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sUAS (Small Unmanned Aircraft Systems) and Infrared Imaging:

Practical Applications for Broadcast Engineering

Paul Shulins
President,
Shulins' Solutions

Introduction to Shulins' Solutions

- Provides unique monitor, control and protection solutions for transmission sites, drone-based tower inspections and a full range of consulting services based on years of practical experience on the ground building and operating broadcast facilities.
- Solves problems with an attention to detail that only comes from firsthand experience in the field. All of our products and services come from the point of view of the user, and are crafted with the passion of a lifelong broadcaster.

Paul Shulins - President and CTO

RF System Monitoring

Stellar Eclipse broadcast site monitoring platform provides a systems approach to monitoring and protection of RF systems from simple to complex featuring the exclusive VSWR Sentinel protection technology.

sUAS Drone Inspections

sUAS Drone based tower structure visual and infra-red surveys provide an indispensable tool to diagnose the health of RF systems and tower structures without the risk of climbing the towers.

Broadcast Technology

Consulting to meet the demands of broadcasters specializing in remote control solutions, studio design and construction, antenna protection systems and ratings metrics.

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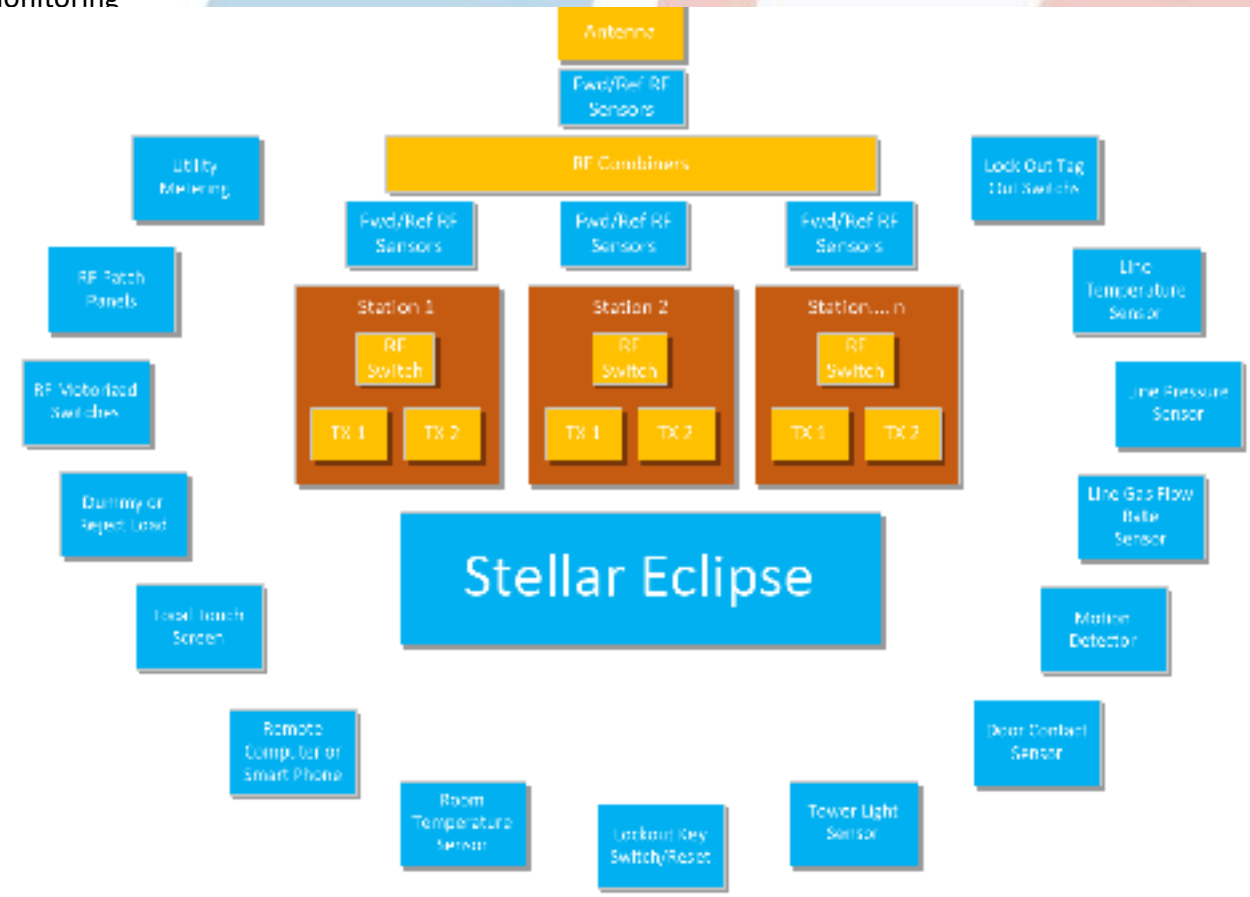
IEEE Broadcast Technology Symposium!

- Returns to Washington DC on November 14-15
- NAB Headquarters in Washington , DC
- Diverse topics by top industry experts
- Radio Engineering/TV Engineering
- Focus on problem sharing solving experiences and leading edge research
- Keynote Speakers include the President Elect of IEEE : Tom Coughlin
- Awards presentations
- Joint AFCCE/BTS Luncheon
- Registration now open: https://bts.ieee.org/broadcastsymposium.html

Stellar Eclipse

- Site Monitoring and VSWR protection for single or multiplexed TV and FM transmission systems
  - Modular design so the system can grow as you do
  - Carefully tracks transmission line gas pressure with options for gas flow rate monitoring
  - Proactively monitors dehydrator/nitrogen prevent costly surprises
  - Flexible Motorized RF switch control and status eliminating extra costs
  - Simple connections for building security, and tower light monitoring
- Comprehensive VSWR Sentinel
  - Opens transmitter interlocks within 100 milliseconds detected above the desired threshold
  - 3 Strikes automatic reset logic included
  - Interlocking of RF patch panels and lockout/tag-out
  - Secure key-switch to lockout RF during tower climbing
- Flexible cloud based remote access
  - Secure SSL and password protected Web Access to real time
  - Limitless user accounts for web data access
  - Secure cloud Based data storage for all parameters
  - Provides alarms via text message and email for any parameters fall out of tolerance
- Proven reliability protects your investment
  - On-the-air protecting hundreds of stations and hundreds of millions of dollars
  - Ideal for new builds or a simple upgrade to existing installations
  - Easy bypass of critical transmitter interlocks for maintenance
  - Fail safe operation keeps your stations on the air during a power loss to the monitoring



Protecting over 70 markets and hundreds of stations in 2021

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The History of IR Science

The Discovery of Infrared Radiation

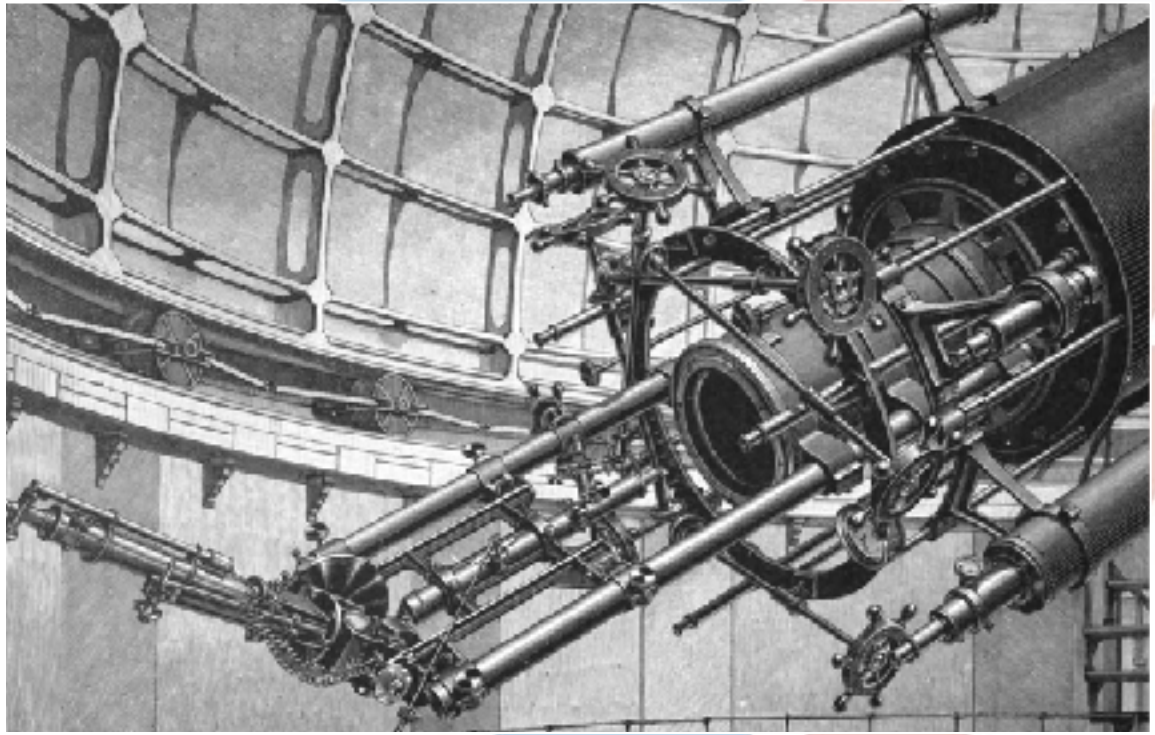
- William Herschel in 1800.
- Scientist, Astronomer, and Composer.
- Used sunlight & a prism.
- Different colors = different temperatures.
- Red light was warmest, area beyond even hotter.

The History of IR Science

Herschel discovered Uranus (7th planet from the sun) in 1781

Uranus

Visual Telescope use to discover Uranus



Early Telescope Spectrometer (late 19th century)

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What is Infrared?

Infrared is classified as electromagnetic radiation longer than visible light generally invisible to the human eye (700 nanometers to 1mm)

However, there is no hard limit to what is visible to the human eye as sensitivity drops off smoothly at 700 nanometers. Sources longer than 700 nm can be seen if sufficiently bright creating a danger to human eyes.

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

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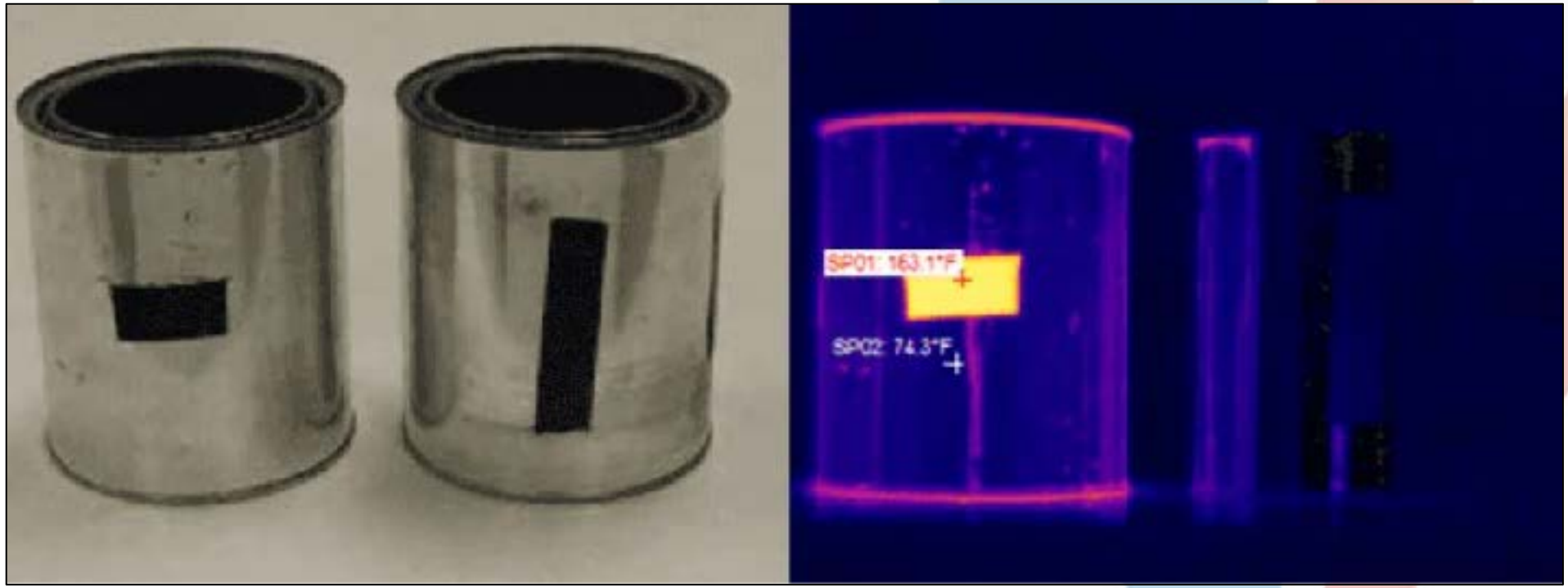
Emissivity

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



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Samples of emissivity 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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Applications for sUAS In broadcast Engineering

- **Qualitative vs Quantitative** Thermography
- Qualitative: Using thermography skills and training to evaluate thermal images. Such examples include solar panels, rooftops, and broadcast transmission lines and antennas.
- Quantitative: Numerical measurement reports using calibrated instruments in a controlled environment that may indicate overheating. Such examples include motors, electrical panels, and human subjects.

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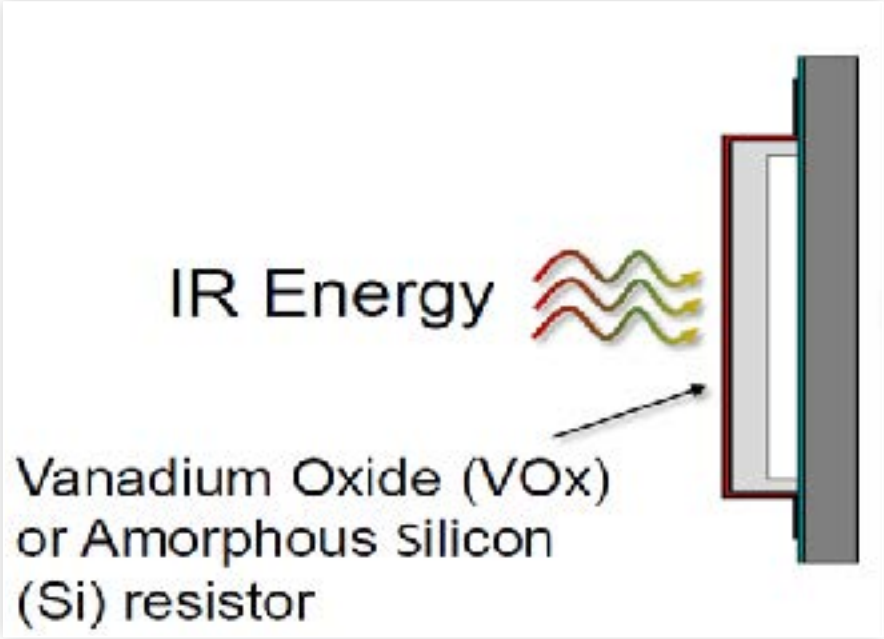
Applications for sUAS In broadcast Engineering

When IR energy strikes the detector, it heats it changing the electrical resistance. These changes in resistance are measured and processed into digital signals used to create an image on the display.



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Applications for sUAS In broadcast Engineering

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

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Why Use IR Imaging?

- 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

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What is an sUAS?

- 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

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Using sUAS (Drones) and IR Imaging

- 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

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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

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What are the FAA's Part 107 Rules?

- A remote pilot certificate is required to operate under part 107 rules
- You must be at least 16 years of age
- Pass an aeronautical knowledge test at an FAA Approved testing center
- Register the drone at: faadronezone.faa.gov (cost $5)
- Engrave or put a permanent label on the drone with the registration number
- Report an incidents or accidents causing more than $500 in damage or serious injury to the FAA within 10 days.

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What are the FAA's Part 107 Rules?

- Keep drone within line of site at all times
- You can only be a visual observer for one drone at a time
- Daylight flights only (30 minutes before sunrise till 30 minutes after sunset)
- Avoid manned aircraft
- You can request a waiver of most restrictions if you can demonstrate that the operation will provide a level of safety equal to the restriction from which the waiver is requested.

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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

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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

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RTK Explained

<u>What is RTK?</u>

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.

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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

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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

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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.

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The importance of Spot Size Ratio

- 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

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DJI Matrice 210 RTK

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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

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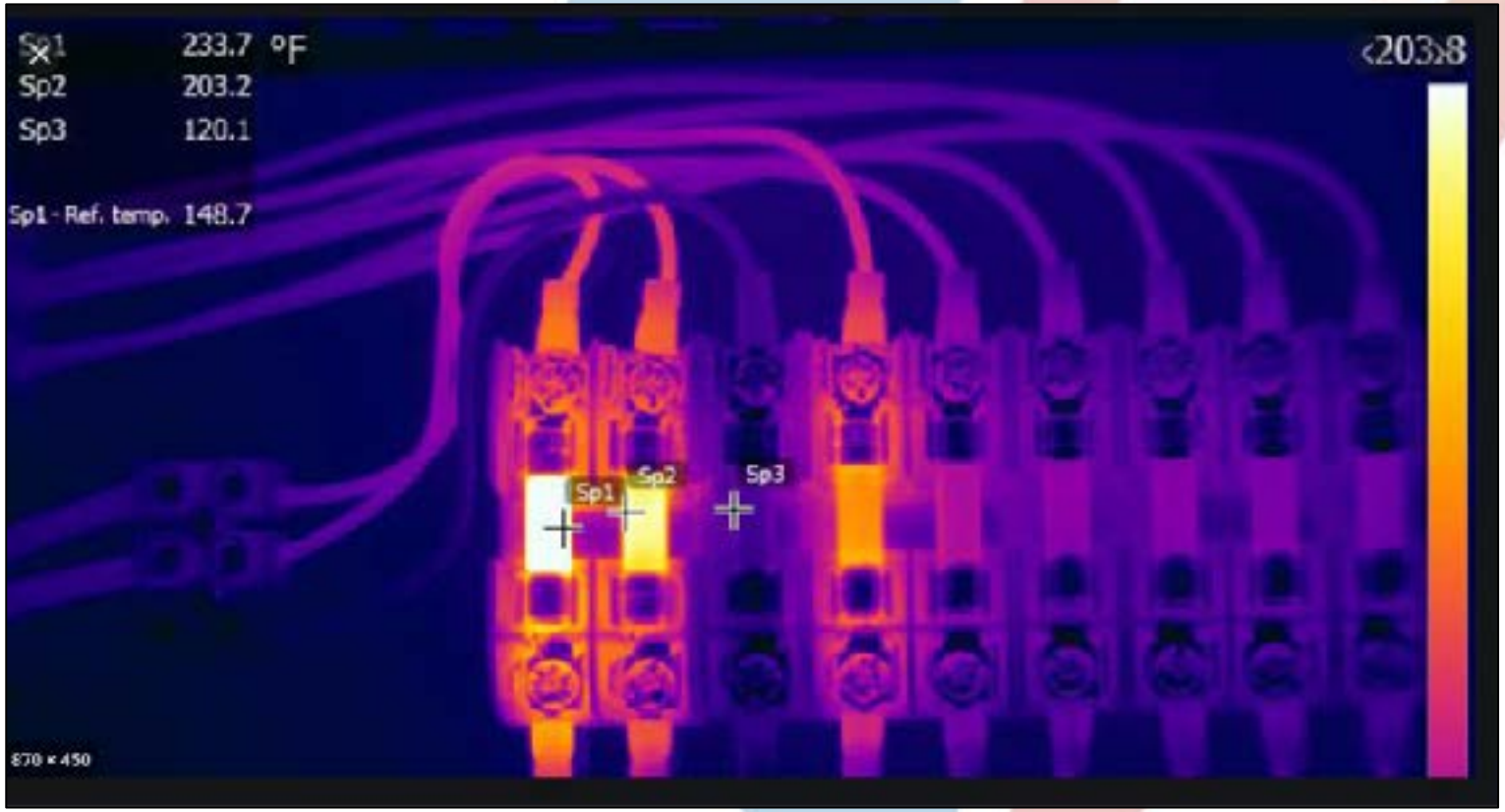
Radiometric Images

- A radiometric image assigns a temperature value to each pixel in the image file.
- Detailed temperature information (users derive temperature information per pixel from objects in the scene)
- Digital data linear in scene temperature (in real-time operation, the pixel values in the digital data correspond to the temperature of the scene)
- Allows for quantitative evaluation of the scene during image post processing (FLIR Tools)



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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

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Using sUAS (Drones) and IR Imaging

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

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Using sUAS (Drones) and IR Imaging

Typical Flight Deck Preparation for Missions:

- Obtain proper clearances for flight and have credentials and paperwork available
- Mark off Landing area with traffic cones
- Use Hard hats and safety vests
- Have emergency phone numbers handy
- Have first aid kit on hand

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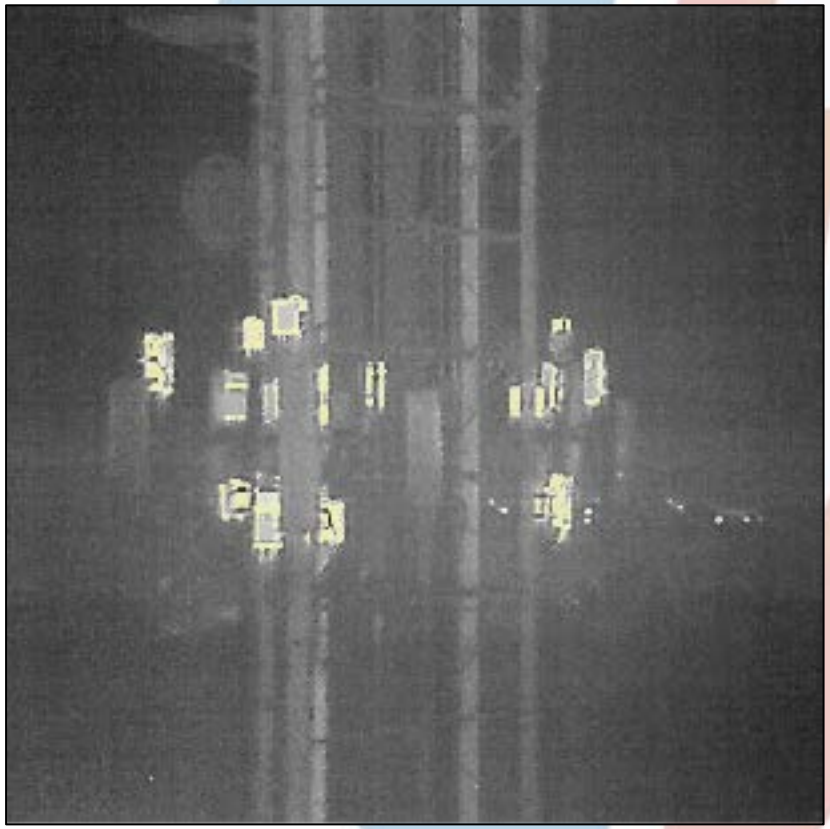
Using sUAS (Drones) and IR Imaging

Cellular Array at 150’AGL



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Using sUAS (Drones) and IR Imaging

8” Energized Transmission Lines

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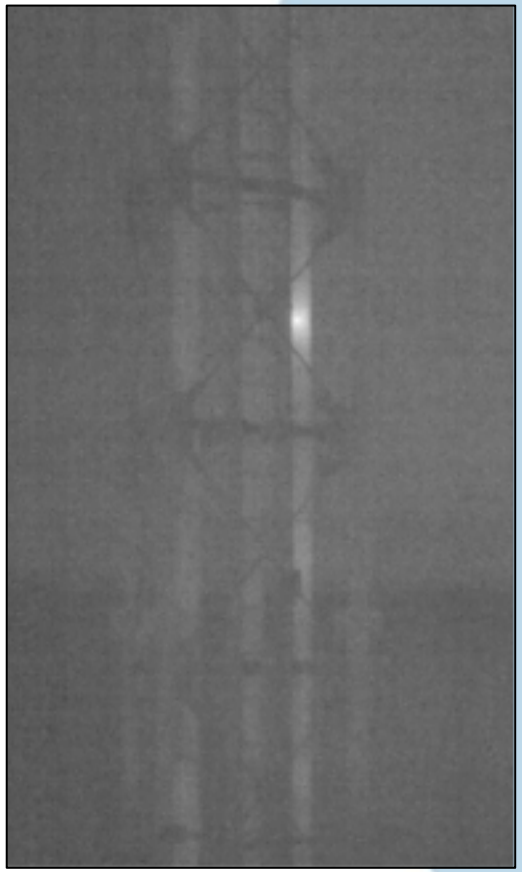
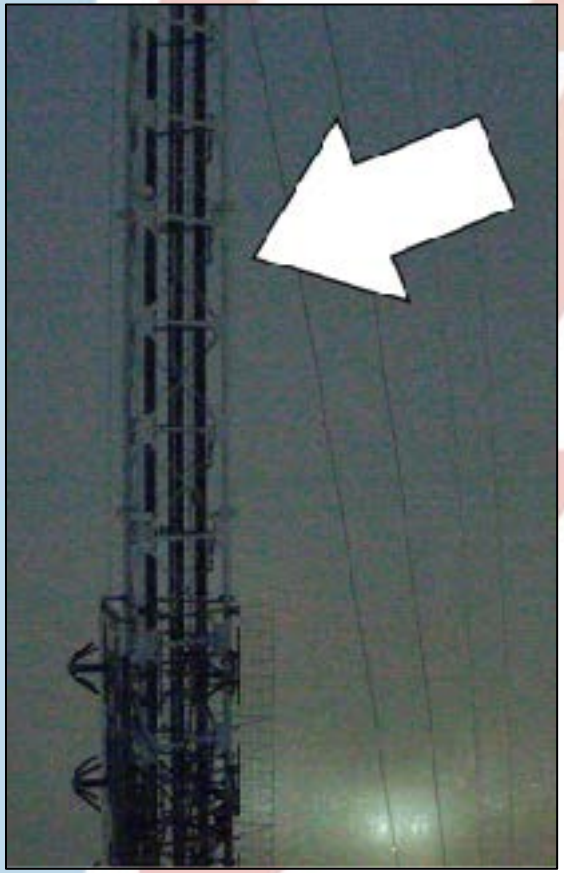
Using sUAS (Drones) and IR Imaging

A disaster waiting to occur





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And it did!

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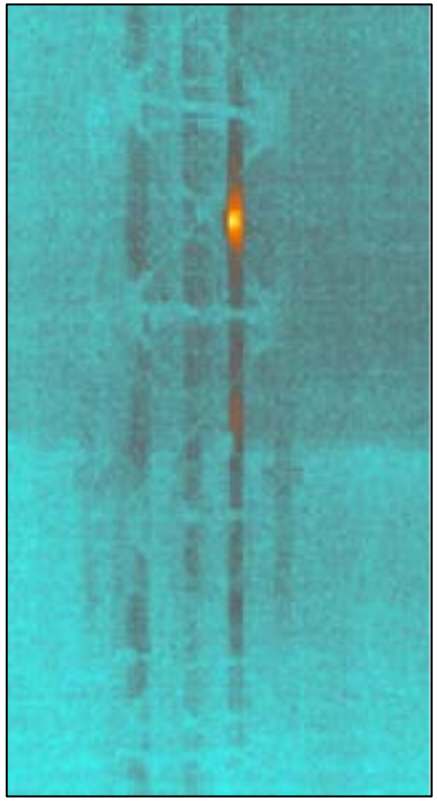
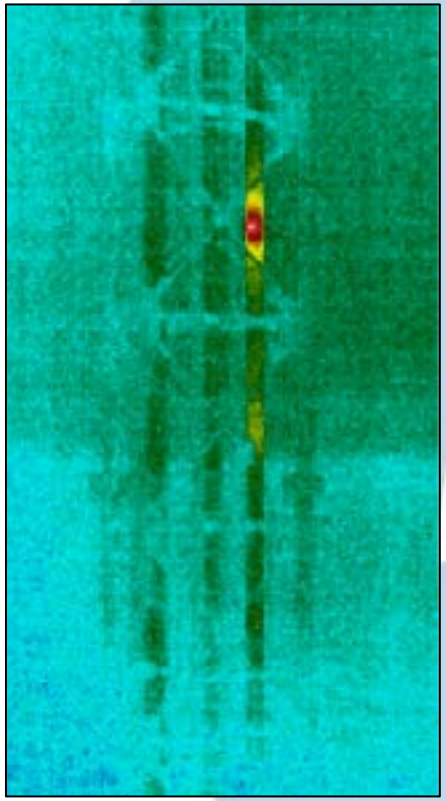
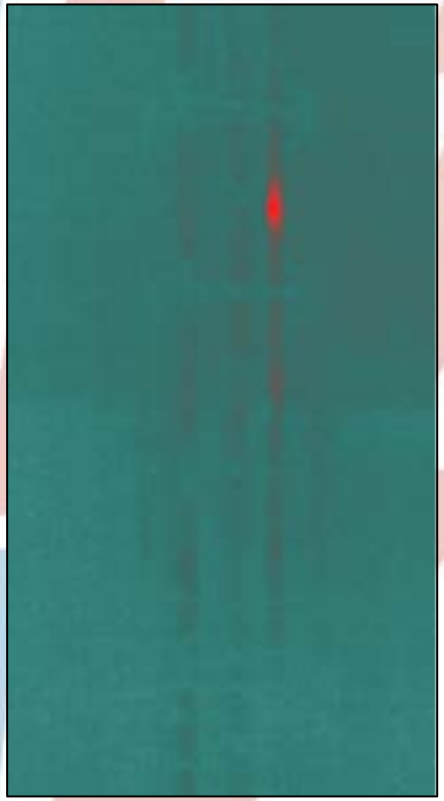
Using sUAS (Drones) and IR Imaging

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.







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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

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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

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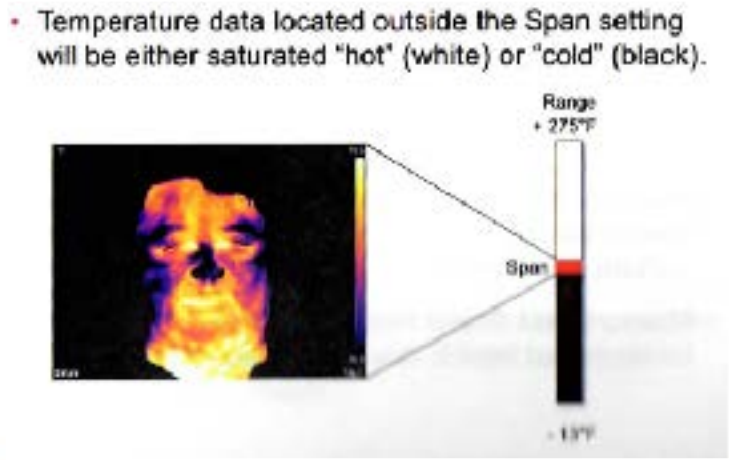
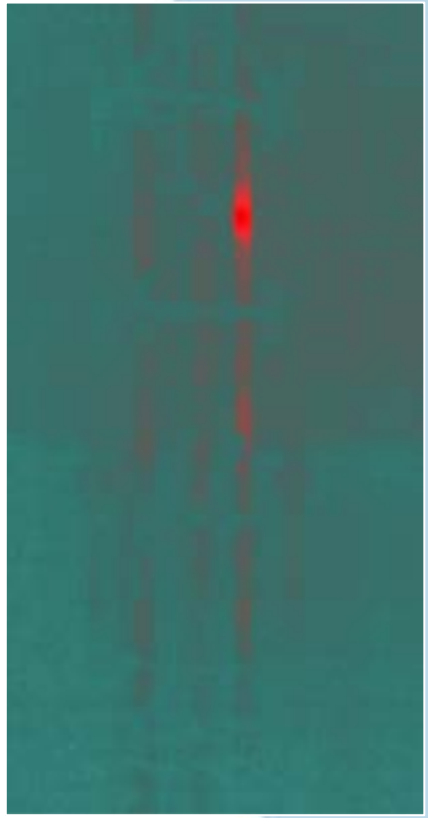
Using sUAS (Drones) and IR Imaging

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

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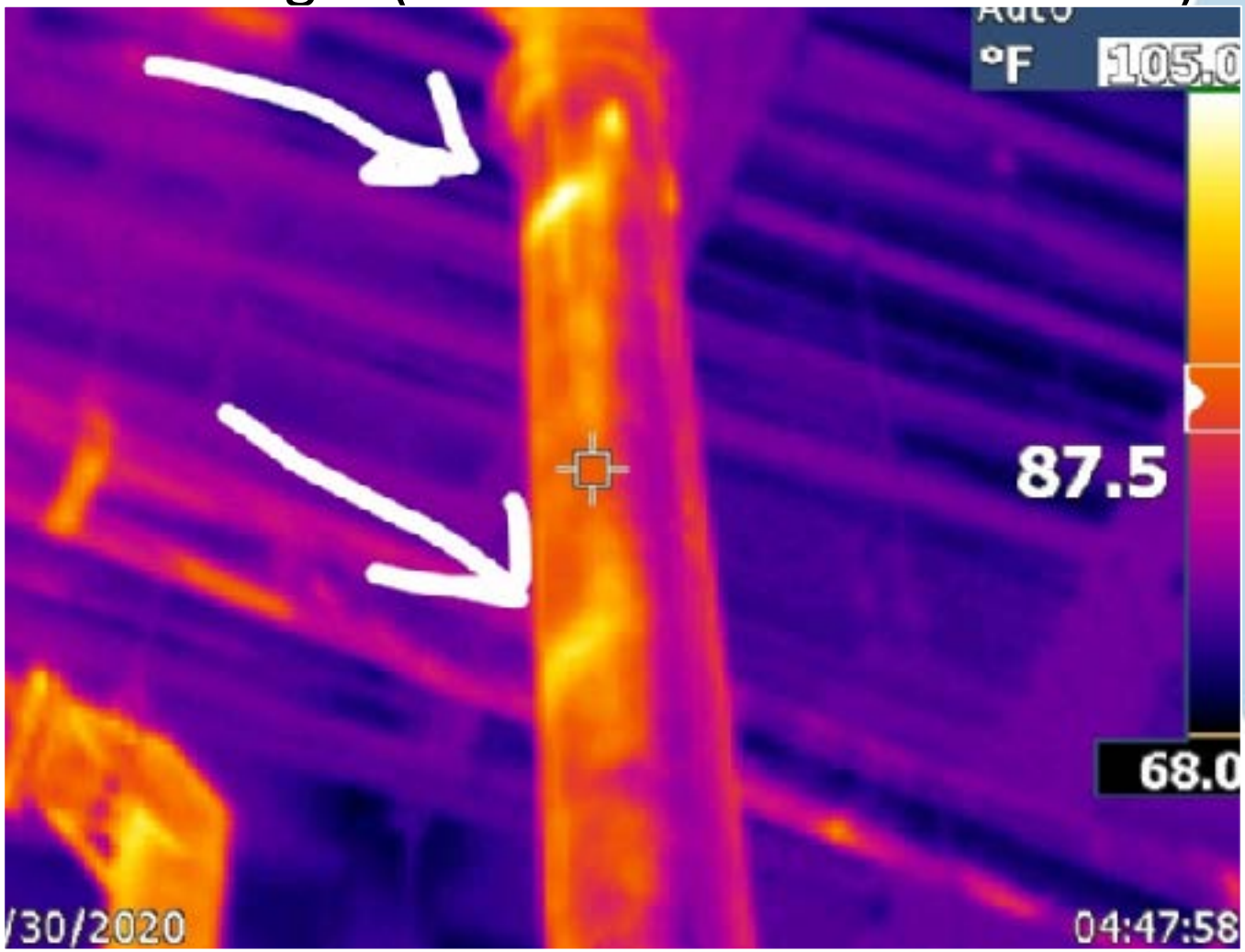
4K RGB Image and Radiometric Image

- 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.

Handheld Camera example

- Indoor target (8” vertical transmission line)



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4K RGB Image and Radiometric Image

- 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

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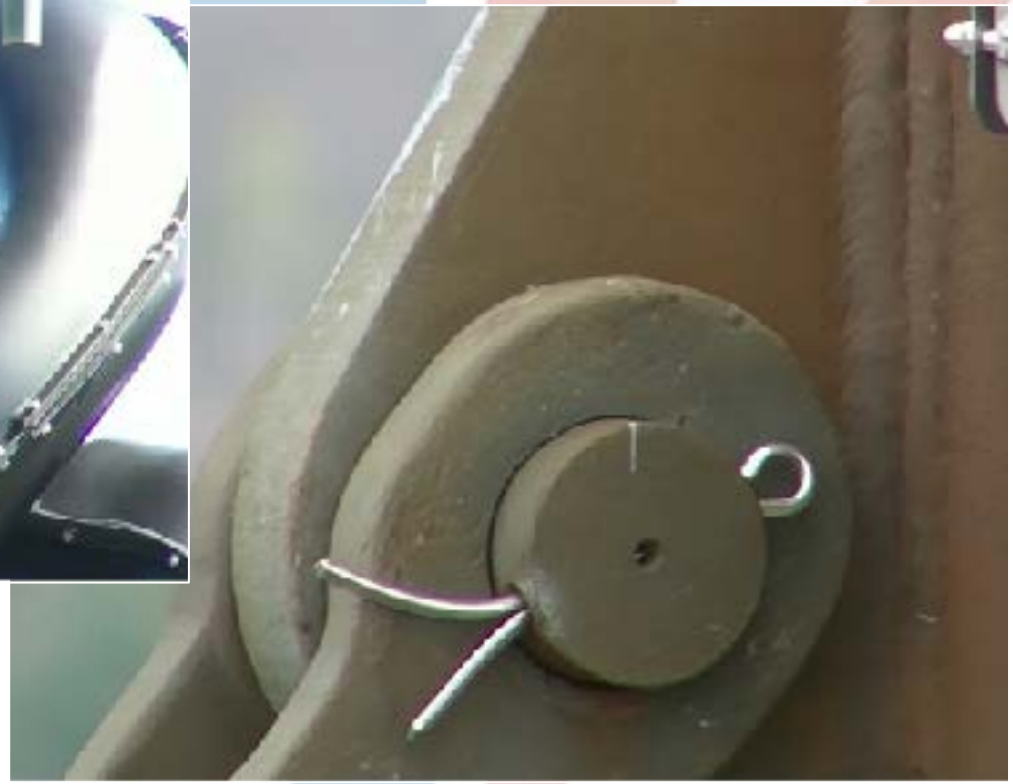
RGB Tower Inspections using the Z-30 Camera

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



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RGB Tower Inspections using the Z-30 Camera

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RGB Tower Inspections using the Z-30 Camera

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Conclusions

- Drones can be used in many cases to perform visual, and IR imaging of broadcast towers and antennas
- Proper certification piloting the drone is required (part 107 FAA License)
- 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

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Resources

- Paul Shulins: paul@shulinssolutions.com
- Infrared Training - (infraspection.com)
- Infrared Training – (infraredtraining.com)
- Level 1,2,3 Thermography Certifications through ITC
- Free FLIR Tools Software – (www.FLIR.com)
- Free training - YouTube.com from ITC and FLIR

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Thanks To

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- Jim Leifer, American Tower Corporation

Questions?

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