AFCCE Lunch, February 19, 2021

- sUAS and Infrared Imaging
- Practical Applications for Broadcast Engineers
- Paul Shulins, President, Shulins' Solutions

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Who Discovered Infrared Radiation?

- William Herschel in 1800.
- Scientist, Astronomer, and Composer.
- Used sunlight & a prism.
- Different colors = different temperatures.
- Red light was warmest, area beyond even hotter.

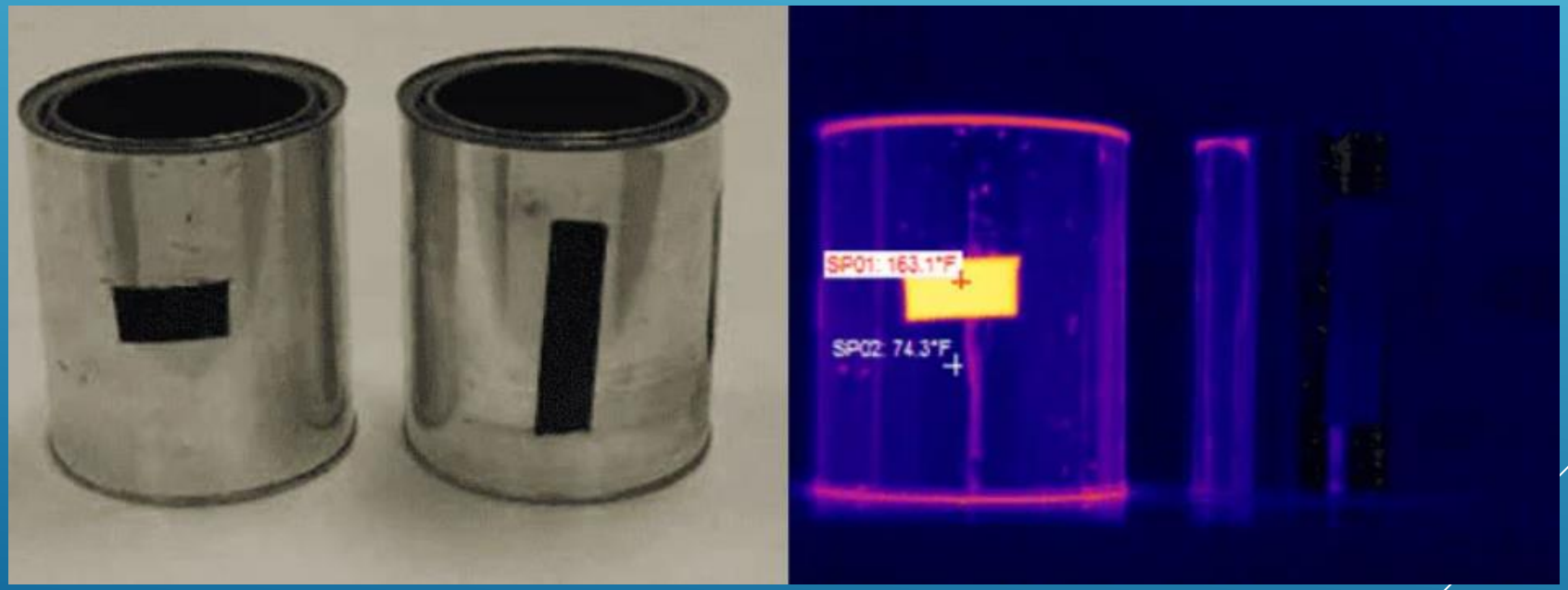
Emissivity

Emissivity *is a measure of how efficiently an object radiates heat, i.e., how well the surface of an object "tells the truth" about its temperature.*

- Emissivity values range from 0 (a theoretically perfect mirror that reflects all energy) to 1 (a theoretical object called a blackbody that perfectly absorbs and radiates all energy).
- In general, if the emissivity of the target you are trying to measure is below 0.5, you are unlikely to be able to get an accurate temperature measurement. In these cases, you may need to consider finding ways to increase your target's emissivity. Emissivity is one of the more challenging factors you need to be aware of when taking temperature measurements. However, it can be understood and with the right techniques it can be correctly compensated for.

Emissivity

High-emissivity surfaces like electrical tape can be used to accurately measure the temperature of low-emissivity surfaces like shiny metal.



Samples of emissivity values for various materials:

Copper: polished	**0.05**
Copper: oxidized	**0.65**
Enamel: lacquer	0.90
Fabric: Hessian, green	0.88
Fabric: Hessian, uncoloured	0.87
Fibreglass	0.75
Fibre board: porous, untreated	0.85
Fibre board: hard, untreated	0.85
Filler: white	0.88
Firebrick	0.68
Food & Organic Materials	0.95 - 0.97
Formica	0.94
Galvanized Pipe	0.46

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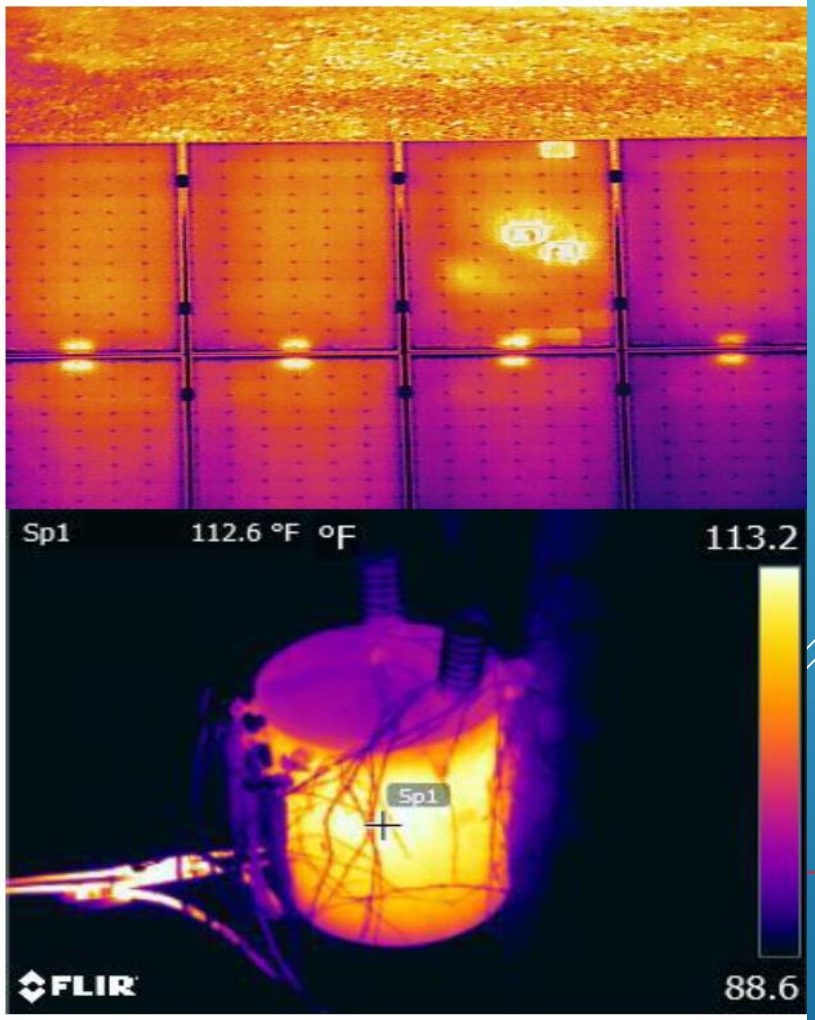
Qualitative vs. Quantitative Thermography

- **Qualitative**-using your background, knowledge and experience to interpret the patterns in the image. Solar panel defects only require identifying the thermal anomaly

- **Quantitative**-measuring temperatures and reporting conditions that may indicate overheating of the components.



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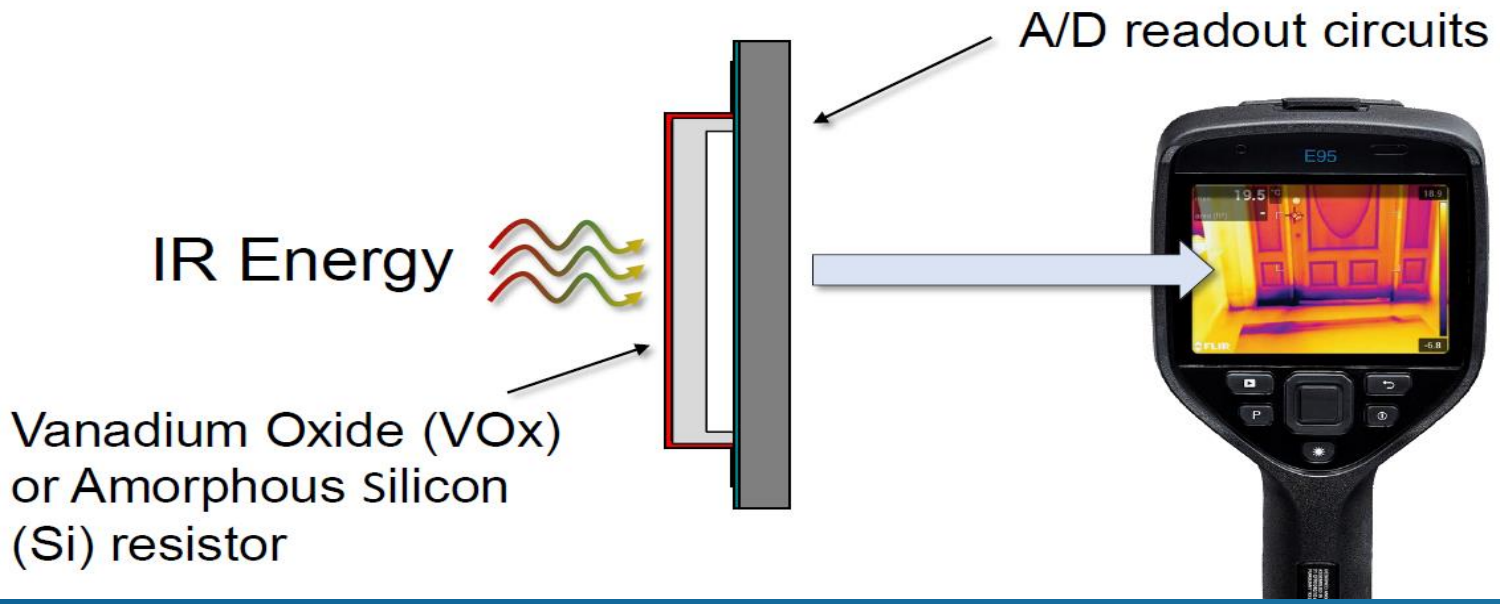
Thermal Detector

- When infrared energy strikes the detector material it heats it, which changes its electrical resistance.
- This resistance change is measured and processed into digital signals which can be used to create an image.



Applications for sUAS In broadcast Engineering

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- Primary use cases for sUAS in broadcast engineering:
- Visual Tower Inspections
- IR Scans for heating
- RF Signal Measurements
- Thermal imaging of AC power panels

Why Utilize Infrared Imaging?

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- IR Imaging allows us to detect electromagnetic radiation that is not readily visible in a traditional photograph
- IR Imaging gives us a 6th sense of what is occurring in and around our electrical / RF systems
- Applications:
- Tower Transmission lines
- Broadcast Antennas
- RF Patch Panels
- RF Combiner Modules
- RF Switches
- Electrical AC Power Panels

What is an sUAS?

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- Defined as a Small Unmanned Aircraft System
- Consisting of an unmanned Aircraft
- Weighing <55 pounds (25 kilograms)
- A sUAS includes the UAV (aerial vehicle) and the system on the ground connecting the operator to the UAV
- The sUAS also includes the operator on the ground.

Using sUAS (Drones) and IR Imaging

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- Small aircraft allow us to inspect areas on a broadcast tower that are not easily accessible
- Safer and less expensive than a tower crew
- Ability to fly in a wide range of weather conditions
- Ability to fly on short notice
- Ability to provide views from above the tower looking down

Using sUAS (Drones) and IR Imaging

- Practical and regulatory operational considerations:
- Requires Part 107 Pilot to operate the drone
- Requires second person as qualified spotter
- Most often requires FAA and local approvals to fly above 400’ AGL
- Liability Insurance
- Hull Insurance

Using sUAS (Drones) and IR Imaging

- Flight Conditions:
- Requires wind speeds within tolerance *(varies with equipment and the skill of the pilot)*.
- Requires ceiling and visibility clearance.
- Ideal to fly at dusk or dawn to minimize solar loading.
- Flight should take place when all stations are operational for thermal measurements.

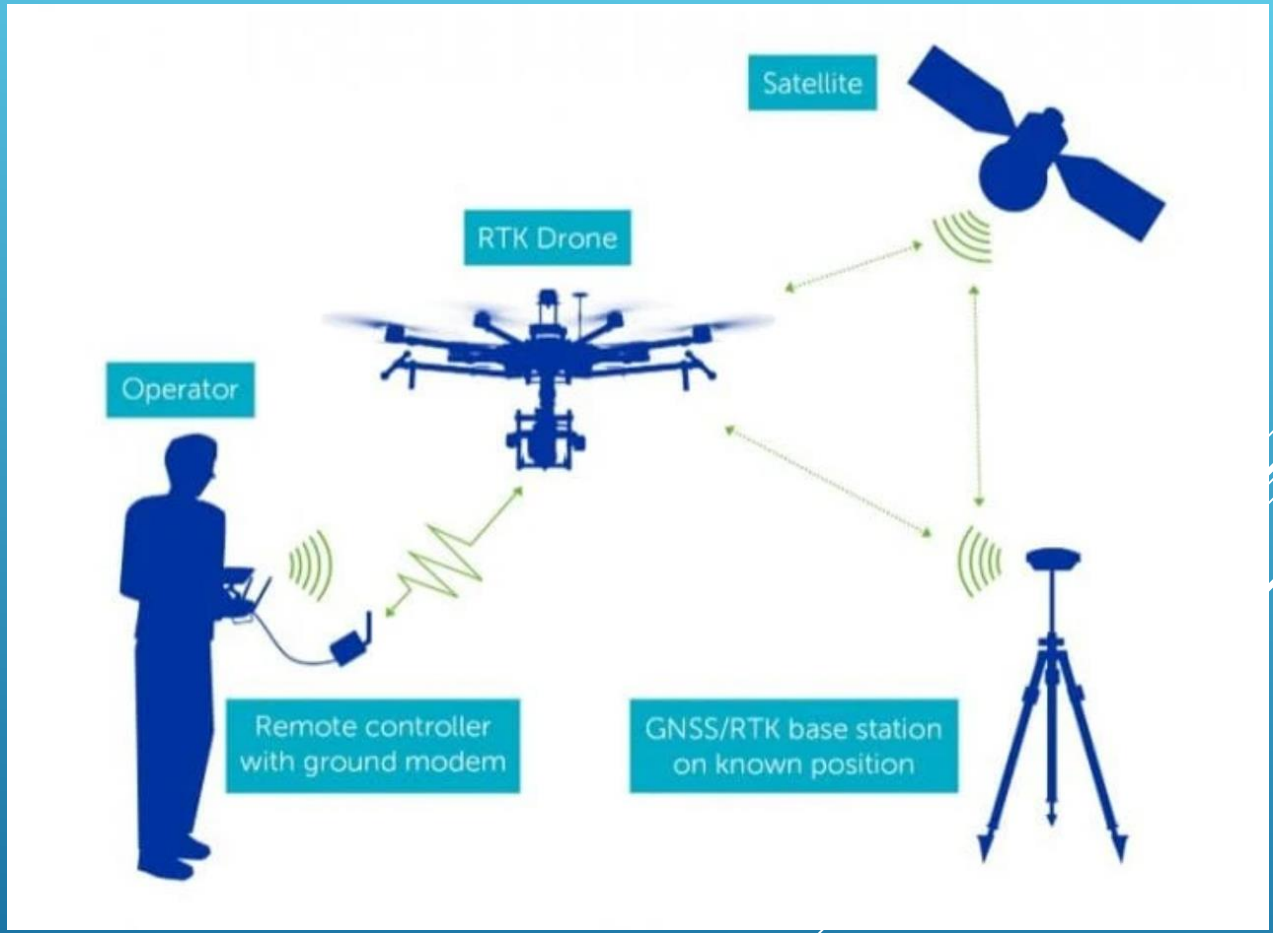
Using sUAS (Drones) and IR Imaging

- RF Interference cautions:
- Use RTK Technology whenever possible
- Fly as far from the radiating elements as possible to still obtain useful resolution
- Choose an appropriate focal length lens for the camera
- Use caution for guy wires and other obstacles
- Never fly over people or animals

RTK EXPLAINED

What is RTK?

Real-time kinematic (**RTK**) positioning is a satellite navigation technique used to enhance the precision of position data derived from satellite-based positioning systems (global navigation satellite systems, GNSS) such as GPS, BeiDou, GLONASS, Galileo and NavIC.



Using sUAS (Drones) and IR Imaging

- RTK Technology benefits:
- Pinpoint Accuracy
- Less concern about winds
- Brings the electronic compass away from the RF aircraft and RF sources
- You always know the exact position resulting and accurate hoovering and positive control even in gusty conditions

Using sUAS (Drones) and IR Imaging

- RTK Mobile Station
- Provides real-time differential GPS Data
- Results in centimeter positioning accuracy
- Includes high gain antenna
- Supports GPS, GLONASS, Beidou, and GALILEO GPS signals

Using sUAS (Drones) and IR Imaging

- Challenges and limitations of an uncontrolled environment:
- Meaningless to specify or compare precise temperatures!
- Wind is our enemy; it is by far the largest variable in measuring temperatures on a tower.
- ***A 3 Mph wind can cut the temperature reading in half!***
- The Value of thermal imaging for towers is to detect uneven or unexpected energy loss and not so much the absolute value of those readings
- Angle of image acquisition is critical and requires an angle >60 degrees.
- The emissivity of different components will produce dramatically different thermal indications. It is important to identify labels and other surface material differences to avoid misinterpretation of the data.

The importance of Spot Size Ratio

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- Spot size ratio is the ratio of the distance from the camera to the target, compared to the size of the target.
- Example: An sUAS with a camera with a 13mm lens, will cover 12 inches from 155 feet distant.

Lens	9mm	13mm	19mm	25mm
IFOV	1.889	1.308	0.895	0.680
SSR	107:1	155:1	227:1	299:1

DJI MATRICE 210 RTK

Using sUAS (Drones) and IR Imaging

- FLIR XT-2 Camera with 19mm IR lens and 4K RGB Imaging
- 640 x 480 resolution
- 30 FPS Frame rate
- Calculate spot image size based on the sensor size, lens focal length, distance from target, and required resolution

Using sUAS (Drones) and IR Imaging

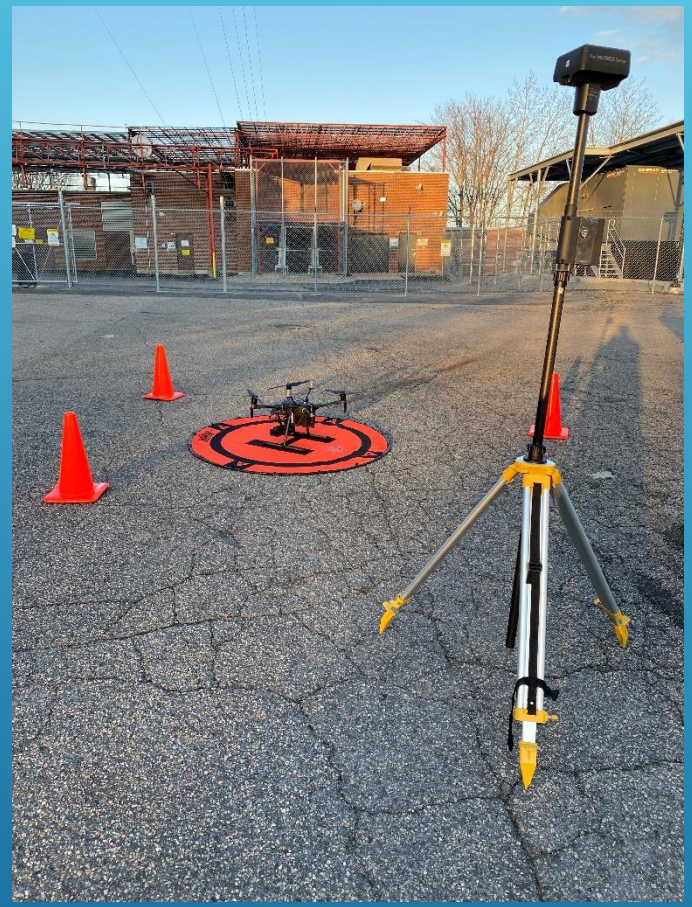
- DJI Zenmuse Z30 Camera (RGB Imaging)
- 640 x 480 resolution
- 30 X Optical Zoom
- 6X Digital Zoom
- 2.13 MP sensor

Using sUAS (Drones) and IR Imaging

- Cendence Controller
- Crystal Sky Display
- Discrete batteries
- Sunlight readable touch screen display

Using sUAS (Drones) and IR Imaging

Typical Flight Deck:



Using sUAS (Drones) and IR Imaging

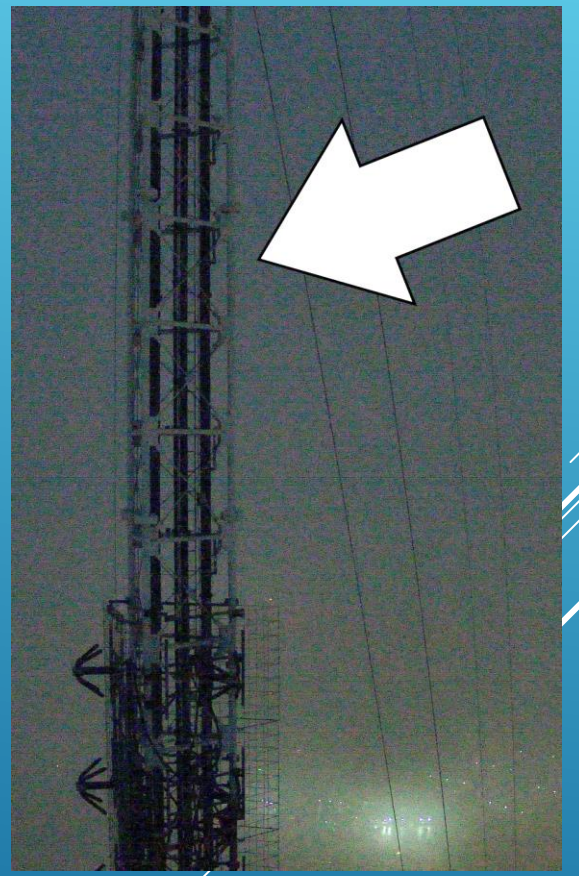
Cellular Array at 150’AGL

Using sUAS (Drones) and IR Imaging

8” Energized Transmission Lines

Using sUAS (Drones) and IR Imaging

A disaster waiting to occur

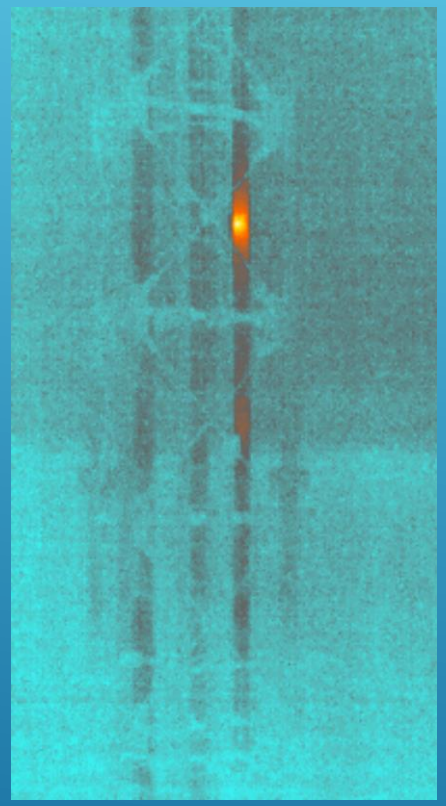


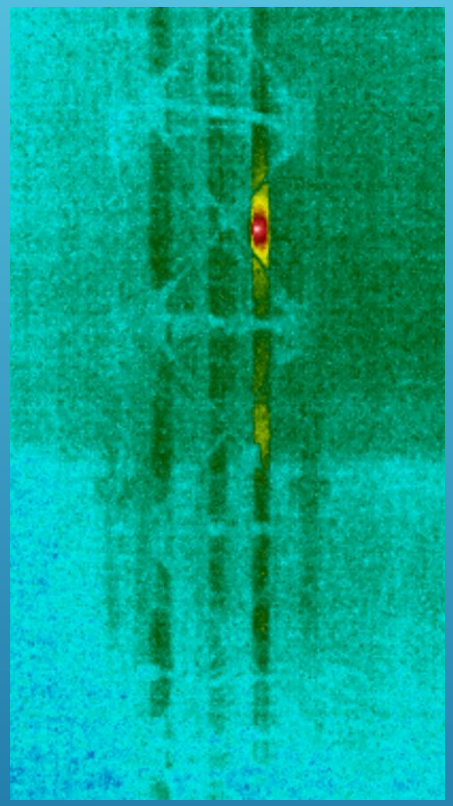
And it did!

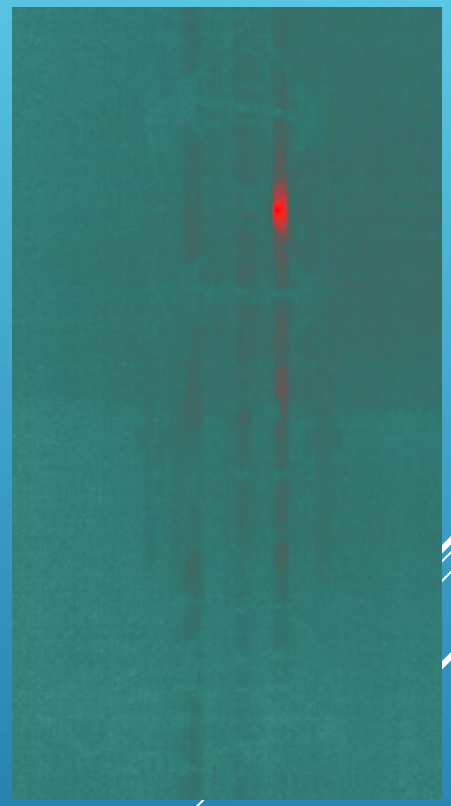
Using sUAS (Drones) and IR Imaging

Different color palettes applied in post processing can help to identify areas of uneven heating

1. There are no right or wrong choices for color palette selections
2. Some palettes are more effective for certain applications
3. Palettes can provide apparent contrast depending on the colors used
4. Specific color palettes allow problems to really stand out.







Focus, Range, Distance (FORD)

Requirements for image capture:

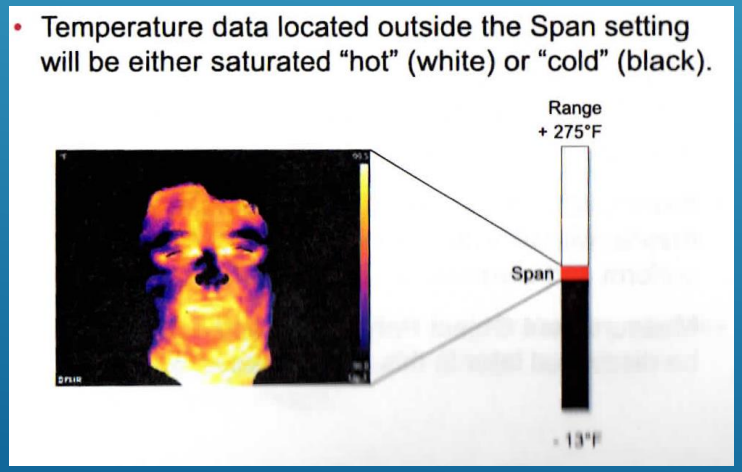
1. The thermogram must be in focus
2. It must be taken in the correct temperature range
3. You must be close enough to the target you are attempting to evaluate
4. These parameters cannot be corrected in post processing, so it is critical to get it right while acquiring the images

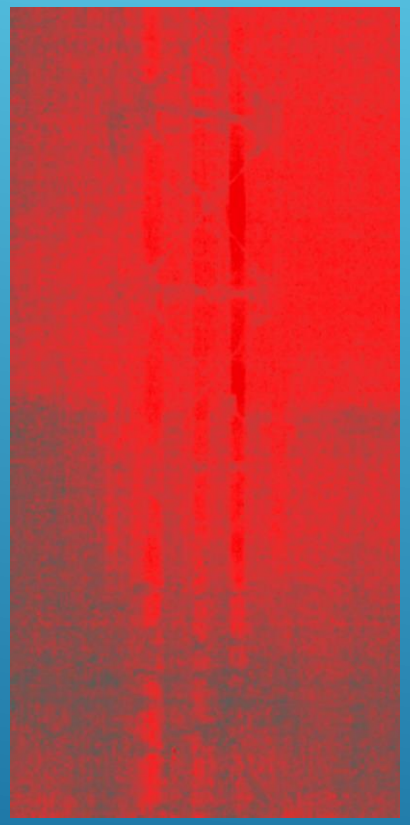
The importance of proper image focus

- Challenges to focus:
- Current sUAS cameras employ fixed focus lenses but focus can be degraded by:
- Flying too high
- Flying too fast
- Yawing aggressively
- Gimbal stabilization issues
- Humidity

Using sUAS (Drones) and IR Imaging

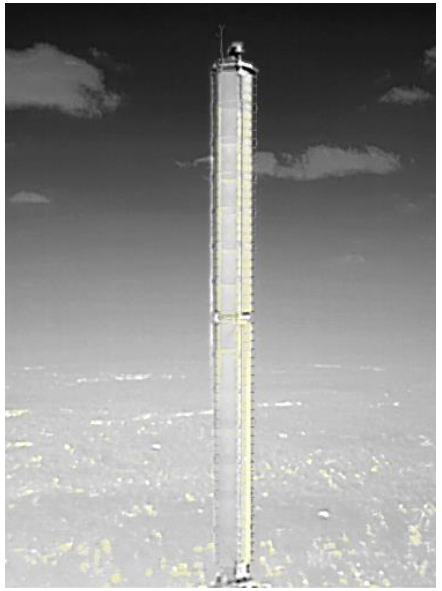
Adjusting the span in FLIR Tools software allows us to ignore the thermal ranges that are not relevant (i.e., the sky background), and we can stretch the image to reveal more detail in the areas that we are interested in. In this case it is the transmission line.





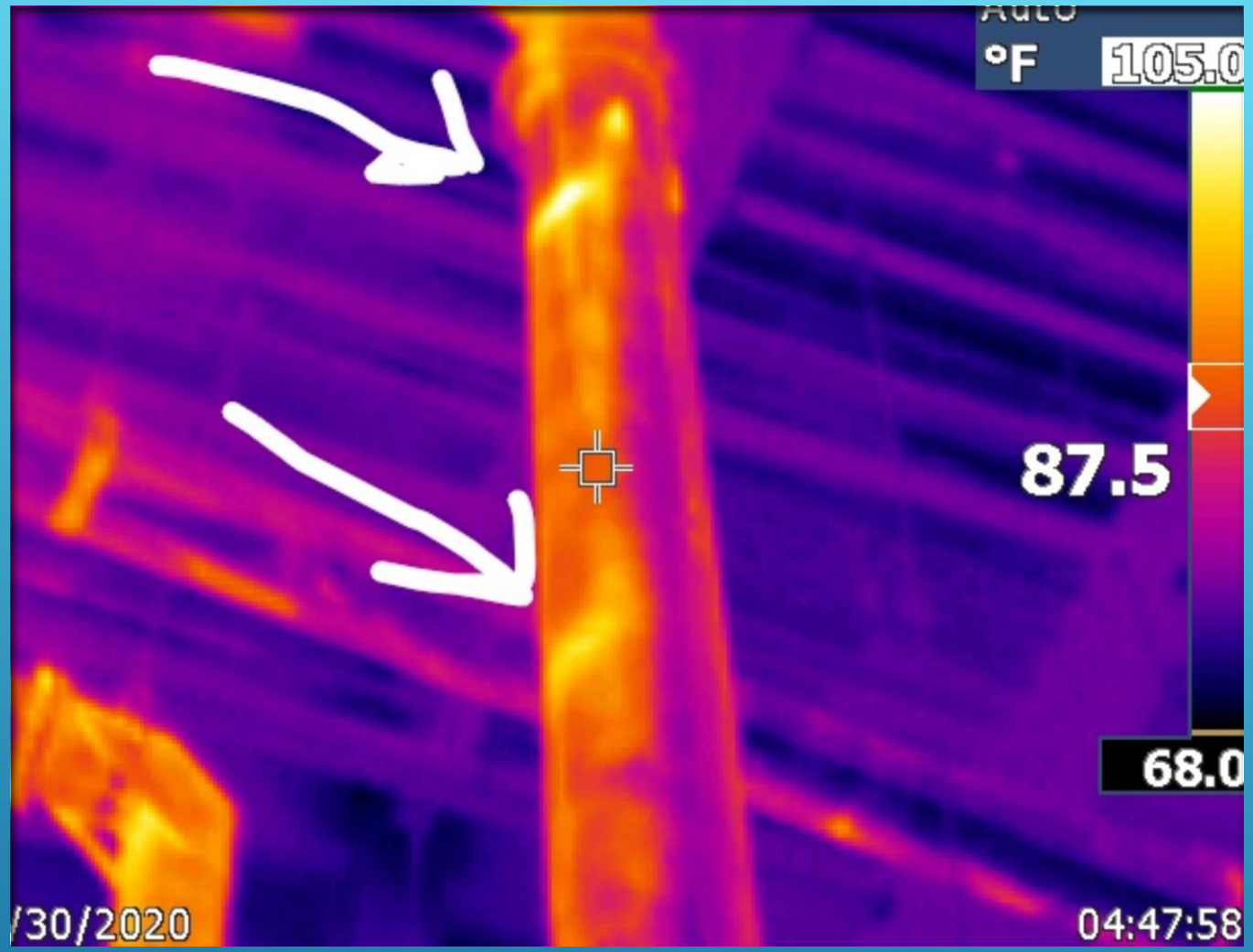
No Stretch

Stretch



- Power dividers behind the radomes are visible
- The manufacturer of the antenna can verify the power divider locations and supply an opinion on the thermal signature as to whether it is normal or not.

4K RGB IMAGE AND RADIOMETRIC IMAGE



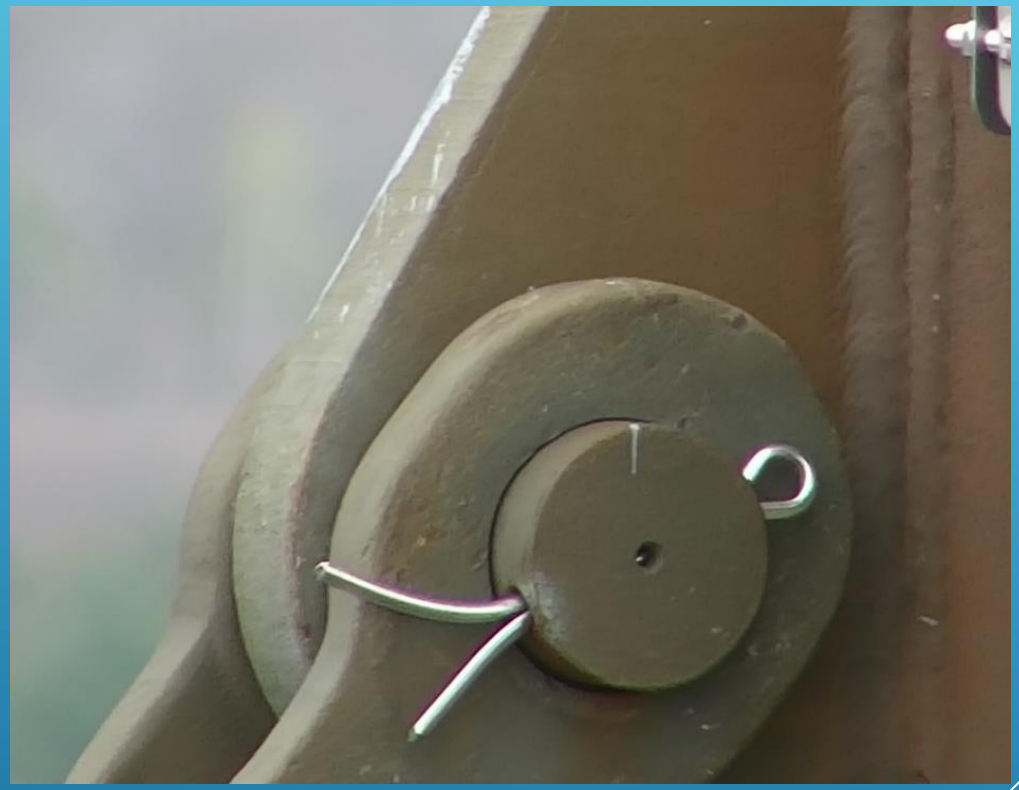
HANDHELD CAMERA EXAMPLE

INDOOR TARGET (8" VERTICAL TRANSMISSION LINE)

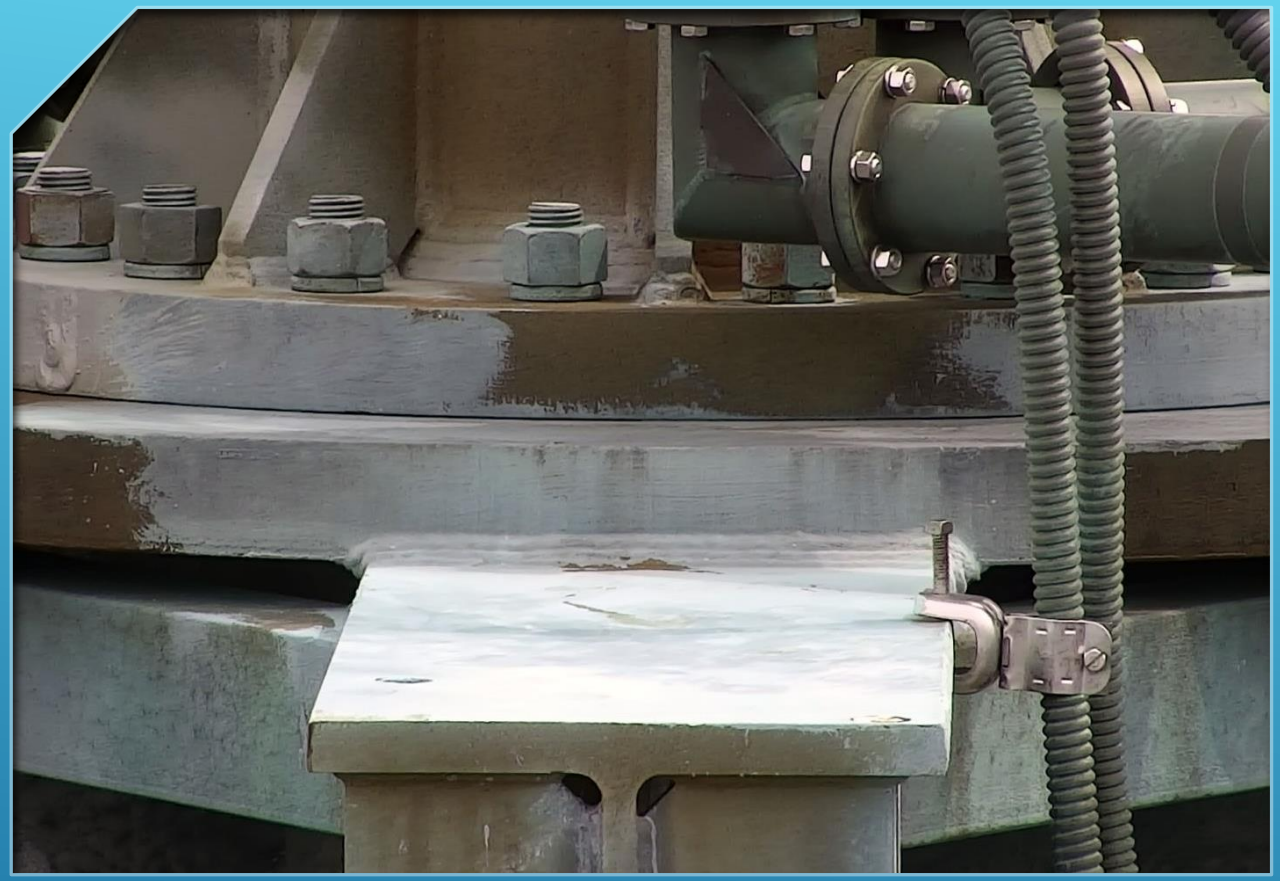
- Optimum time to shoot tower IR just after sunset
- Still daylight FAA Rules
- Safe to see tower and maintain safe clearances
- Sun 4-8 degrees below the horizon, so no solar loading

4K RGB IMAGE AND RADIOMETRIC IMAGE

- Optical zoom along with gyroscopic stabilization allows for detailed inspections while staying a safe distance from the tower and radiating elements of the antenna.



RGB TOWER INSPECTIONS USING THE Z-30 CAMERA

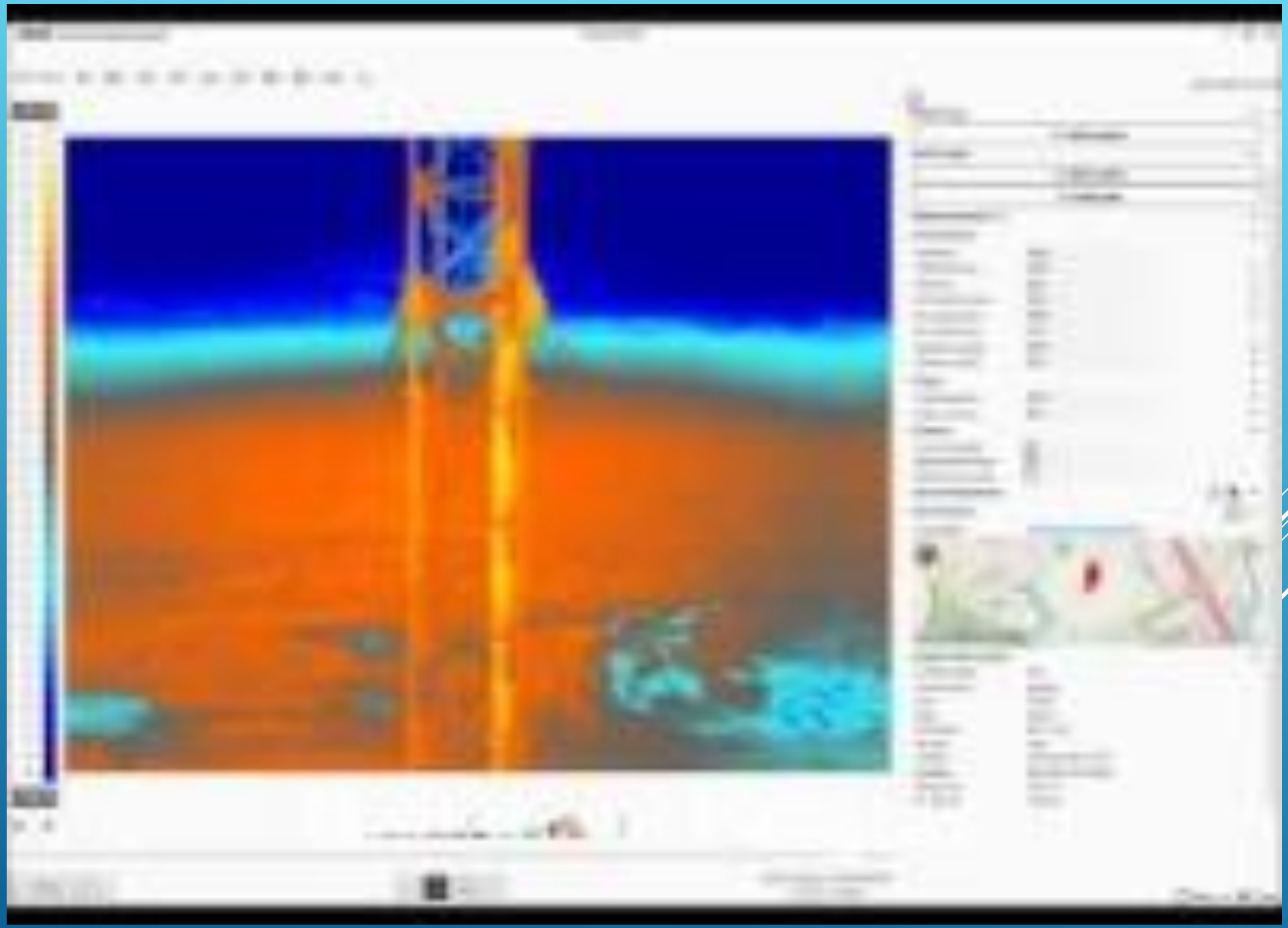


RGB TOWER INSPECTIONS USING THE Z-30 CAMERA

RGB TOWER INSPECTIONS USING THE Z-30 CAMERA

VISUAL TOWER SCAN

IR TOWER SCAN



Conclusions

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- Drones can be used in many cases to perform visual, and IR imaging of broadcast towers and antennas
- Proper certification for piloting the drone is required
- Proper Airspace authorizations are required
- Interpreting IR imaging requires an understanding of how heat transfer occurs, and how IR cameras detect electromagnetic radiation in the IR spectrum
- Drones can also provide a unique platform for RF signal measurements
- Utilizing drones for intermediate tower inspections will enhance safety and lower inspection costs

Thanks to:

Shulins' Solutions

- FLIR
- William Schwahn, Level three Thermographer, Instructor
- Infrared Training Center
- Florida Drone Supply
- James Stenberg, American Tower Corporation

- Questions?