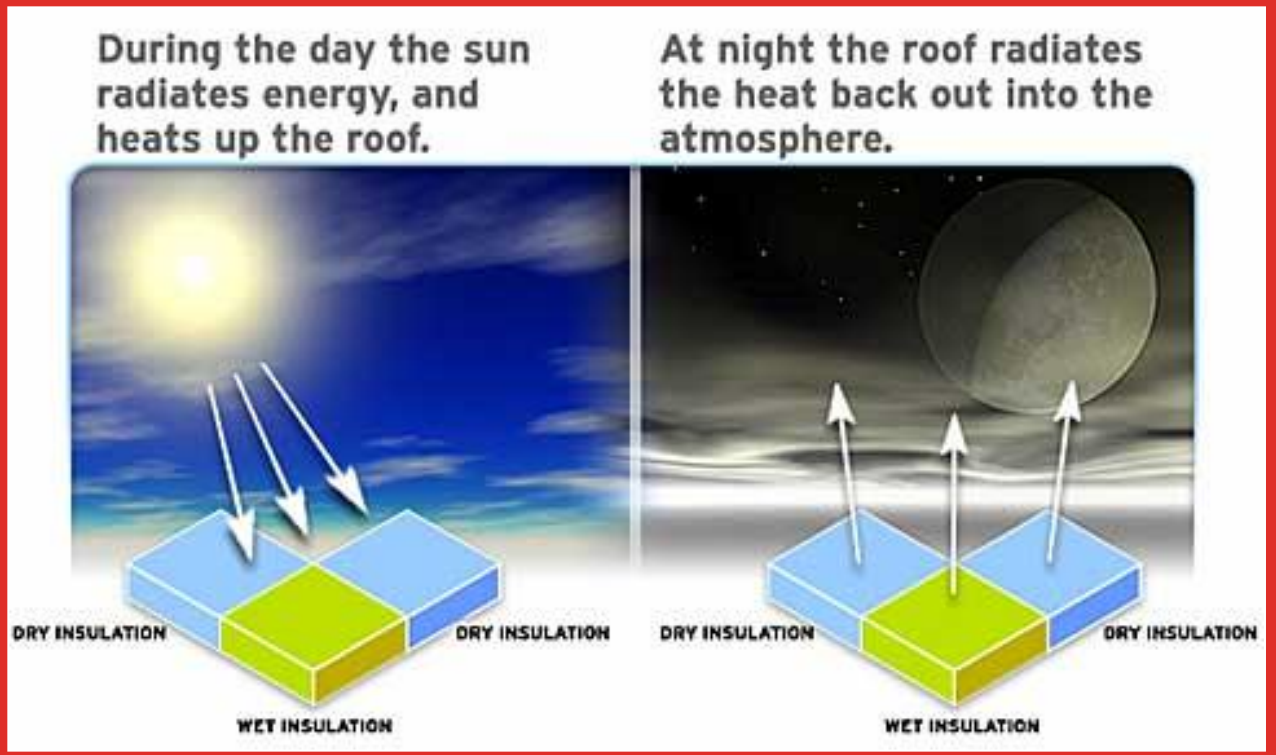
The same thermodynamics and laws of physics apply to all.

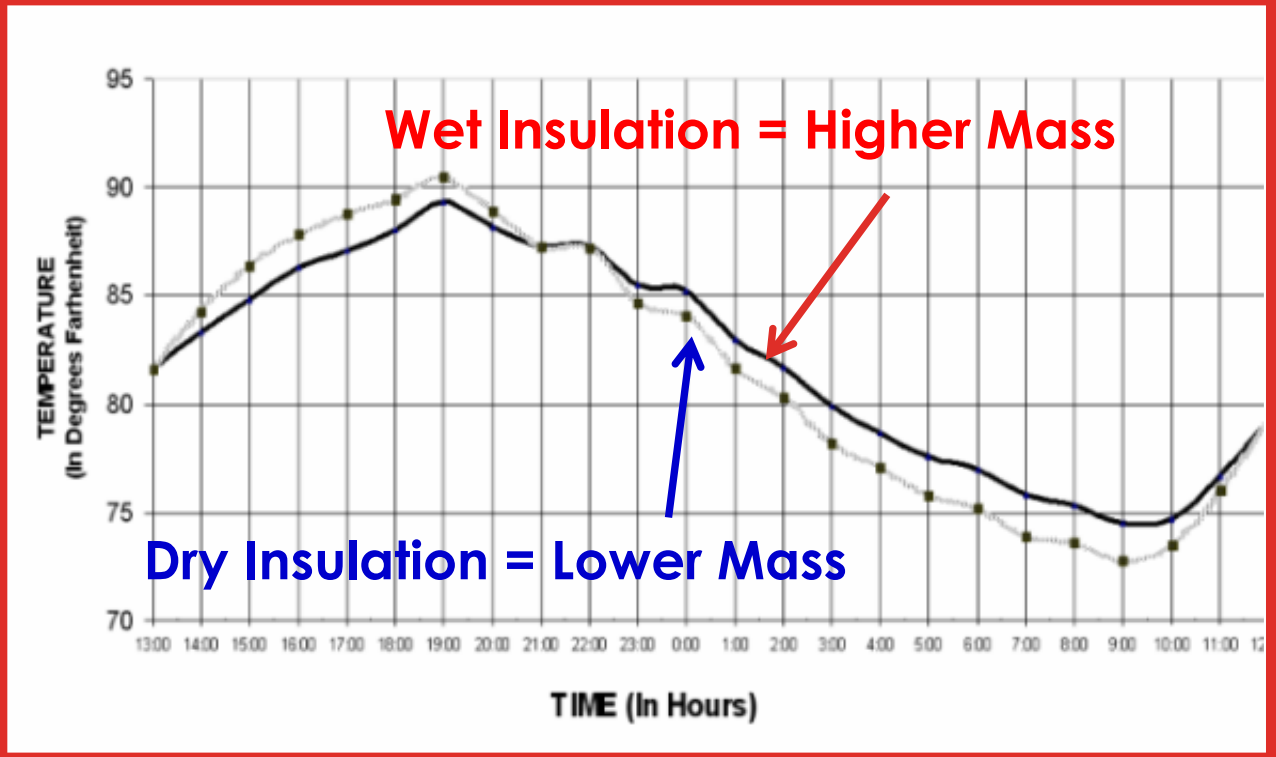
- A dry roof, low winds and no rain are needed on the night of the survey. The more clear the sky, the better.
- Solar Insolation is the main factor as far as thermal conditions.

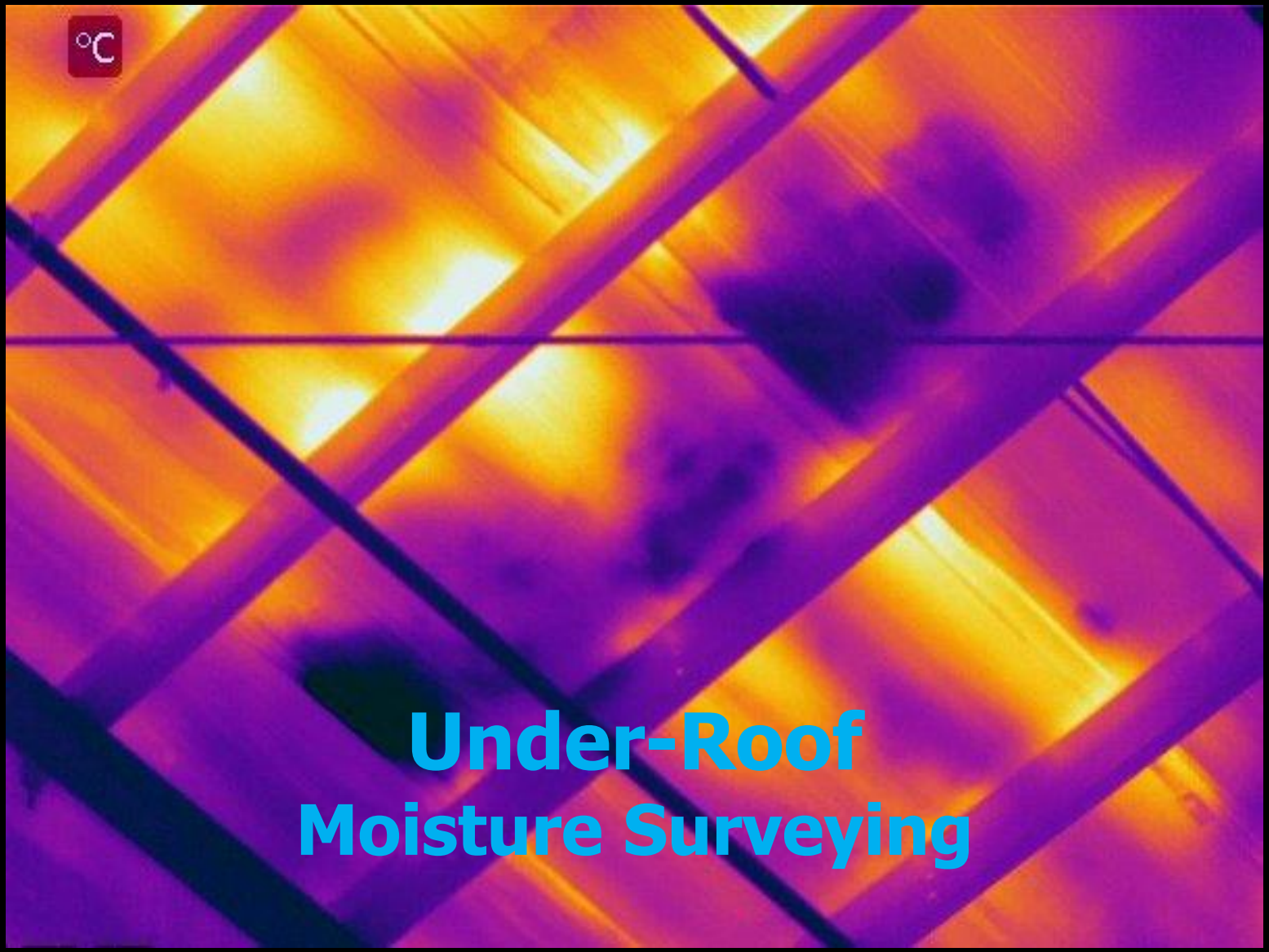
All methods have advantages and disadvantages...


The infrared method is based on pattern recognition

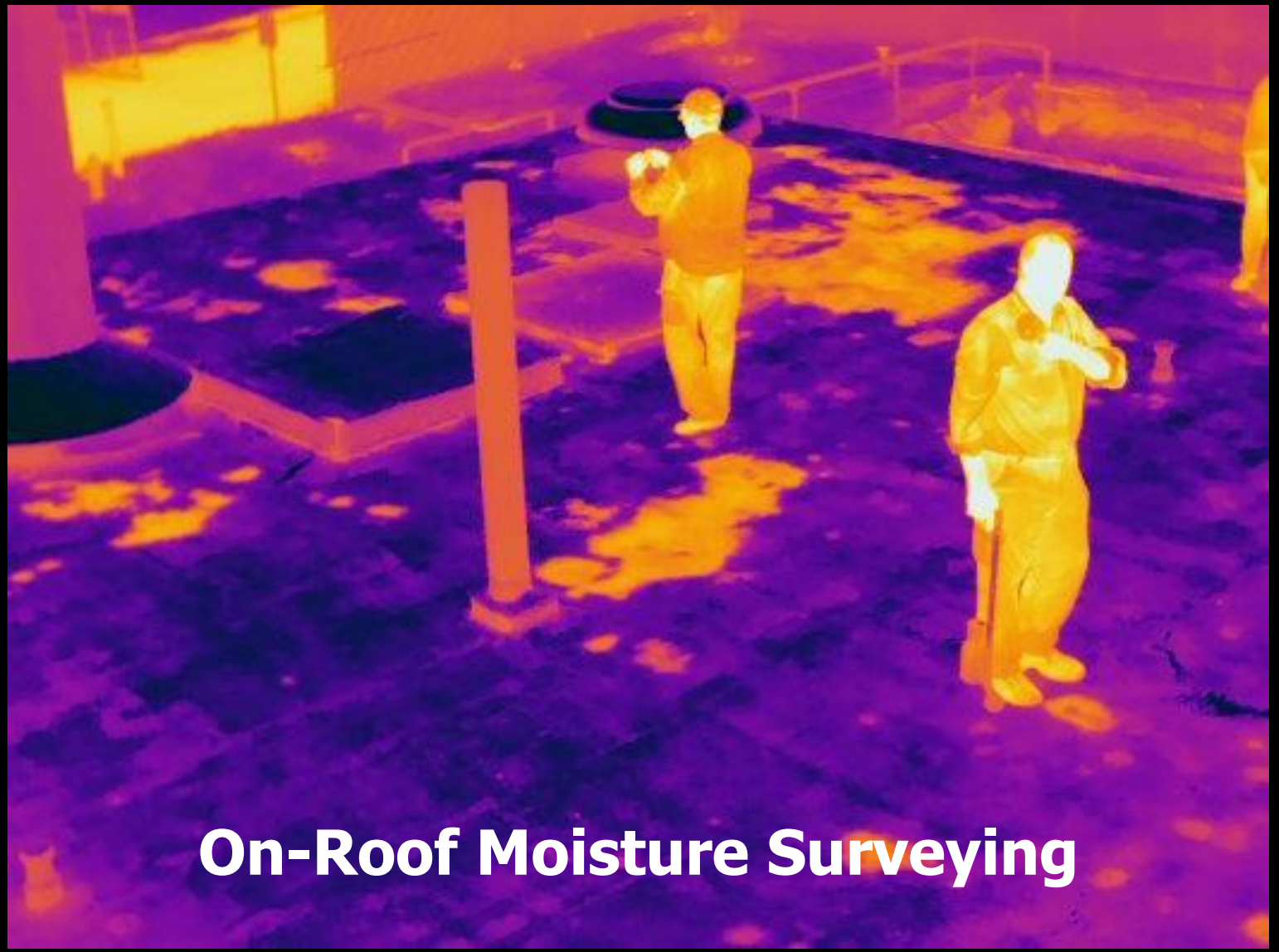

Wet substrates have higher mass and thermal conductivity, therefore higher specific heat capacity


During the day the sun radiates energy, and heats up the roof.
DRY INSULATION
DRY INSULATION
WET INSULATION
At night the roof radiates the heat back out into the atmosphere.
DRY INSULATION
DRY INSULATION
WET INSULATION


Wet Insulation = Higher Mass
Dry Insulation = Lower Mass
TEMPERATURE
(In Degrees Farhenheit)
95
90
85
80
75
70
13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00
TIME (In Hours)

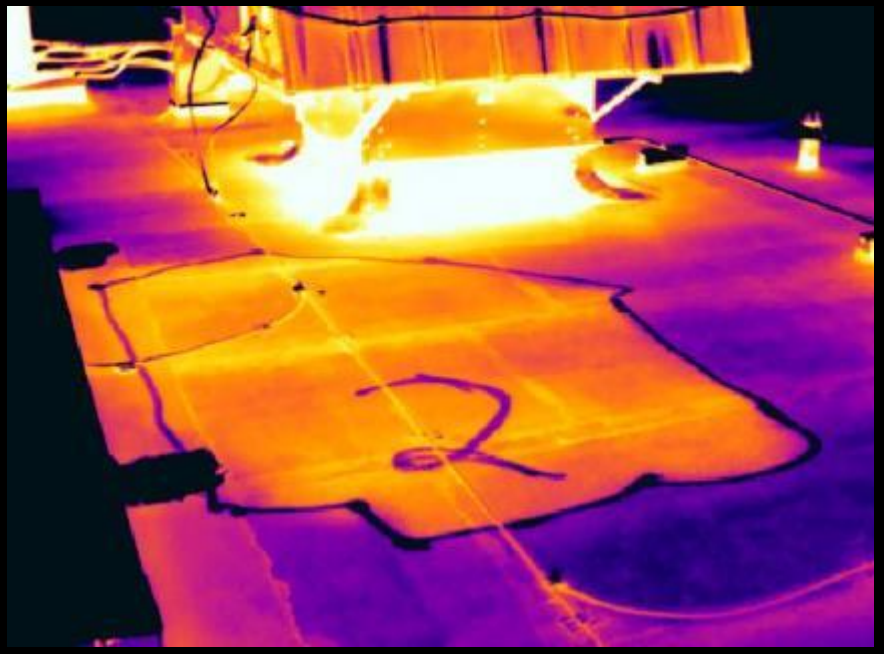


Under-Roof Moisture Surveying



On-Roof Moisture Surveying

Areas of suspect subsurface moisture are marked directly on the roof.

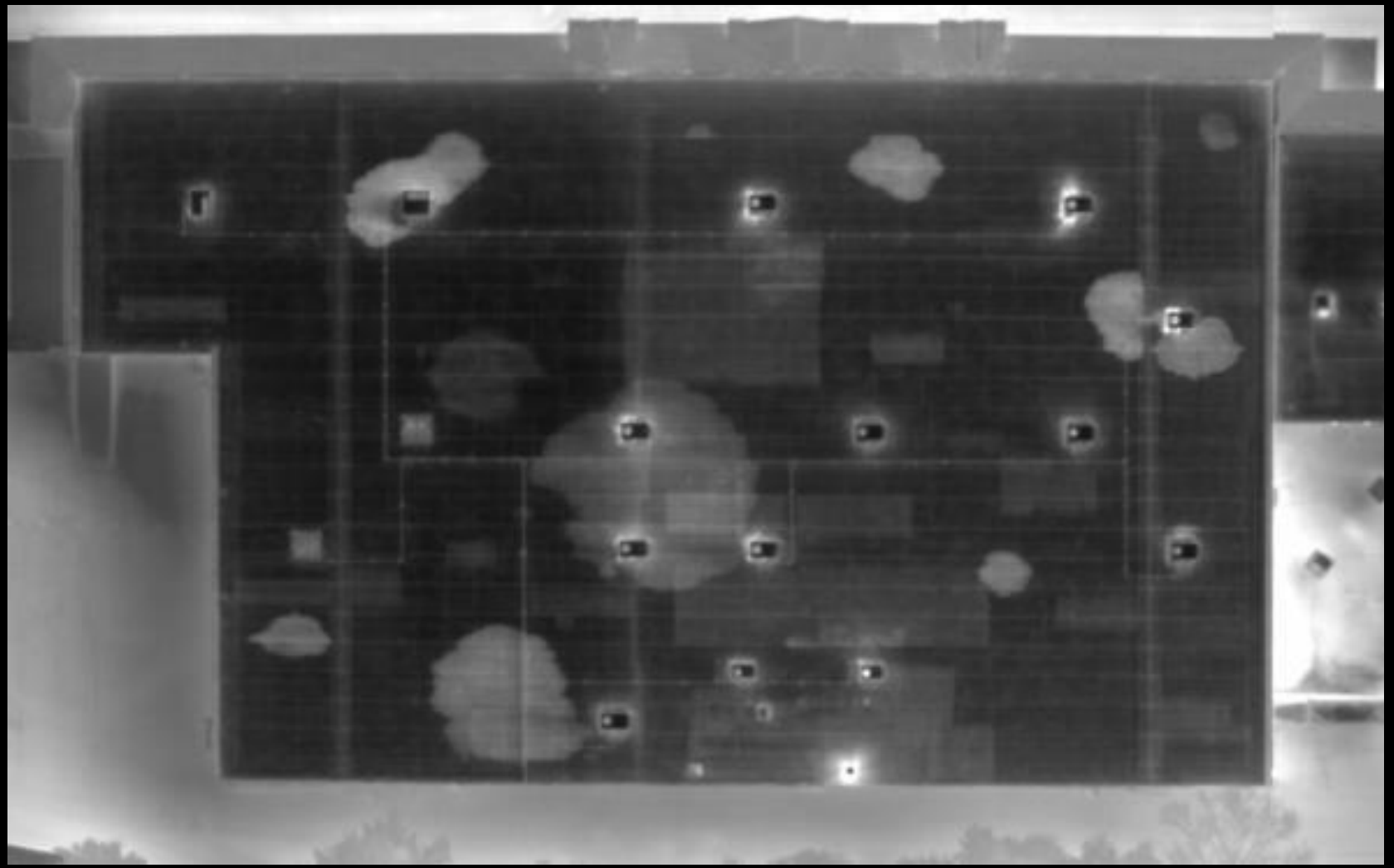


On-Roof Moisture Surveying

Elevated Roof Moisture Surveying

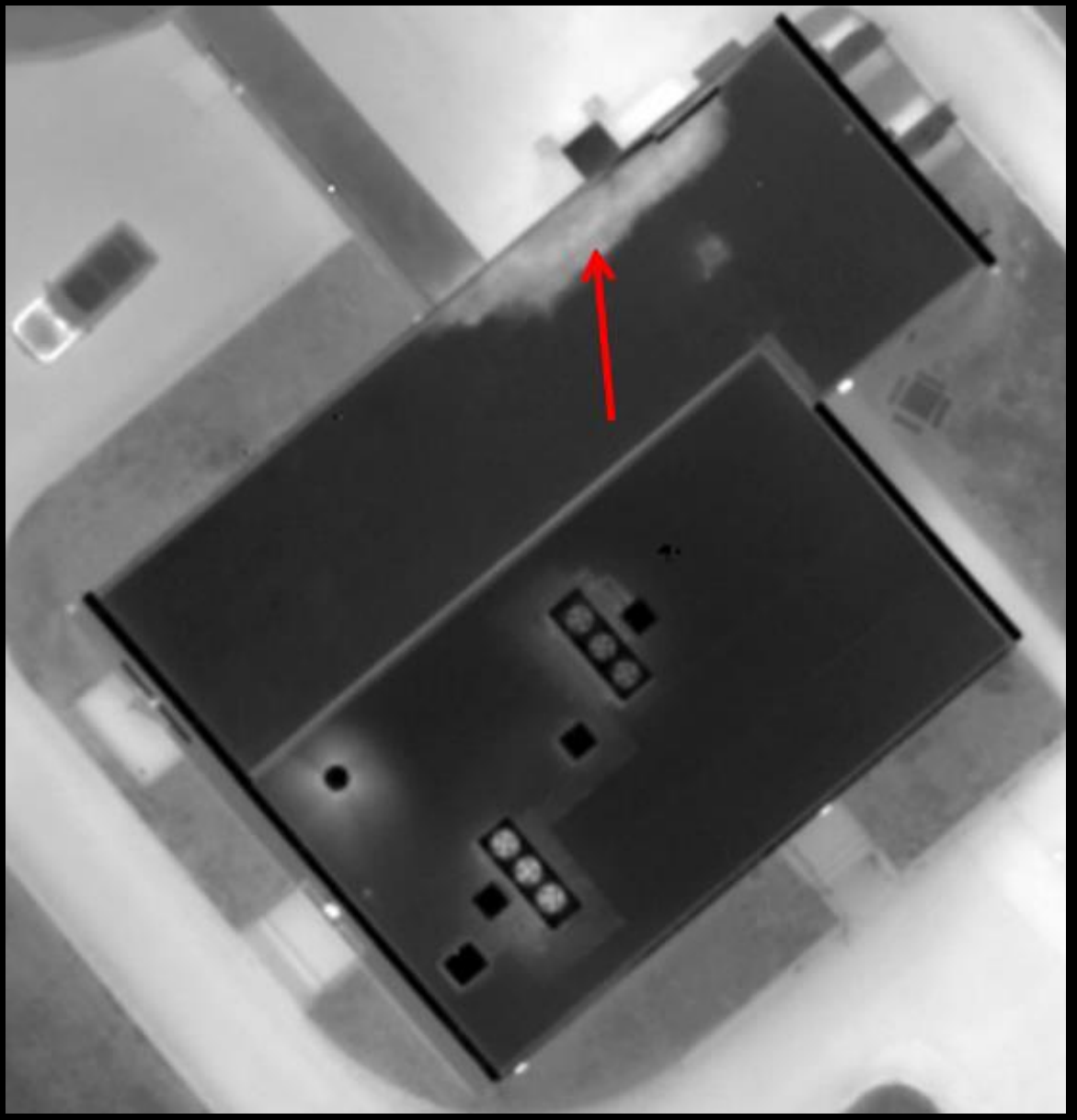
Aerial Roof Moisture Surveying

Aerial Roof Moisture Surveying



GRE = **Ground Resolution Element**

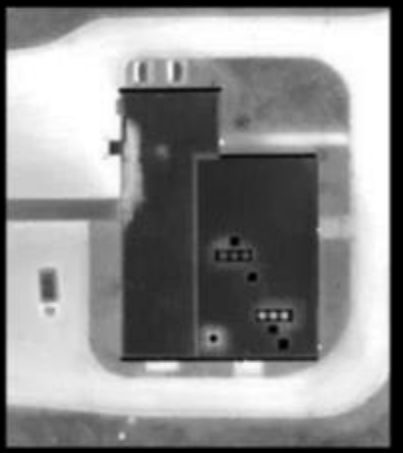
The size of one pixel on the ground.



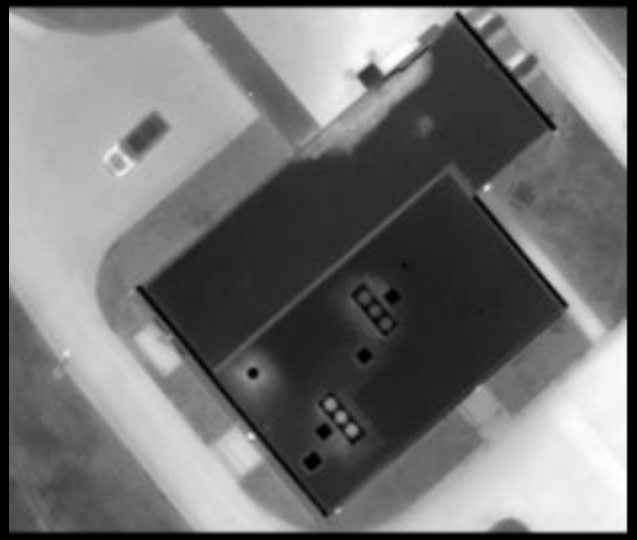
Aerial Roof Moisture Surveying

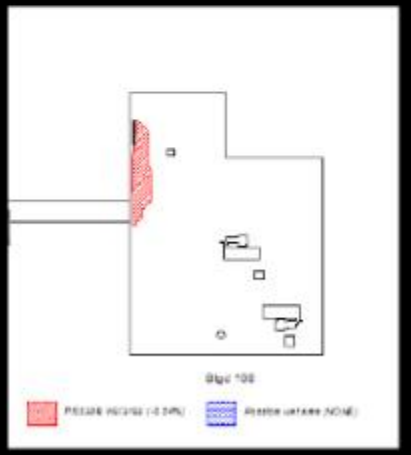
Aerial Reporting

PHOTOGRAPH



THERMOGRAPH





CAD DRAWING

CAD OVERLAY

Aerial Roof Moisture Surveying

Questions

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About the Presenter

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President of Stockton Infrared Thermographic Services, Inc.
President of United Infrared, Inc.

Greg has been a practicing infrared thermographer since 1989. He is a Level III Certified Infrared Thermographer with thirty years experience in infrared thermography, specializing in construction testing, maintenance and energy-related technologies.

Mr. Stockton has published 20 technical papers on the subject of IR thermography and written numerous articles about applications for infrared thermography in trade publications. He is a member of the Program Committee of Thermosense at the SPIE's (Society of Photo-Optical Instrumentation Engineers) Defense and Security Symposium, was the 2012-2013 Chairman of Thermosense, and has many times been the Chairman of the Buildings & Infrastructures Session. Mr. Stockton is also the co-chair of Thermal Imaging Conference, the annual United Infrared user's conference.

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