Innovative Imaging & Research

Low Light Applications for Absolutely Calibrated Large Format Large Dynamic Range Digital Imaging Sensors

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Aerial Digital Cameras

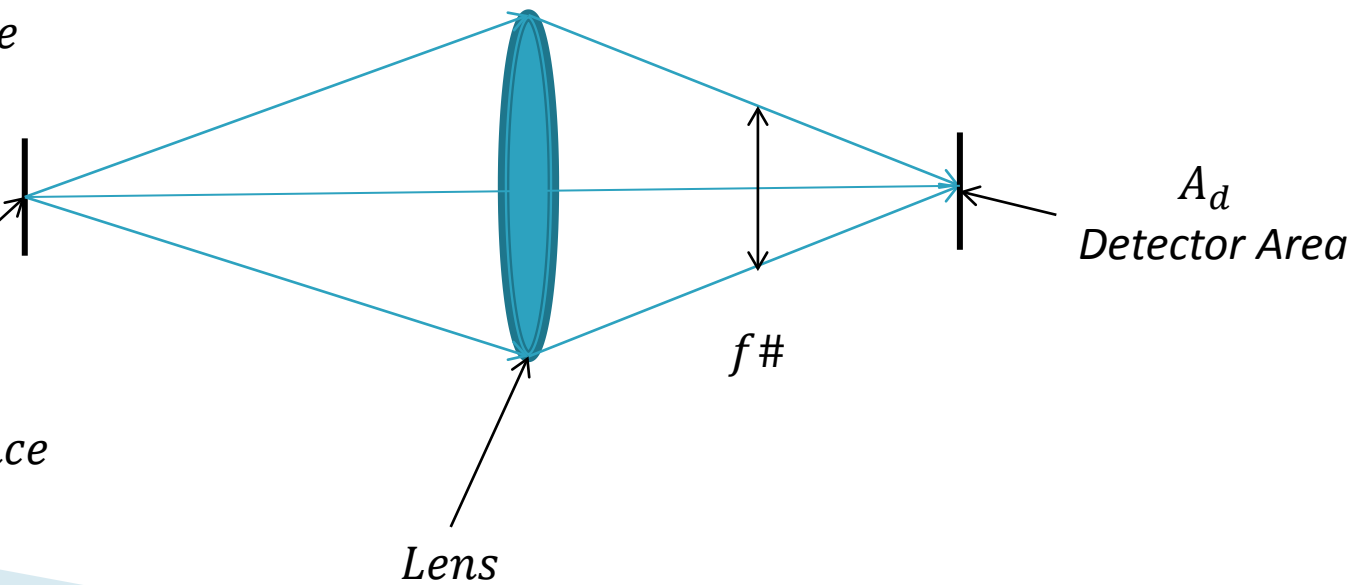
- Aerial imagery is typically taken over a limited set of solar and atmospheric conditions even though information is needed all time
- Digital sensors can be very sensitive
  - Acquire high quality imagery over an enormous dynamic range by carefully controlling aperture and exposure time settings

Z/I DMCII

Digital Camera Radiometric Performance

$$DN = g\,\tau\,A_d\,\frac{\pi}{4\,f\#^2}\int_0^{\infty} L(\lambda)S(\lambda)d\lambda$$

$DN - Digital\ Number$
$\lambda - Wavelength$
$L(\lambda) - Spectral\ Radiance$
$S(\lambda) - Spectral\ Response$
$\tau - Integration\ Time$
$g\ - Gain$
$f\# - f - number$

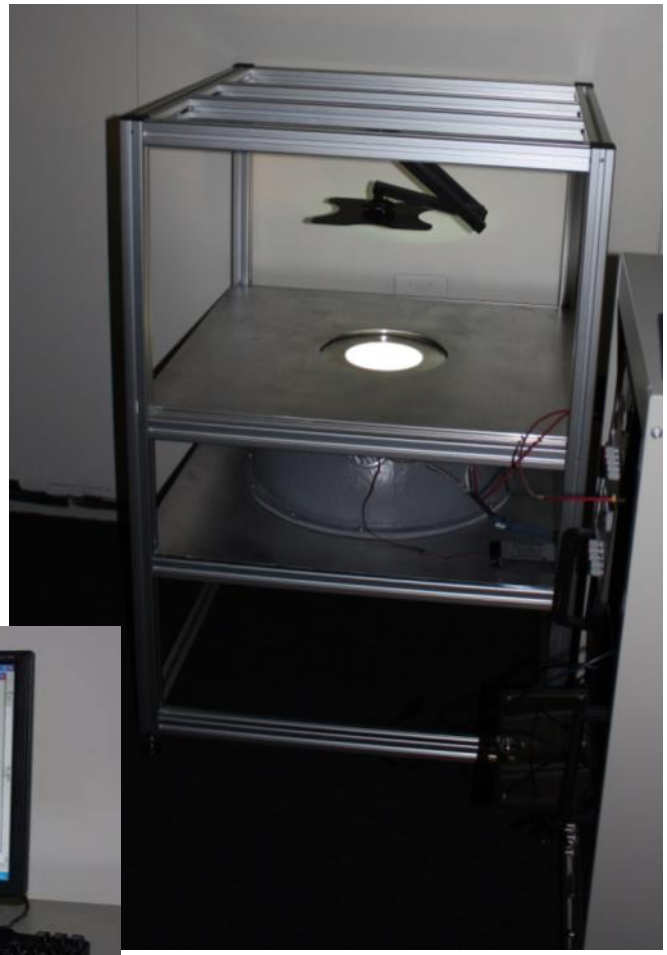


Achieving Low Light Level Imagery

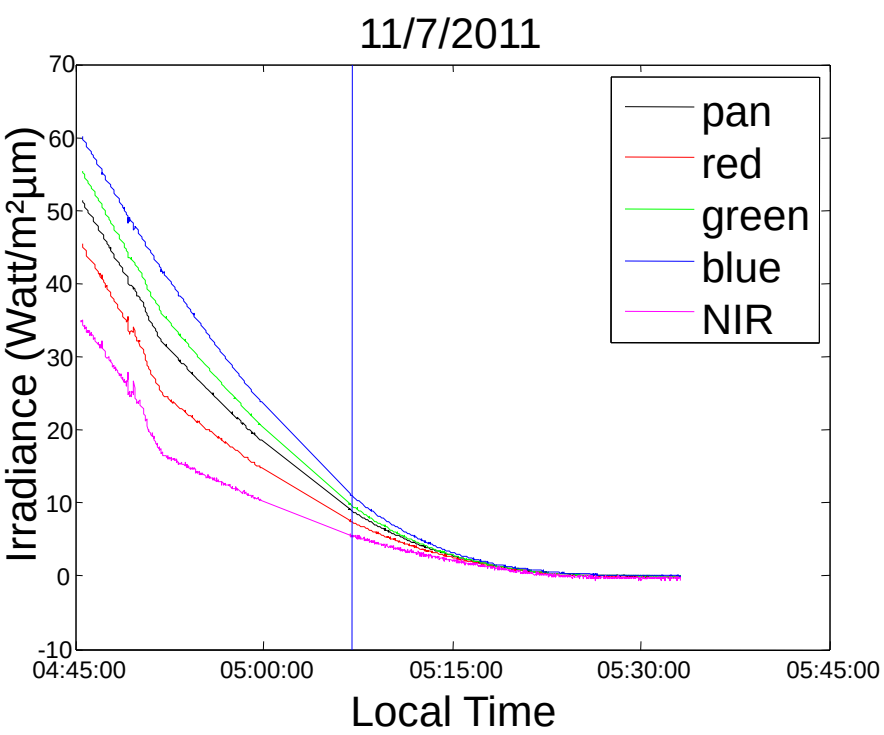
- Understand the radiometric performance of the digital camera
- Know the amount of light available
- Predict camera performance

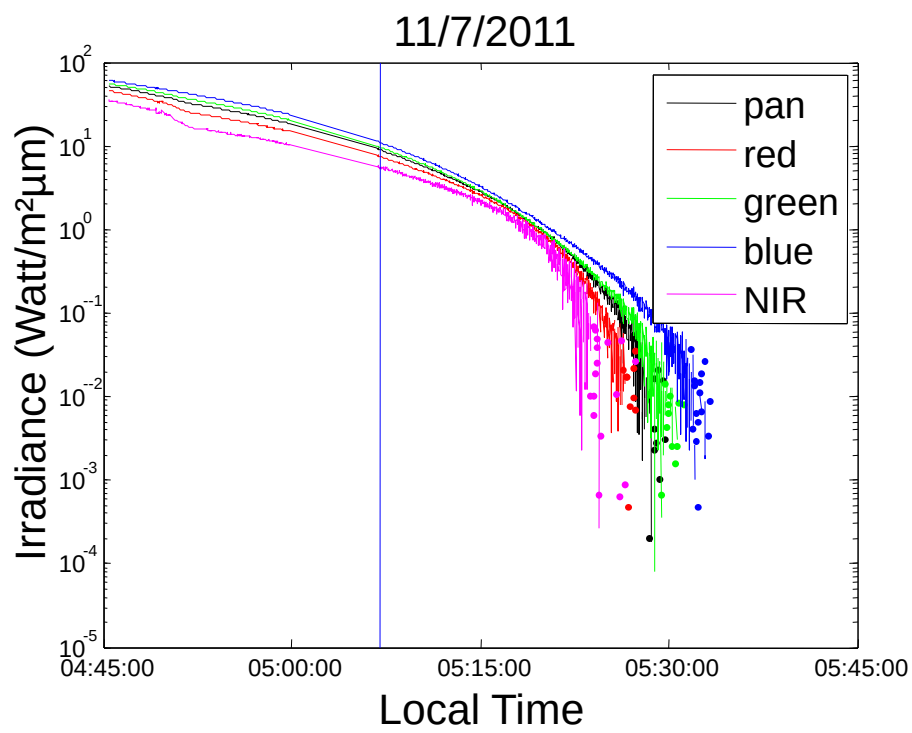
LED Illuminated Integrating Spheres

- High power LEDs are enabling the creation of simple electronically adjustable illumination
- Will enable very large spheres to be constructed
- 0.5 m prototype shown on right



Irradiance Drop-off at Sunset





Sunset November 7, 2011

General Comments

- High sensitivity is produced by increasing exposure time and operating at small f#s
  - Aerial cameras can have nearly 3 orders of magnitude dynamic range by adjusting f# and integration time
- Increasing the aperture and exposure time decreases image sharpness (poorer Edge Response or MTF)
  - Image stabilizing helps with long exposure (Forward Motion Compensation)

DMCII Low Light Imagery

Fall/Winter Collect Examples

Midwest DMCII Aerial Photography

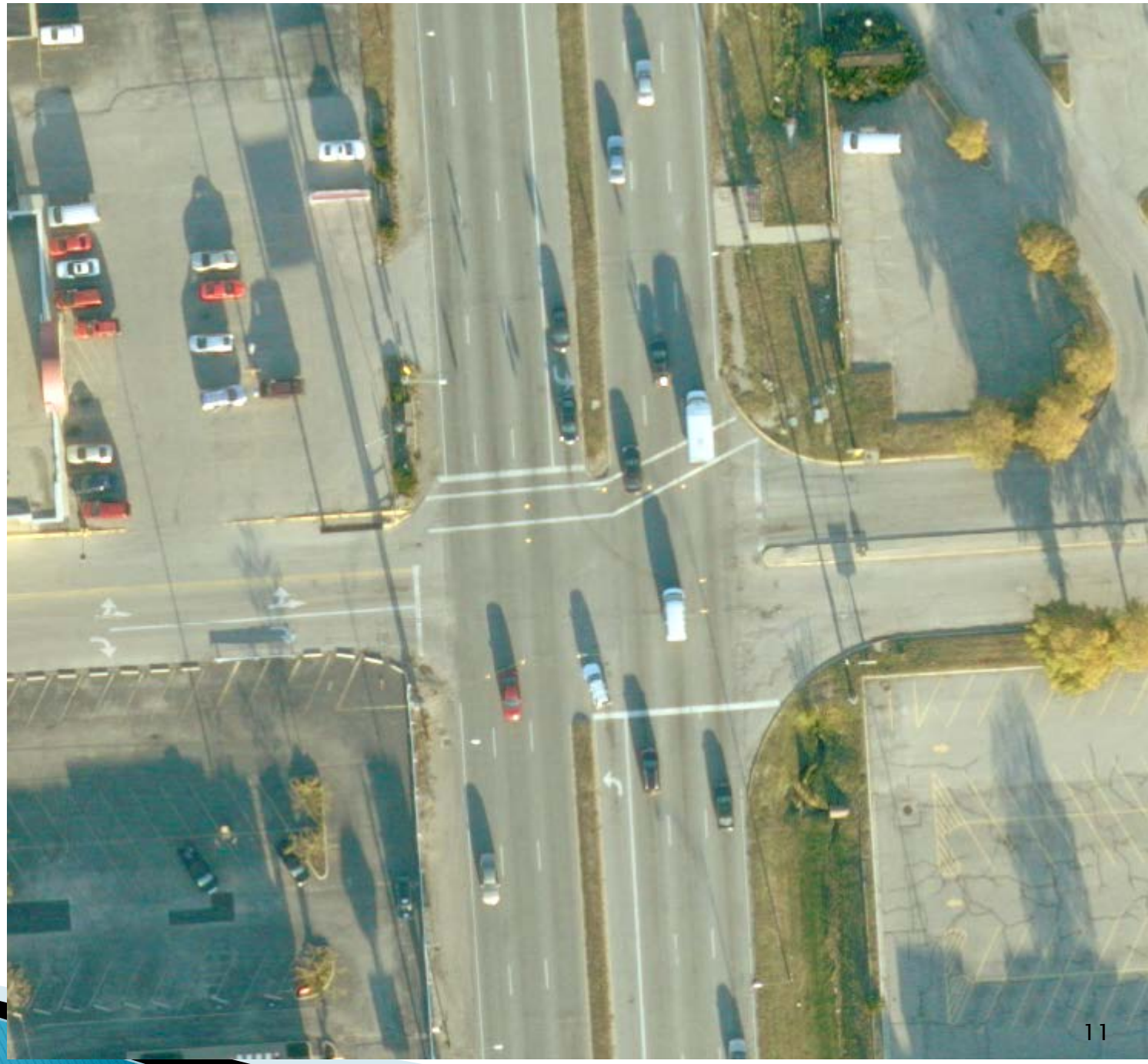
- Midwest Aerial is located in Columbus Ohio and owns and operates a Z/I DMC II digital camera
  - 4 multispectral bands (RGBN)
  - 140 megapixel pan band
  - Imagery acquired at 10, 0 and -10 degrees solar elevation over West Broad Street in Columbus
- Absolutely radiometrically calibrated

Standard
Pan Sharpened
Image

Solar Elev. 10°

Standard
Pan Sharpened
Image Zoom

Solar Elev. 10°



Standard
Pan Sharpened
Image

Solar Elev. 0°

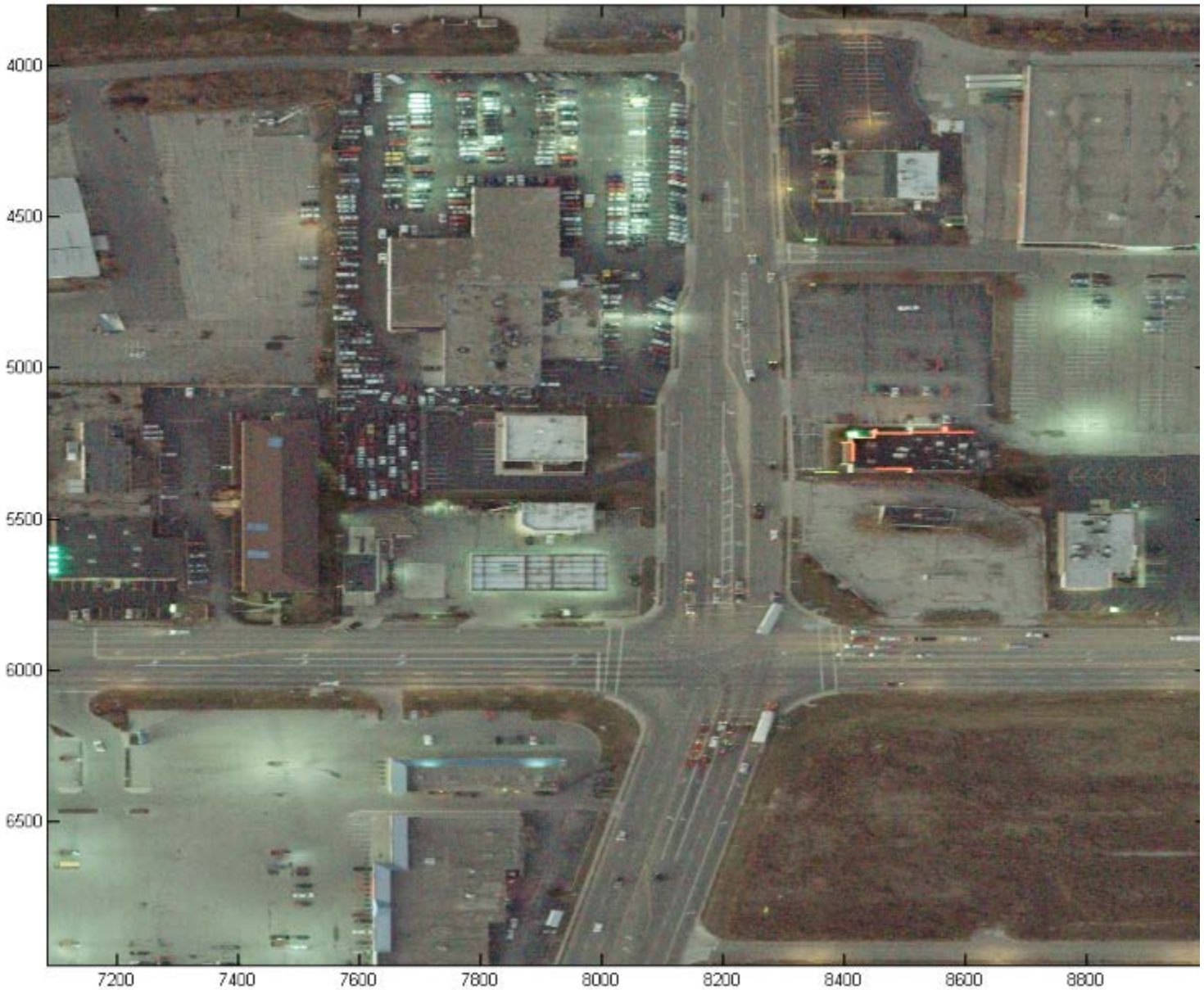
Standard
Pan Sharpened
Image Zoom

Solar Elev. 0°

Imagery acquired ~5 minutes prior to sunset

Imagery acquired ~sunset

Imagery acquired ~5 minutes past sunset



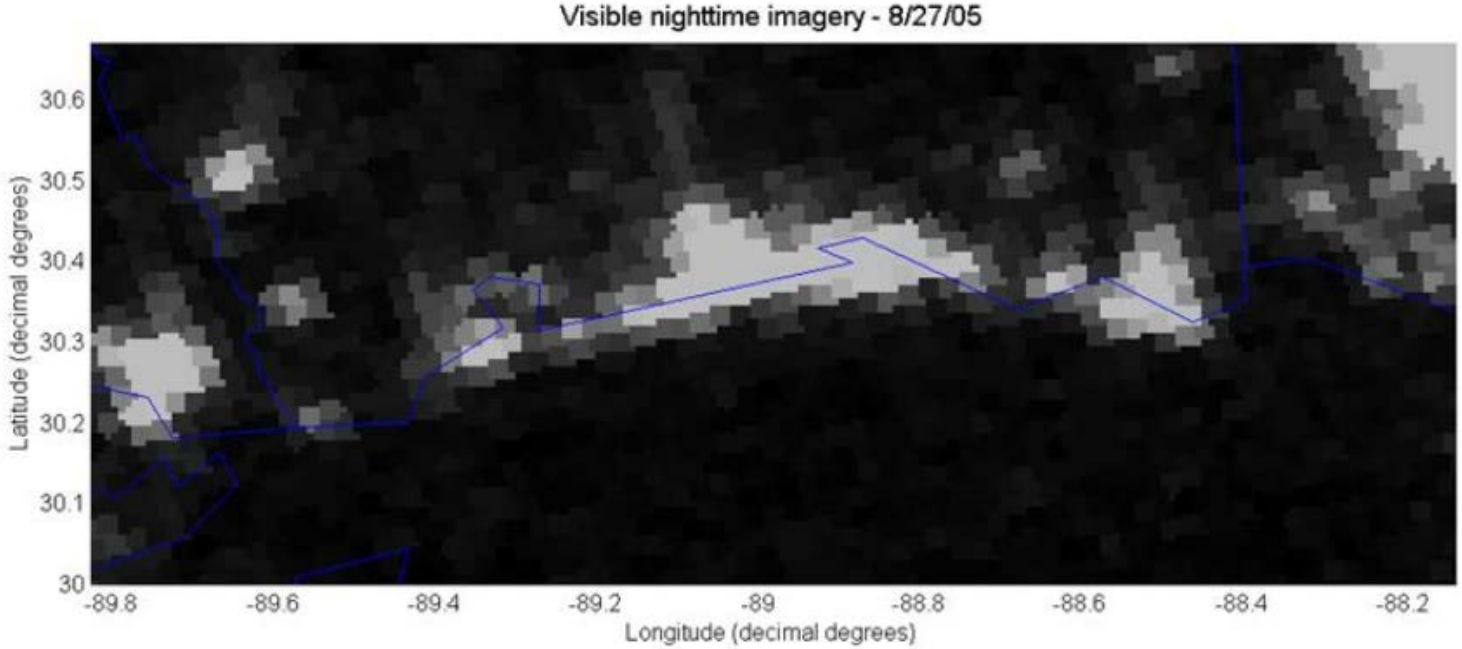
Imagery acquired ~10 minutes past sunset

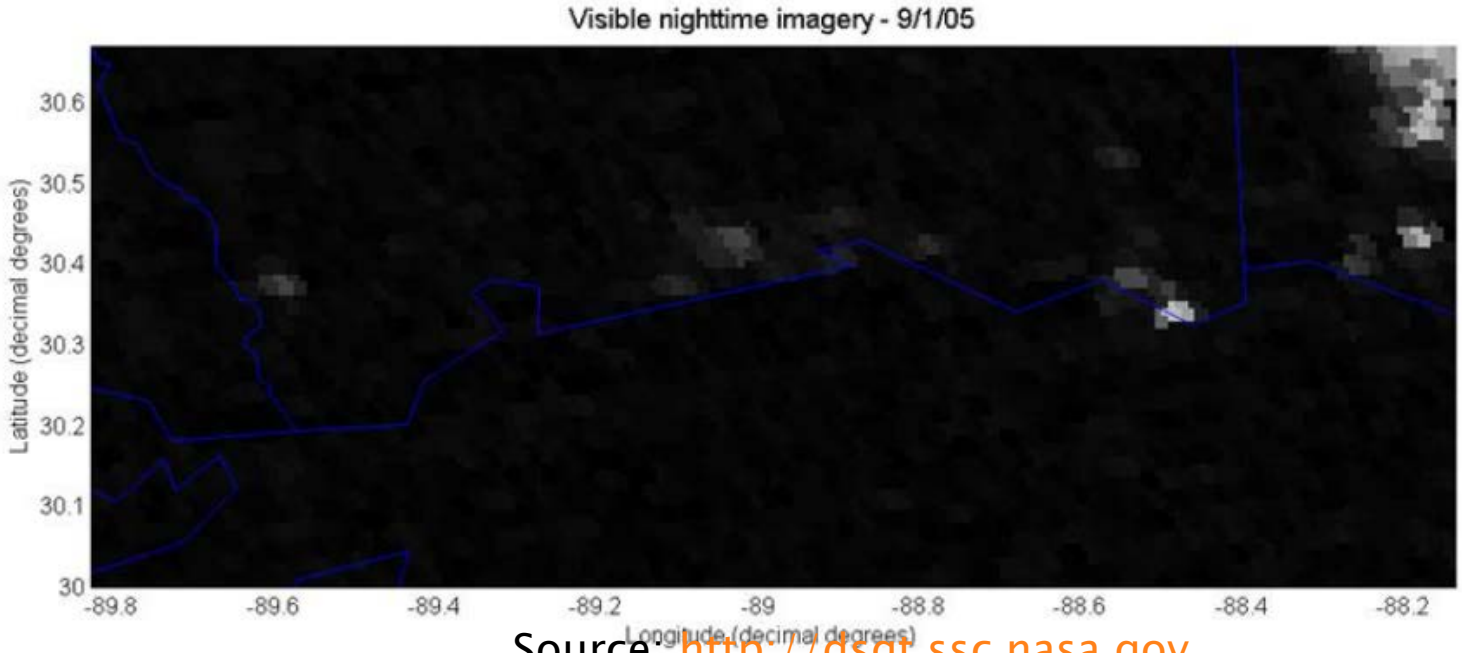
Night Imaging

Emergency Response Applications

- Defense Meteorological Satellite Program (DMSP) has been used to determine power outages by imaging artificially illuminated areas at night
  - 0.55 km fine resolution and 2.7 km coarse mode
  - Broadband 0.58–0.91 micron spectral range
- Smart grid will make this easier

DMSP Imagery over MS Gulf Coast after Hurricane Katrina





Source: http://dsgt.ssc.nasa.gov

VIIRS Hurricane Sandy

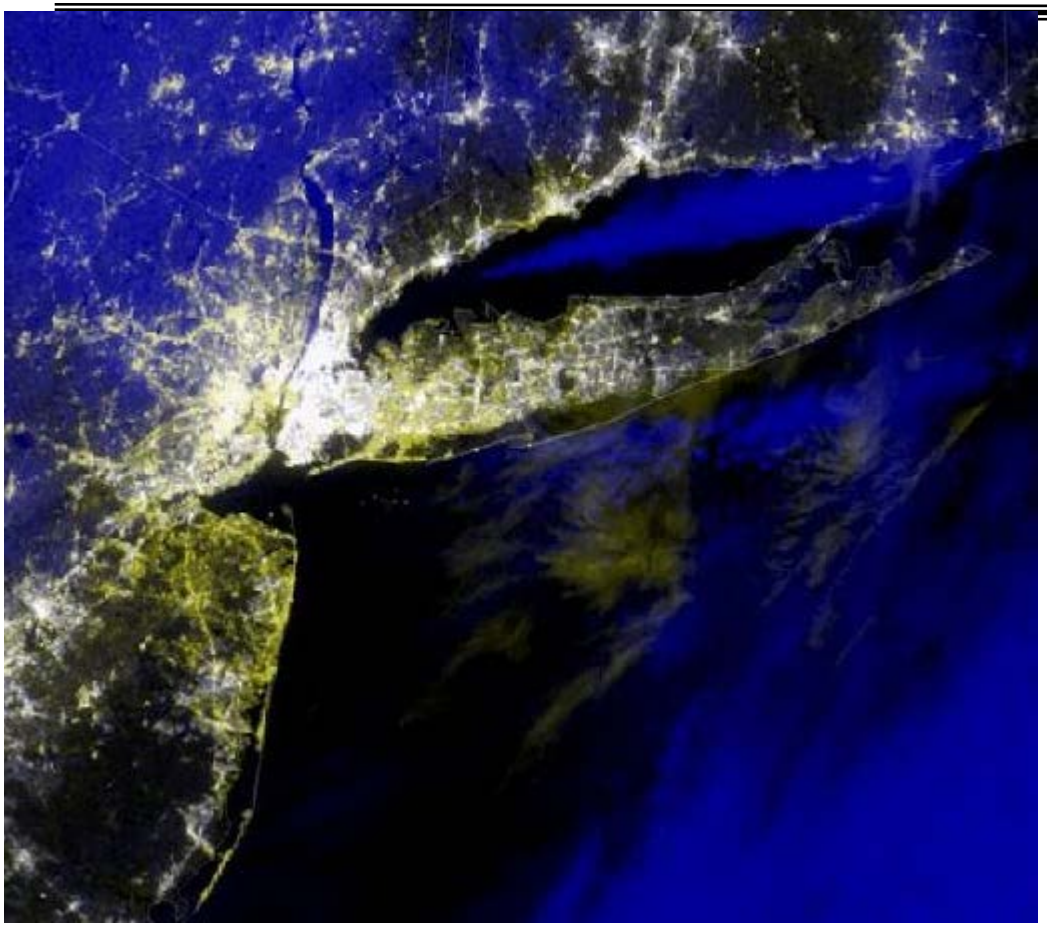


Image credit NASA SPoRT
http://www.nasa.gov/mission_pages/hurricanes/missions/sport/blackout1.html

NASA Short-term Prediction Research and Transition Center (SPoRT) VIIRS maps Hurricane Sandy Blackout

RGB composite for Nov. 1, 2012

Yellow regions indicate urban regions with power before Hurricane Sandy, but not after.

Blue regions are the result of clouds.

"This imagery has allowed emergency response teams to expedite their response to hurricane-ravaged areas," said Dr. Gary Jedlovec, SPoRT project lead at NASA's Marshall Space Flight Center in Huntsville, Ala.

VIIRS Night Time Imaging

Power Outage
Washington/Baltimore

Normal Image

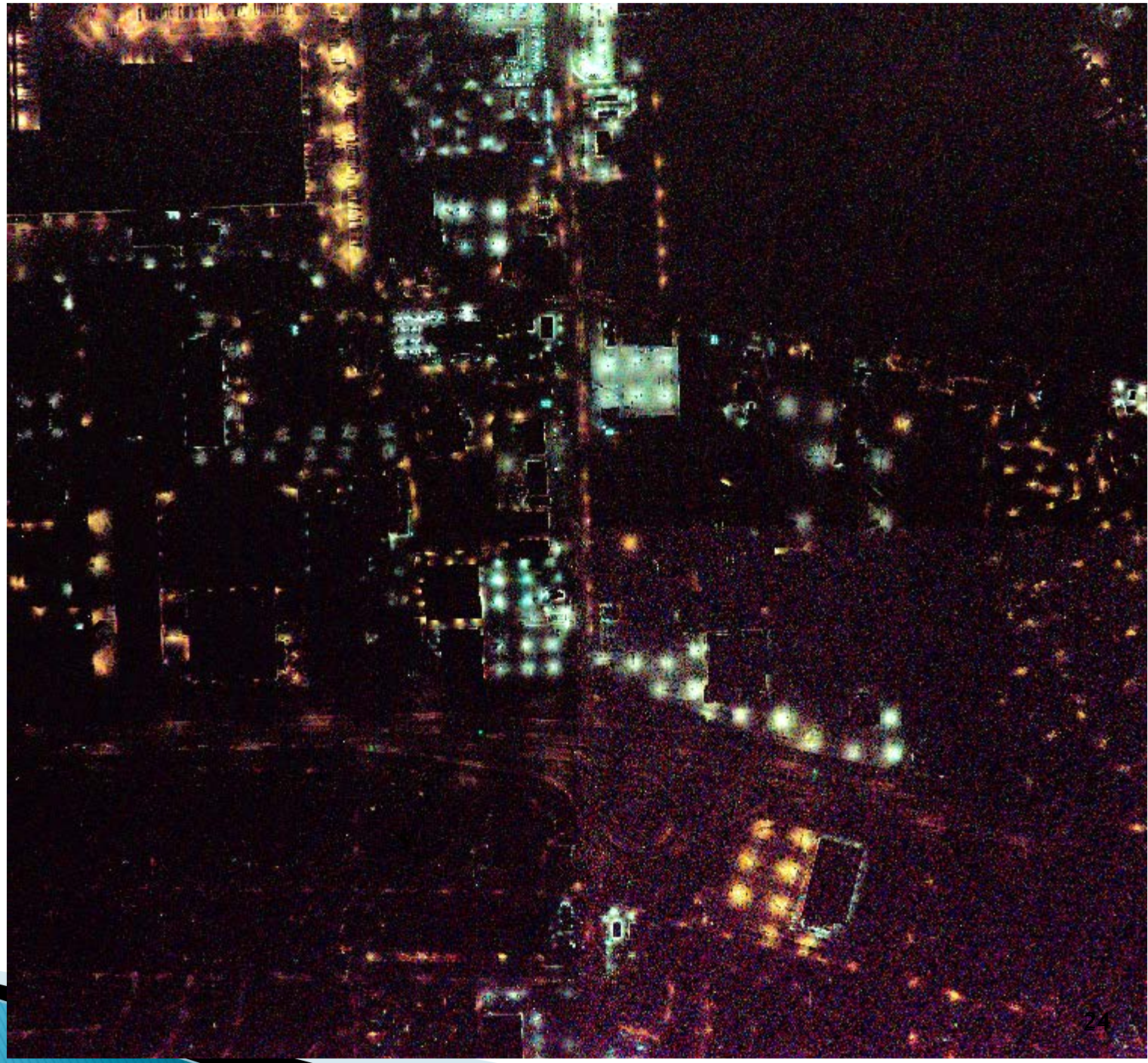
http://earthobservatory.nasa.gov/IOTD/view.php?id=78445

These before and after images from show the power outages over Washington, DC and Baltimore that occurred as a result of a rare, fast-moving thunderstorm system on 29 June 2012.

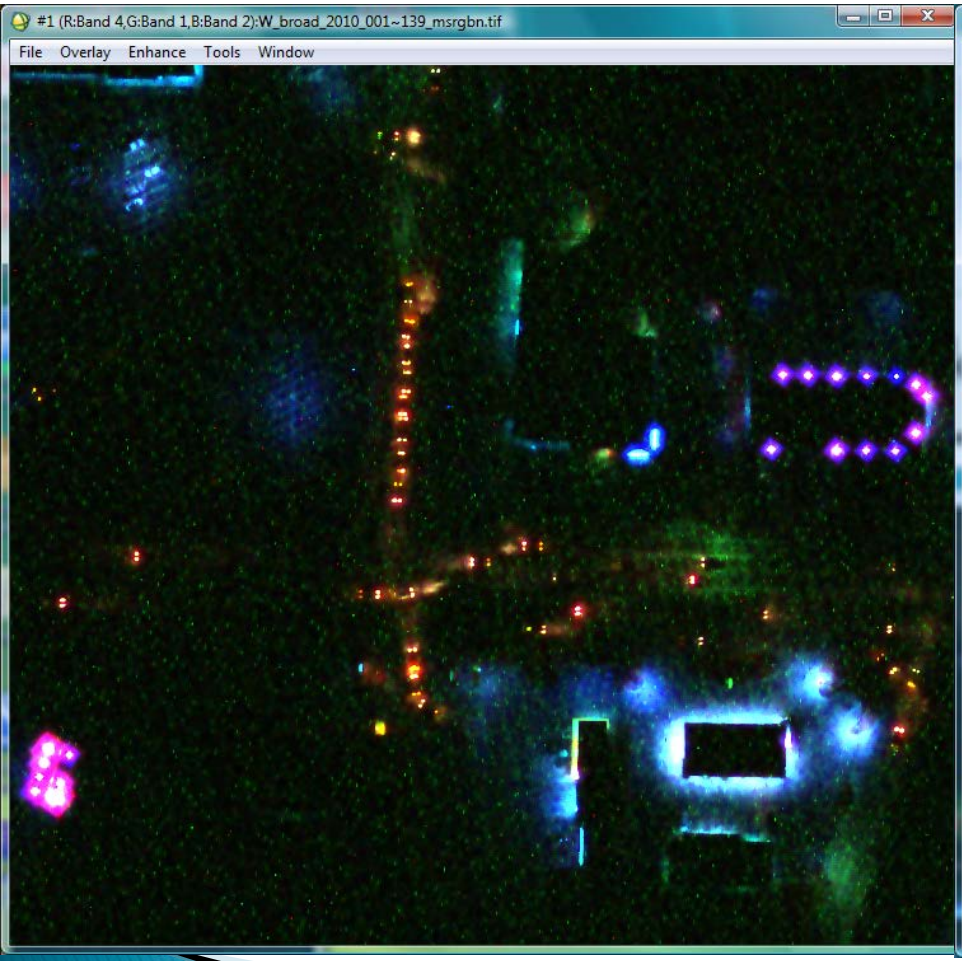
Artificial Illumination Source Identification

Standard
Pan Sharpened
Imagery

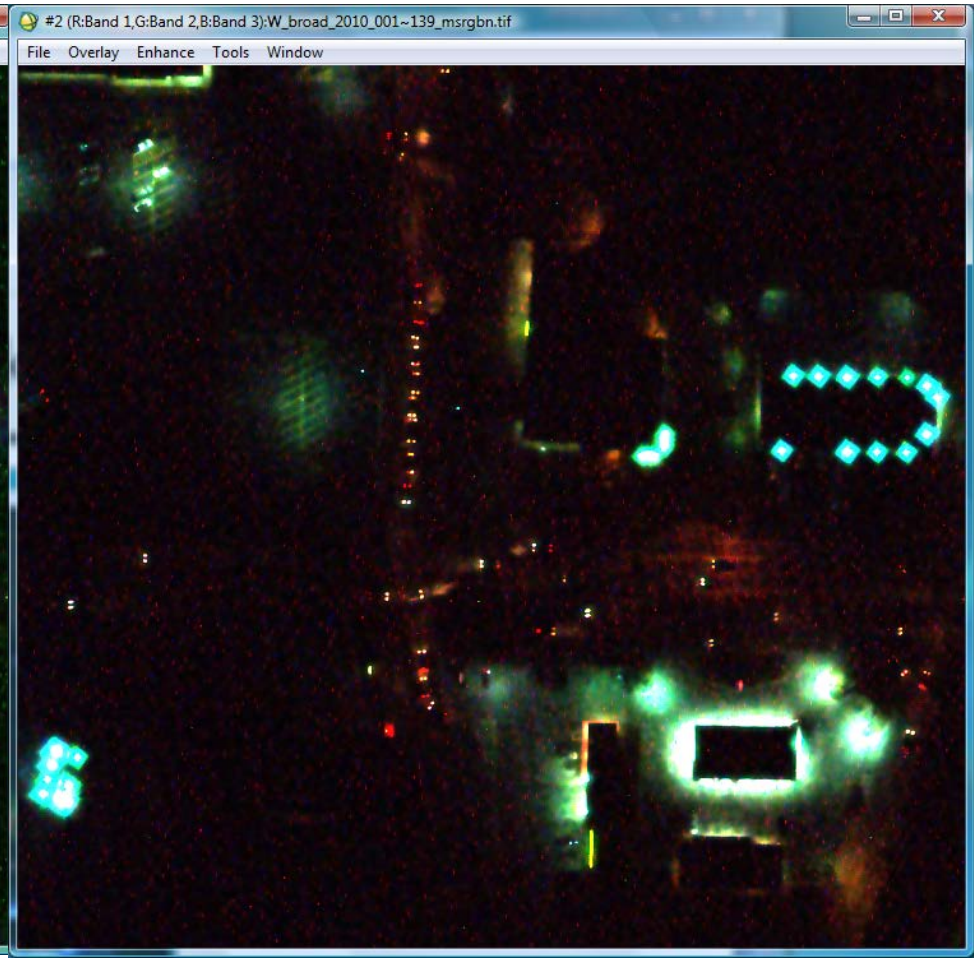
Solar Elev. -10°



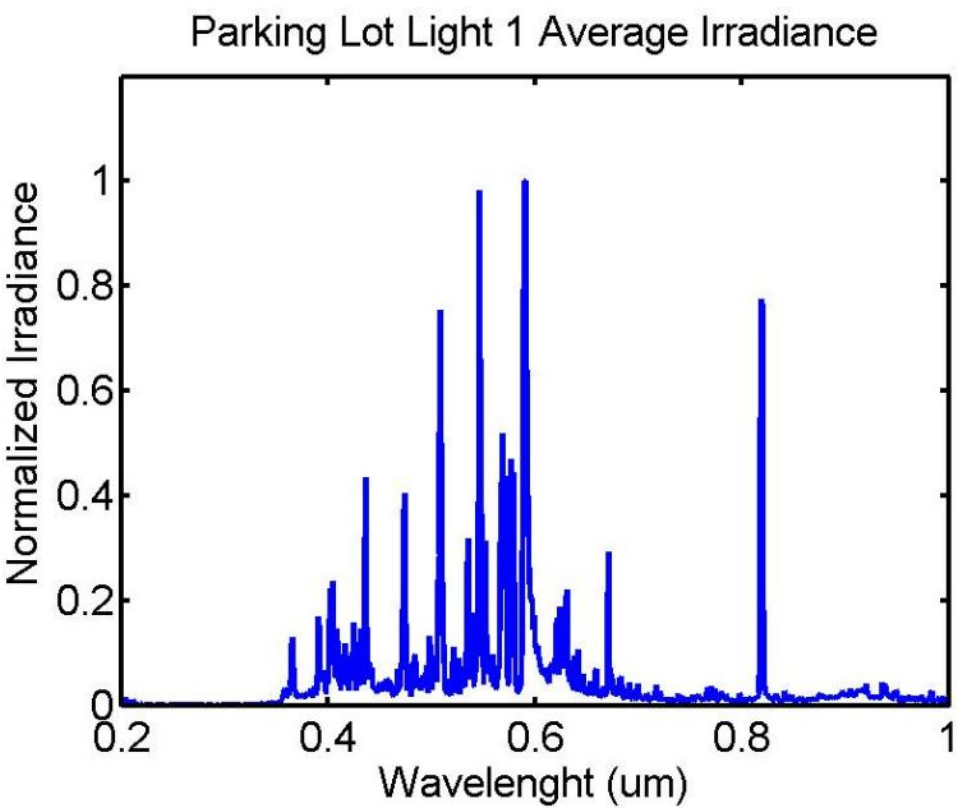
Color Infrared



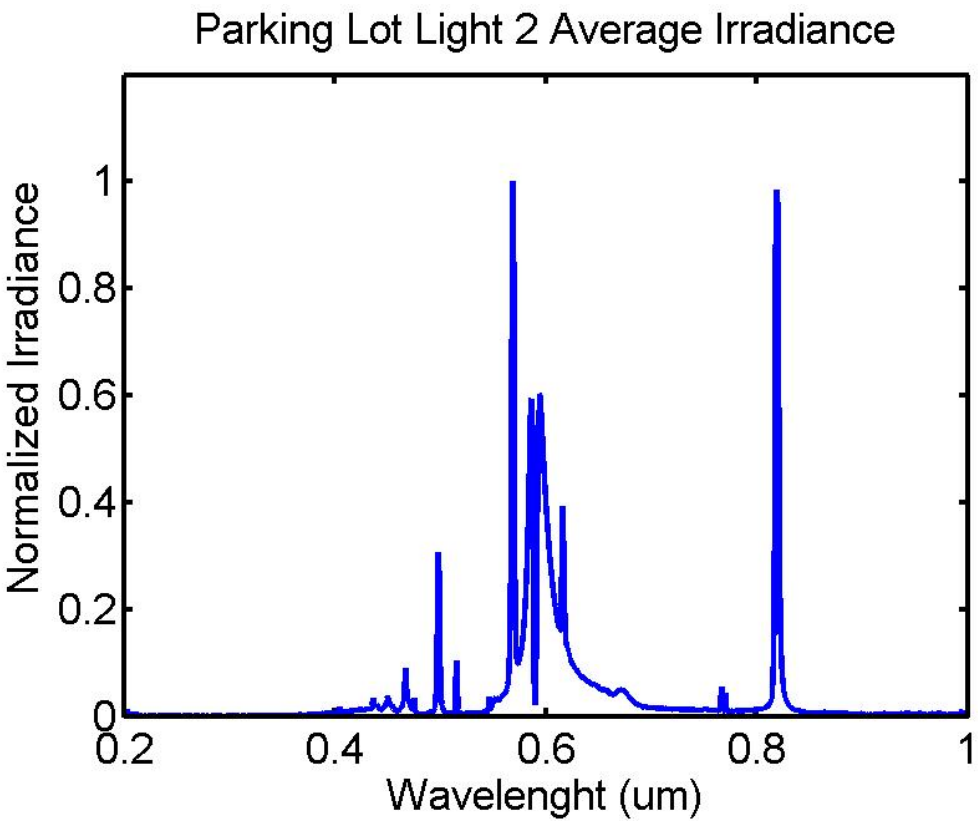
True Color



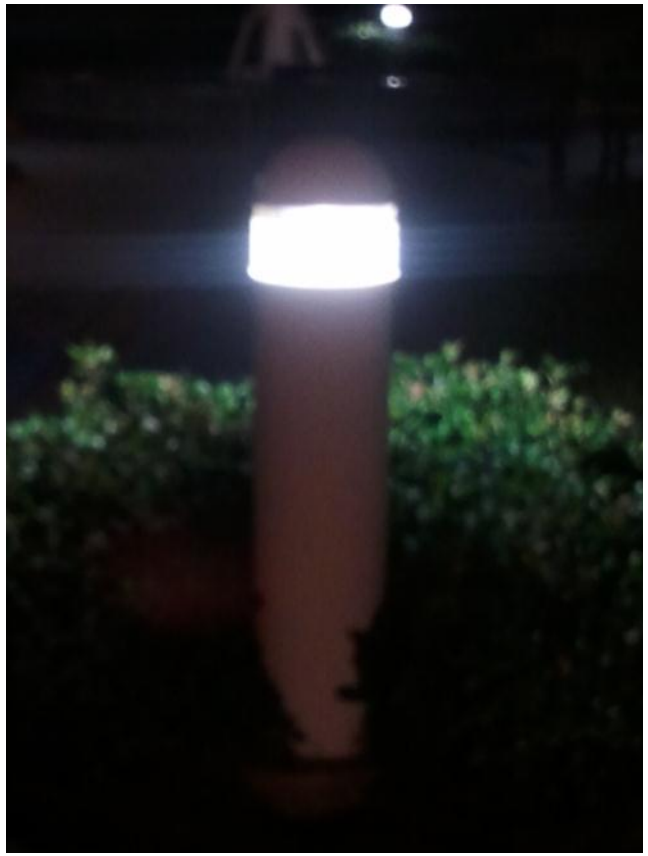
Metal Halide Street Light

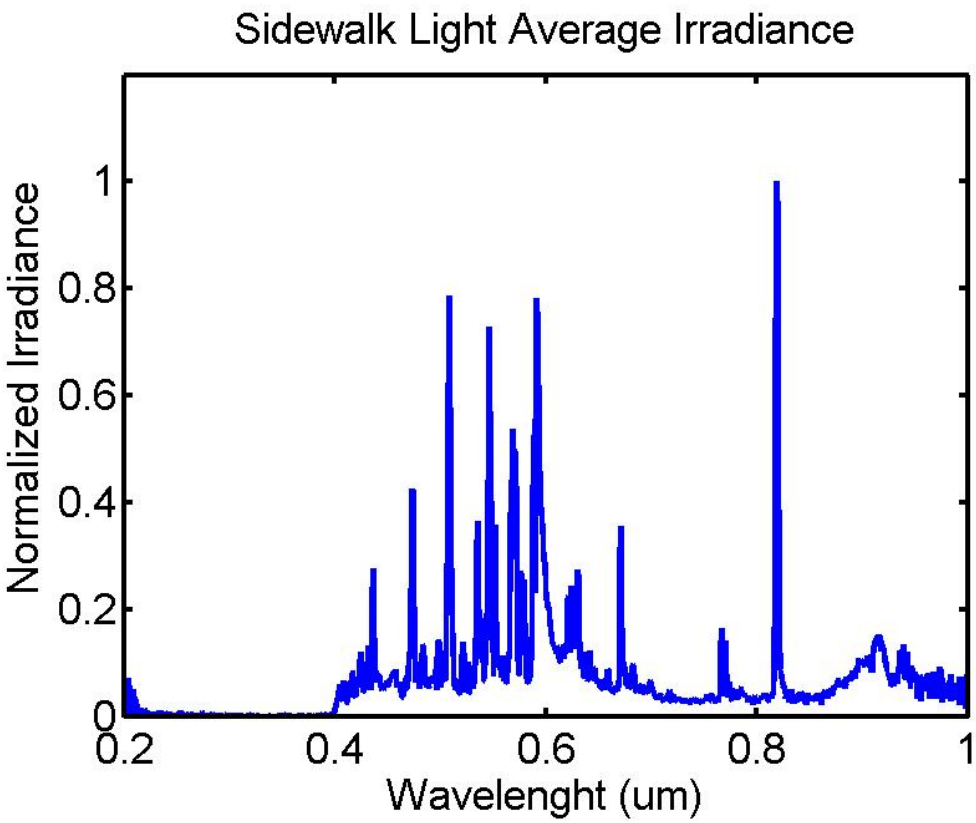


High Pressure Sodium Street Light

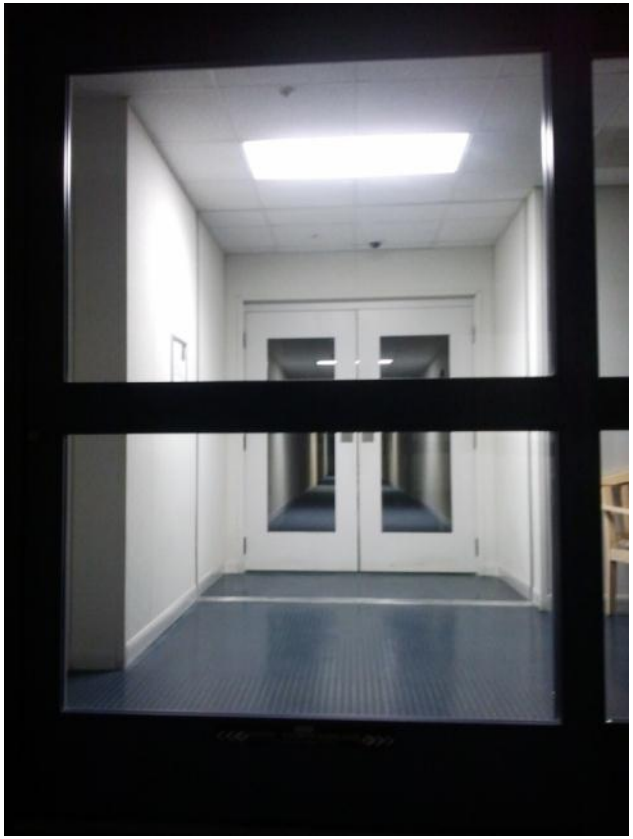


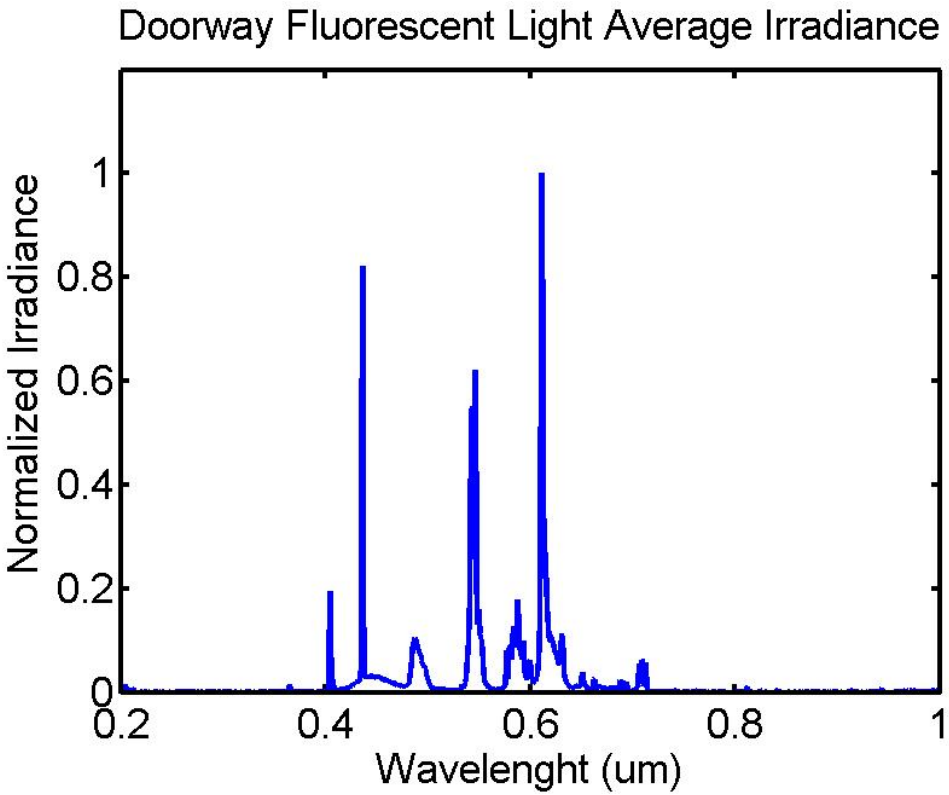
Metal Halide Sidewalk Light



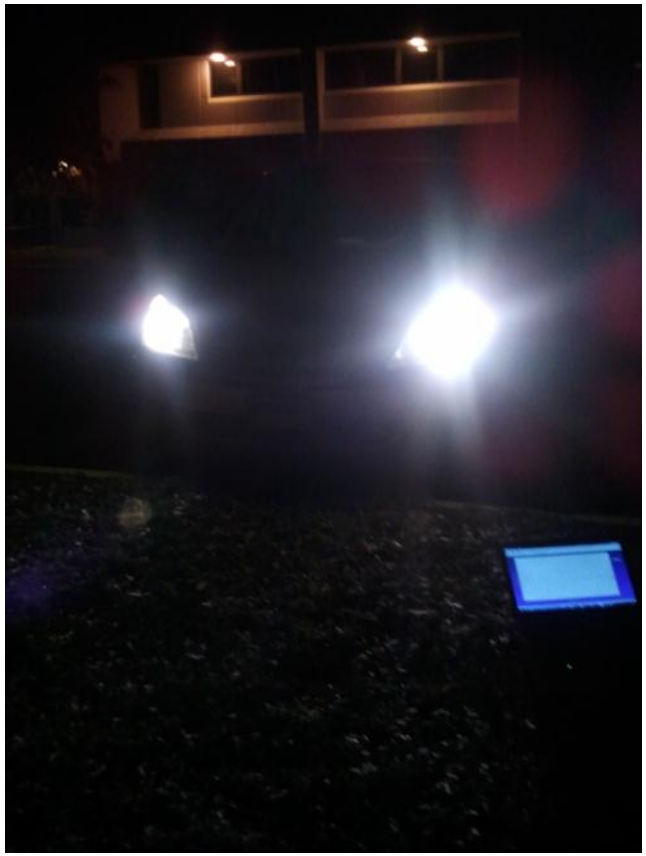


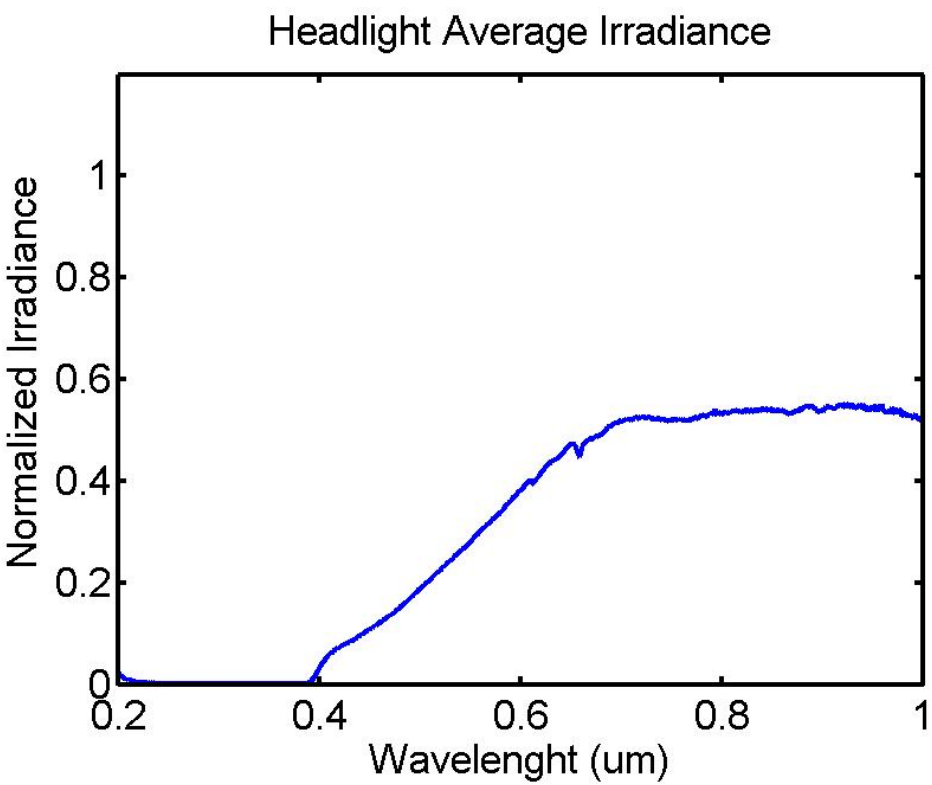
Indoor Fluorescent Light





Headlights

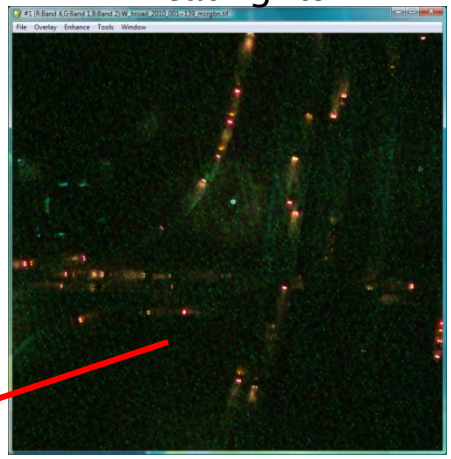



Headlight Average Irradiance
Normalized Irradiance
0
0.2
0.4
0.6
0.8
1
0.2
0.4
0.6
0.8
1
Wavelenght (um)

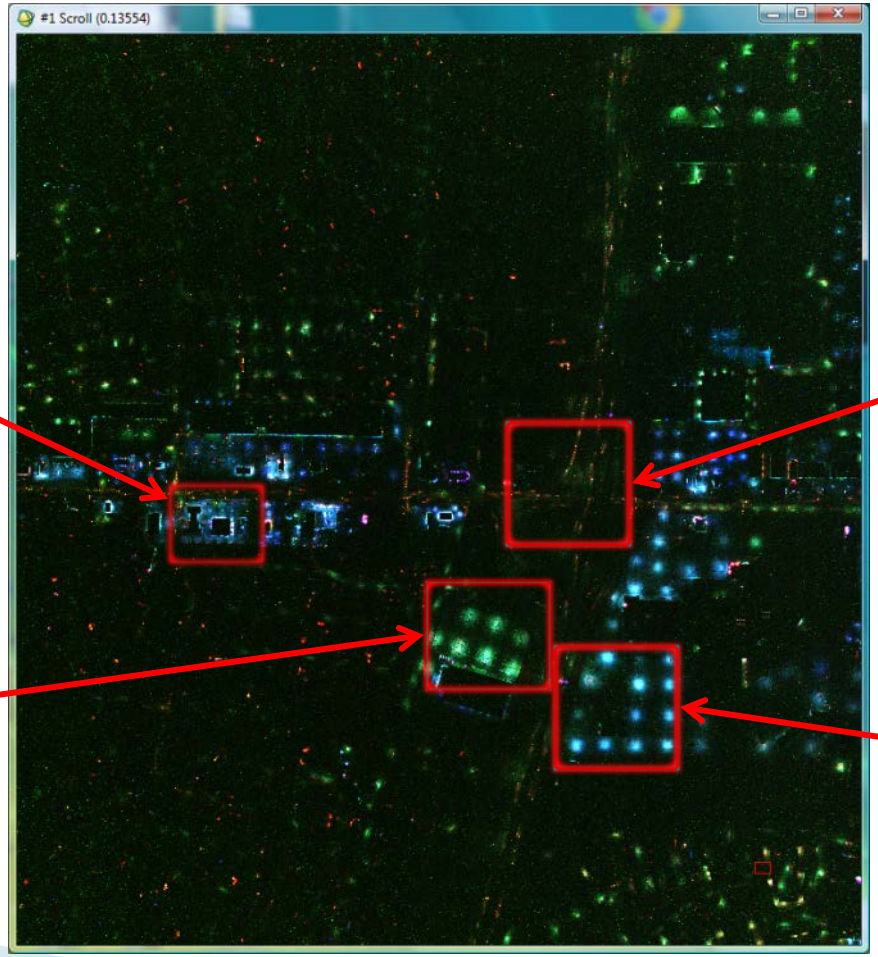
Color Infrared Image

Fluorescent

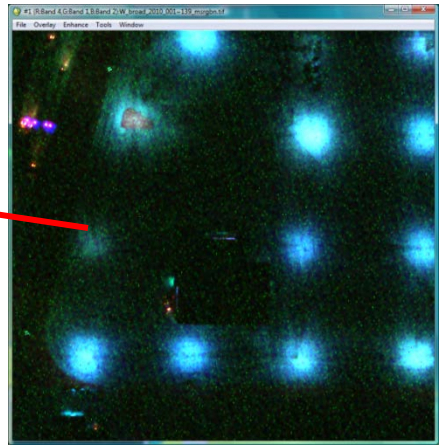
Headlights



High Pressure Sodium

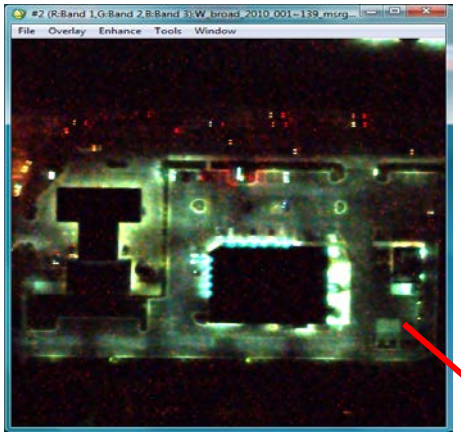


Metal Halide

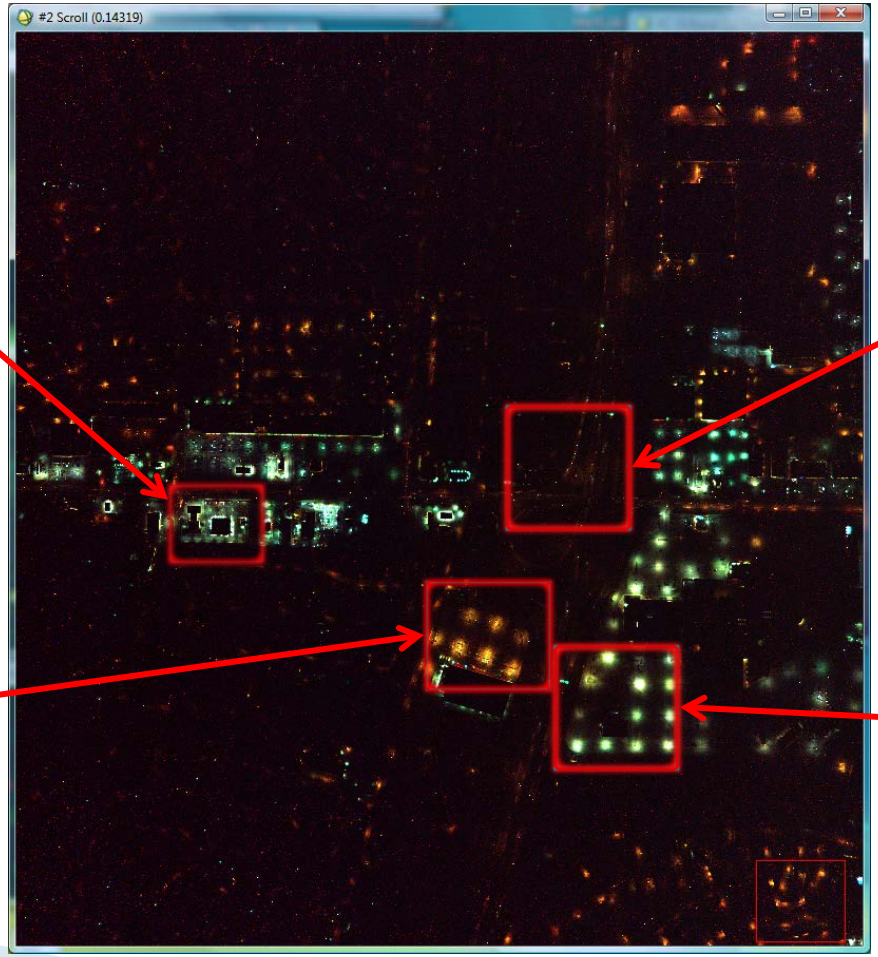


True Color RBG Image

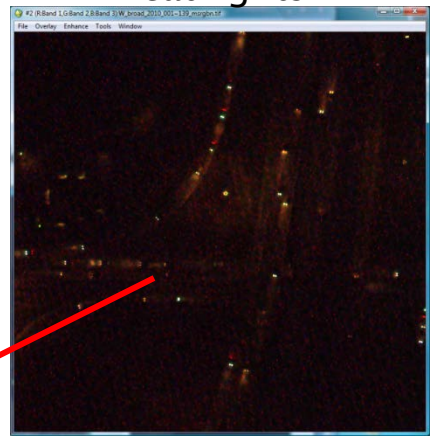
Fluorescent



High Pressure Sodium



Headlights



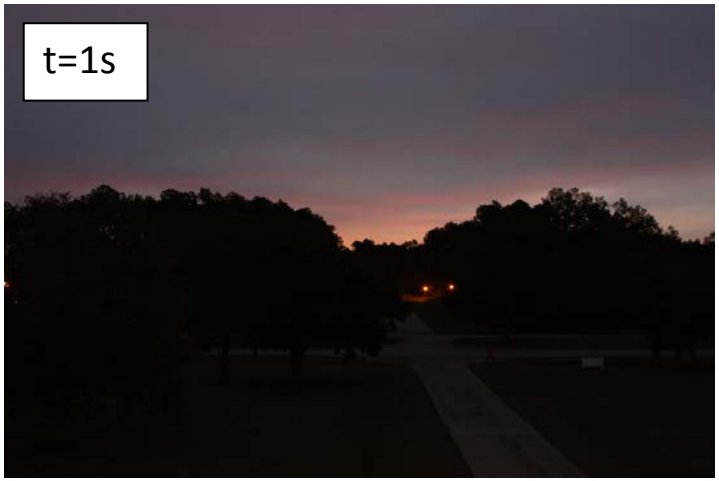
Metal Halide

High Dynamic Range (HDR) Imagery

High Dynamic Range (HDR) Imaging

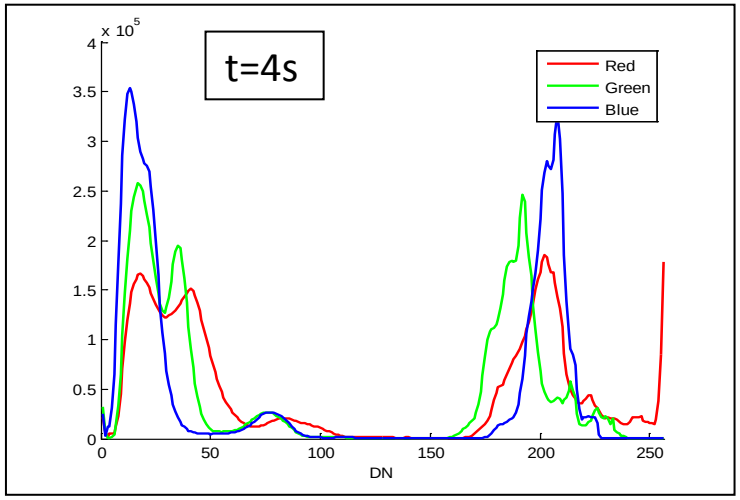
- HDR imaging is a technique that generates an image with a greater dynamic range than ordinarily achievable given an imaging system's hardware.
- The resulting HDR image appears somewhat unrealistic, but contains much more information than a standard image.
- HRD images are generated by acquiring multiple images of the same scene at different exposure settings.
- Each individual image contains a collection of properly exposed pixels and pixels that are both dark (underexposed) and saturated (overexposed).
- HDR techniques mathematically combine these images into a single image using the most appropriate exposure setting for each individual pixel or pixel group within the image.

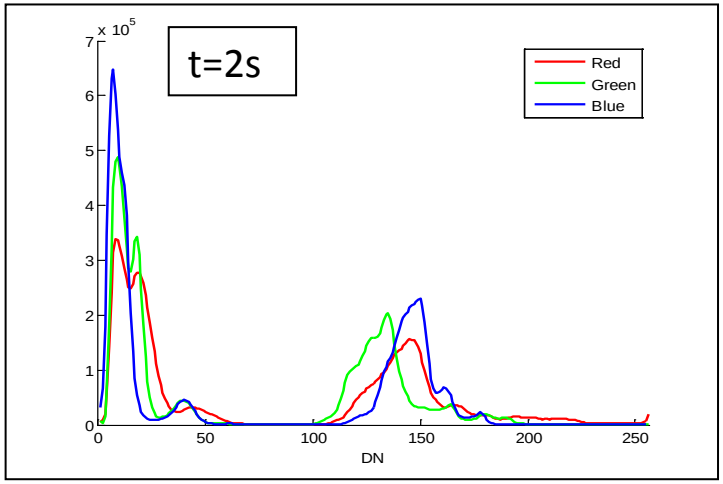
Low Light Imagery

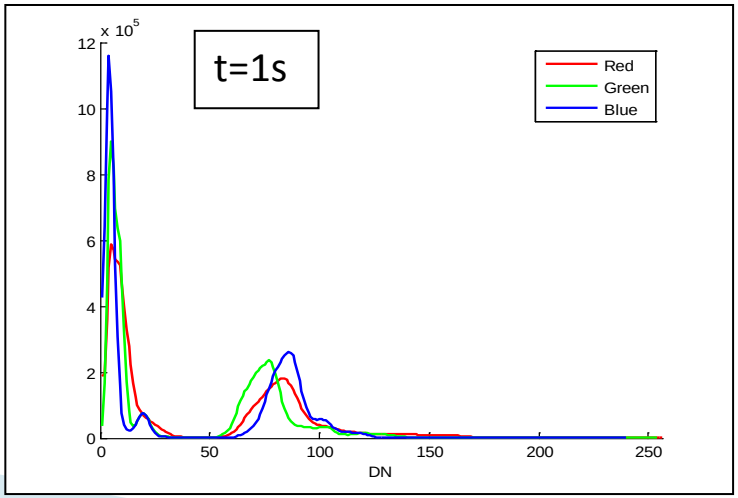


Imagery acquired ~18 min before sunrise at f/8 using a Canon Rebel XS

Image Histograms

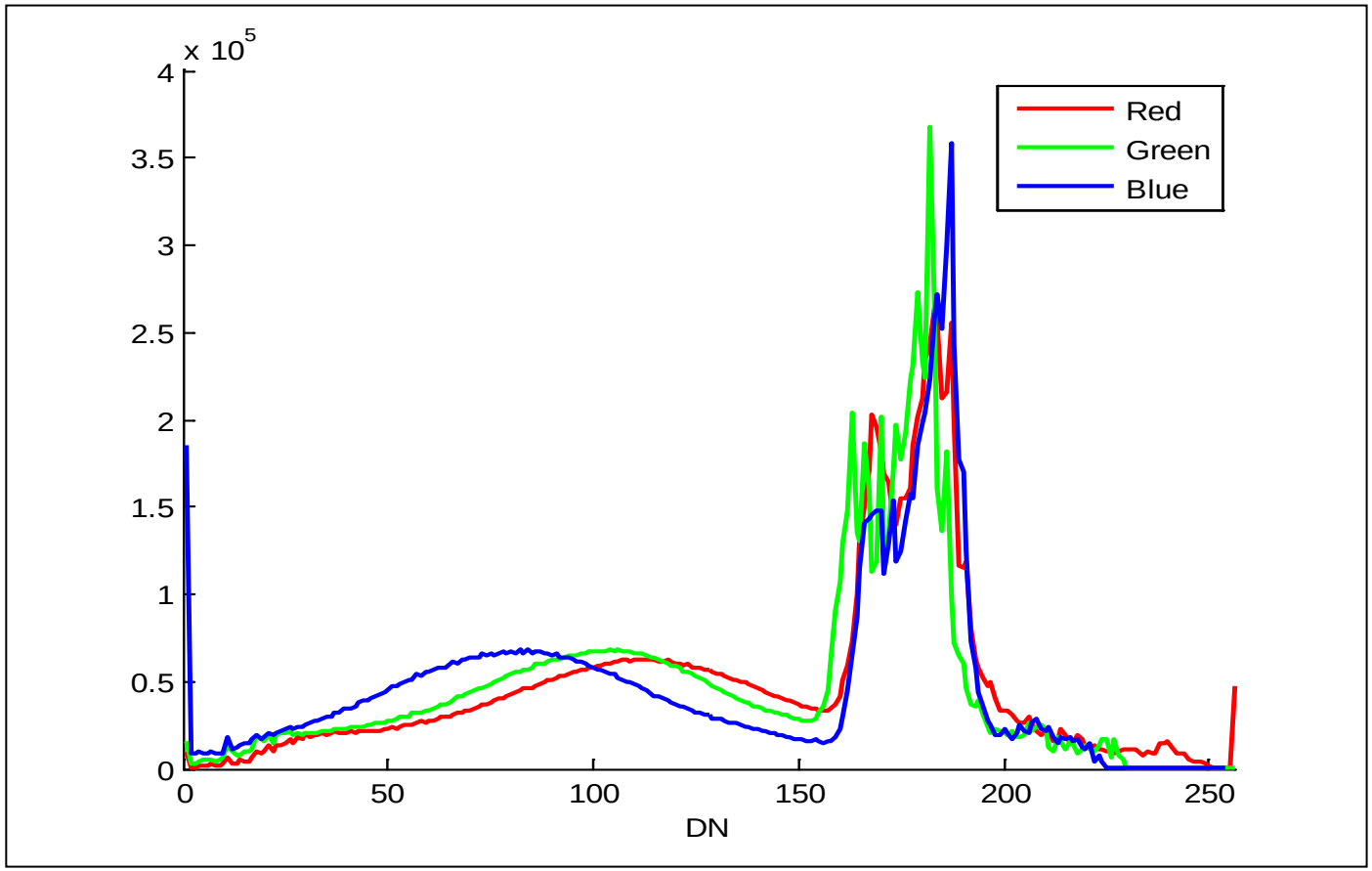






HDR Image

HDR Histogram



Summary

- Aerial framing cameras can produce useful imagery under a wide range of illumination conditions including very low light illumination
  - Approximately 40 minutes a day of increased imagery for many digital cameras using natural lighting
  - Near zero solar elevation angle produces excellent no shadow imagery
- Absolutely radiometrically calibrated camera systems and knowledge of illumination enables one to
  - Predict camera performance aprioi
  - Identify illumination sources
- Nighttime imagery enables high resolution identification of power outages
- Low light level imagery can be enhanced using HDR imagery techniques

Acknowledgements

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- Klaus Neumann–Hexagon Z/I