National Unmanned Aircraft Systems (UAS) Project Office

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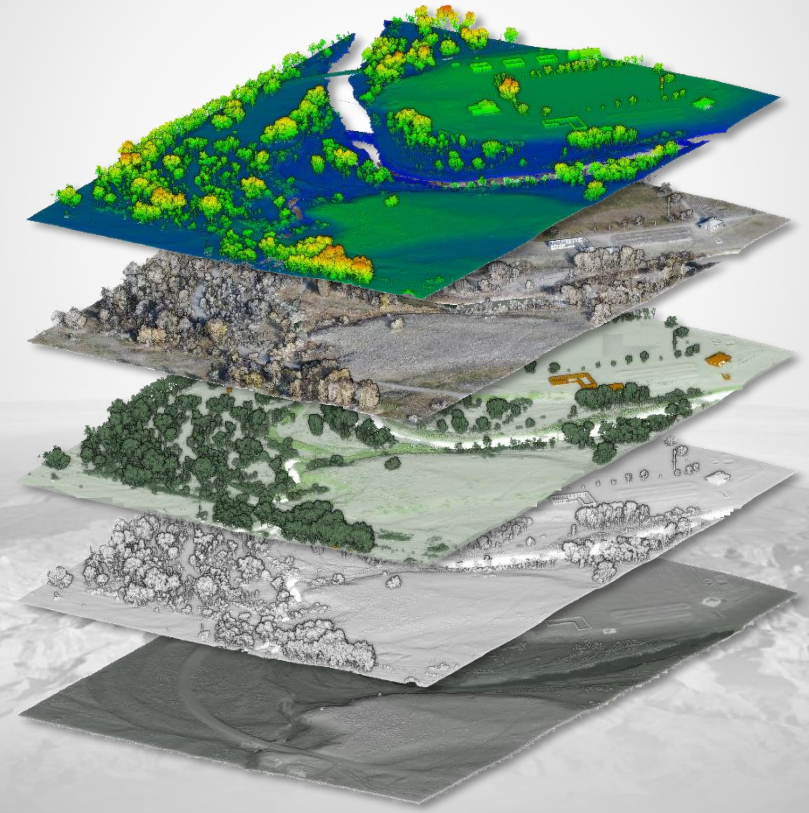

3-D POINT CLOUD DATA
DIGITAL SURFACE MODELS
DIGITAL TERRAIN MODELS
ORTHOIMAGERY
SEGMENTATION AND CLASSIFICATION

UAS PLATFORM RESEARCH
SENSOR INTEGRATION
DATA STANDARDS
GEOSPATIAL PRODUCTS

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2018

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Photography & Camera Anatomy

What makes a good photogrammetric UAS product?

1.) Photography
2.) Geometry
3.) Ground Control / Scale

Example Products produced in Photoscan

Devils Tower, WY
(ground based survey)

Fort Laramie, WY
(photo lidar merge)

Palmyra Atoll
(Multispectral Micasense Rededge)

Talking Points

- Sensors
- Field of View
- Focal Lenght
- Exposure Triangle
- Aperture
- ISO
- Shutter Speed
- Shutter Types
- Filters
- Camera Types
- Camera Set-up

Photography & Camera Anatomy

Photography - What should we target?

- Photoscan has the ability to measure to 0.13 of a pixel. Burry photos will not support those tolerances. Sharp focus, and minimized noise is important!
- Proper exposure, sharp focus, no grain or artifacts, minimize lens movement.
- Use a wide angle lens, change your orientation, proper base to height ratio and overlap.
- High quality surveyed ground control and or IMU systems. Traditionally, 3 times more accurate than you really need.
- Camera anatomy plays an important role in the quality of your photos.

Quality photos are key. Here's a few rules and points to consider in regards to capturing good photos for photogrammetry.

1.) Focal length needs to be fixed.

2.) Proper exposure of the image is required.

3.) Proper contrast in the image.

4.) Image is in-focus, but do not change the focus between photos.

5.) Depth of Field – Selecting a proper aperture.

6.) ISO Selected – Beware of noise.

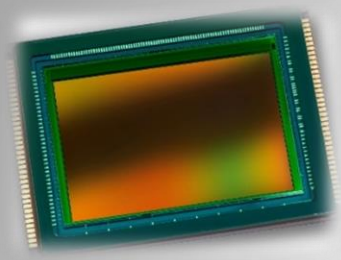
7.) Framed Properly

8.) Minimize shadows

9.) Capturing your photos in a consistent manner. (settings are not changed)

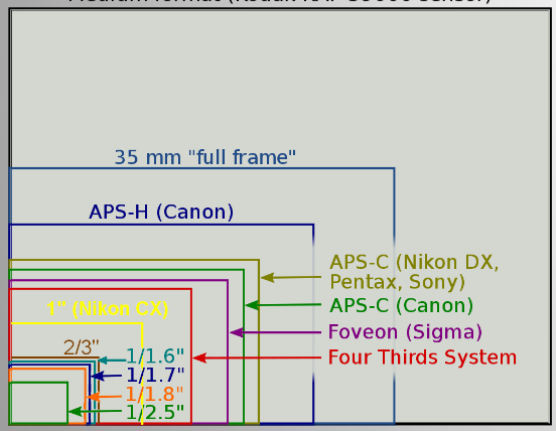
Photography & Camera Anatomy

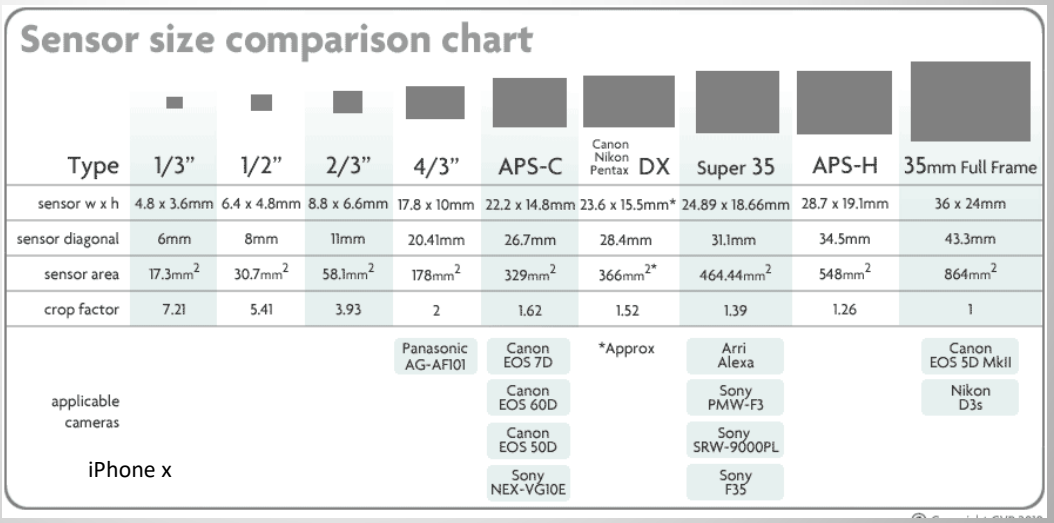
Image Sensors



- The size of the sensor influences the quality of images.
- Larger sensors have a larger dynamic range. Capturing more color values (Bit Depth)
- Larger sensors have more surface area for lighting and exposure.
- Larger sensors have a larger angle of view. (Crop Factor)
- Larger sensors need a larger lens to cast an image over it.
- Larger sensors have less noise at higher ISO settings.
- Larger sensors have higher resolutions because it can fit more pixels.

Medium format (Kodak KAF 39000 sensor)





Medium Format

iPhone x

$600

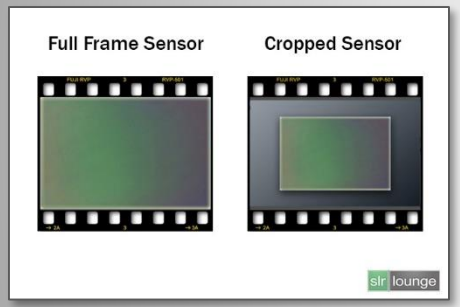
$2000

$20,000 +

Photography & Camera Anatomy

Image Sensors / Field of View

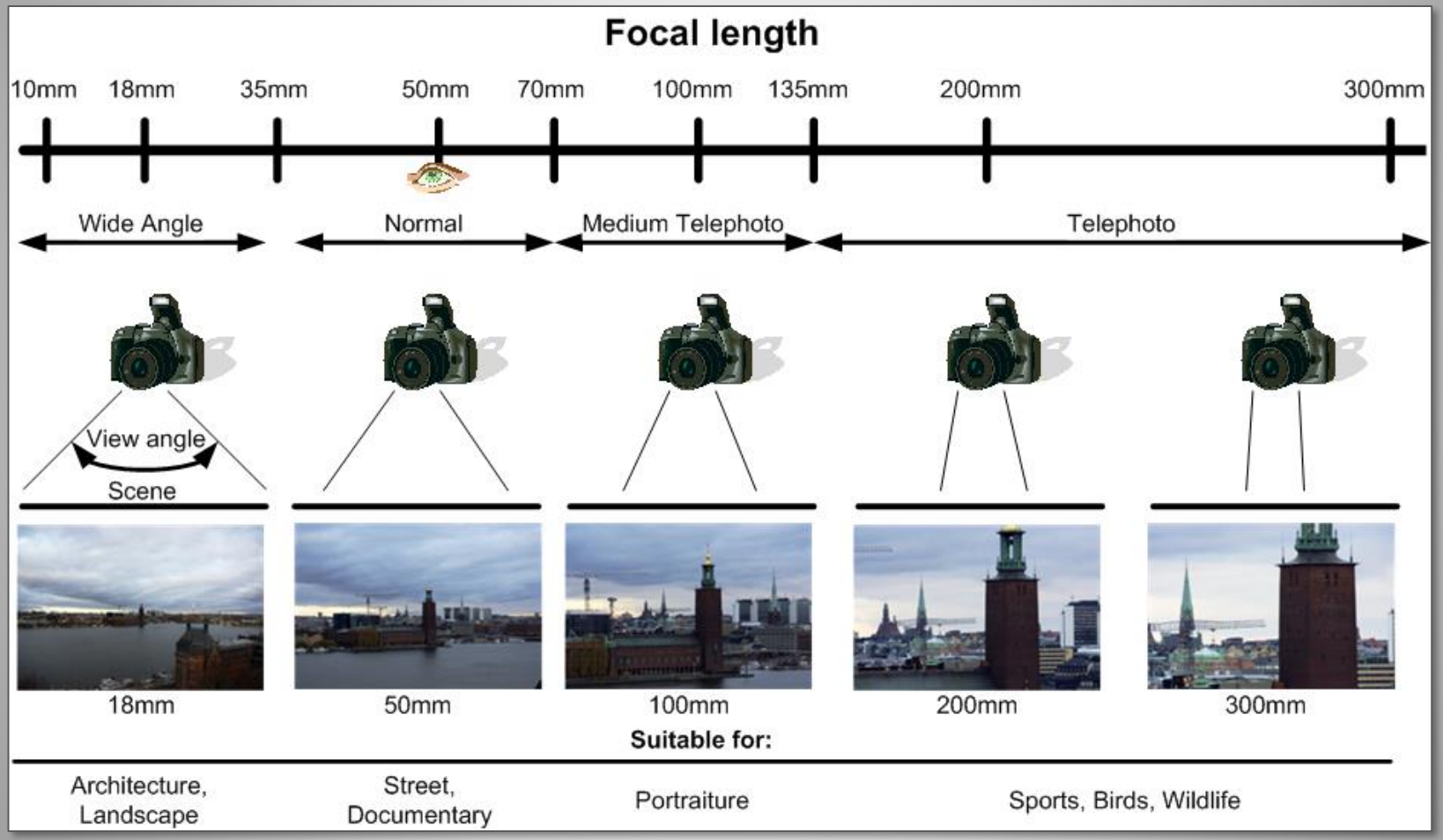
- Crop factor is the ratio of a cameras sensor size to a 35 mm full frame sensor.
- Larger sensors have a larger angle of view.
- Smaller sensors crop the field of view crop.



Photography & Camera Anatomy

Focal Length / Field of View

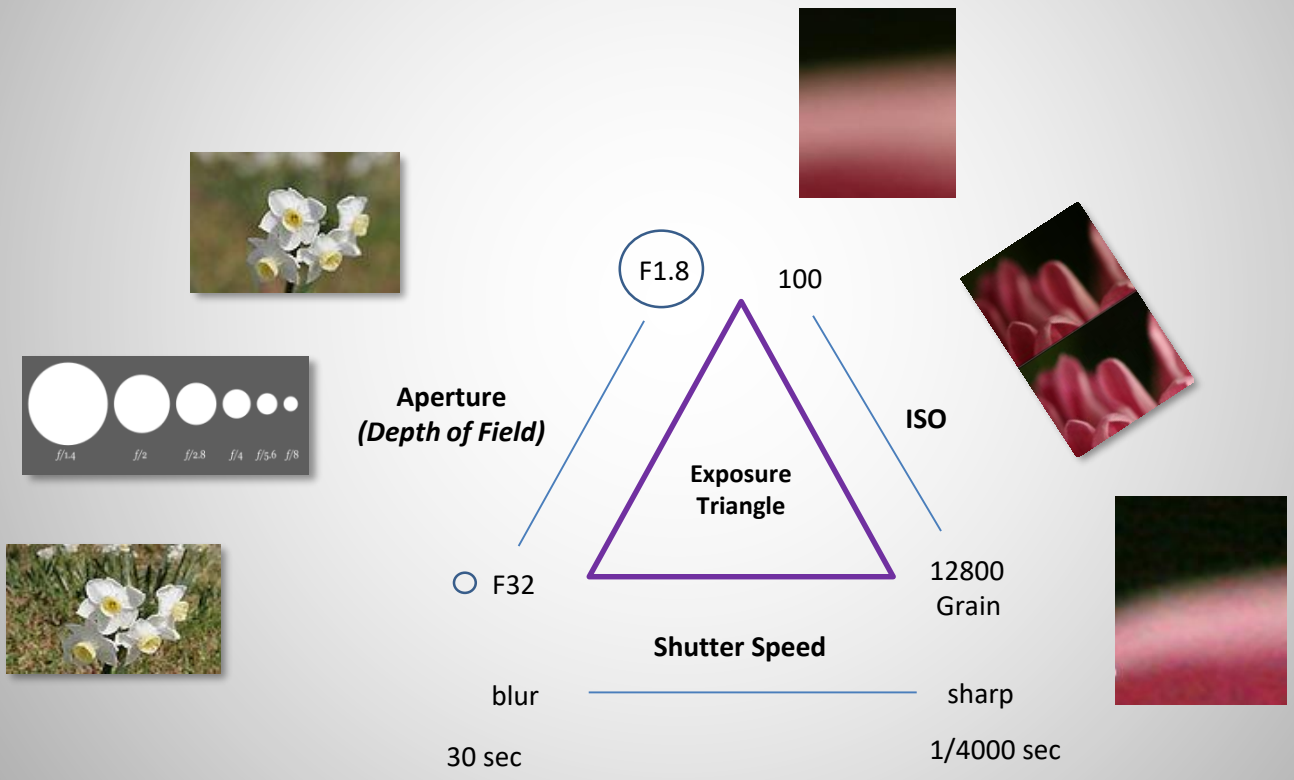
- **The distance between the center of a lens and its focus.**



Photography & Camera Anatomy

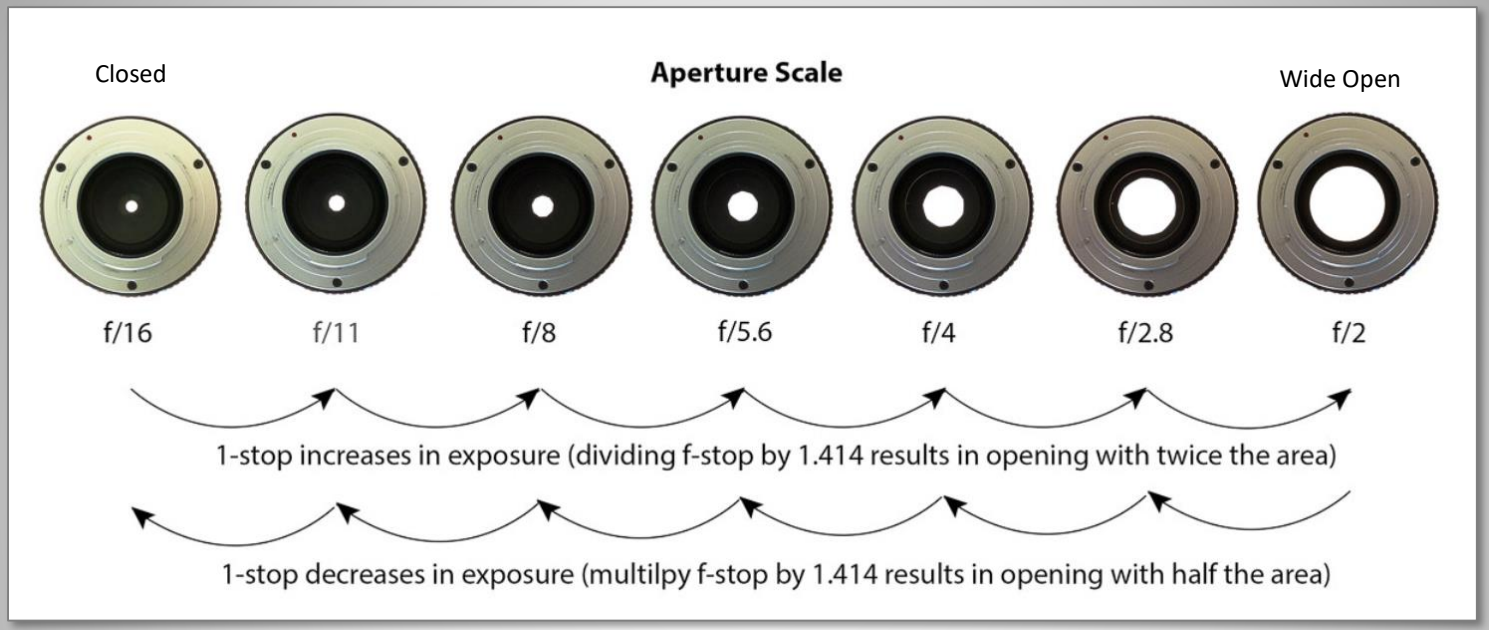
Principles of Photography / The Exposure Triangle

The exposure triangle is a common way of associating the three variables that determine the exposure of a photograph: aperture, shutter speed, and ISO. One must balance all three of these to achieve a desired result, an adjustment of one requiring adjustments of at least one of the others.



Photography & Camera Anatomy

Aperture – A space through which light passes an optical or photographic instrument. Measured in F-stops.

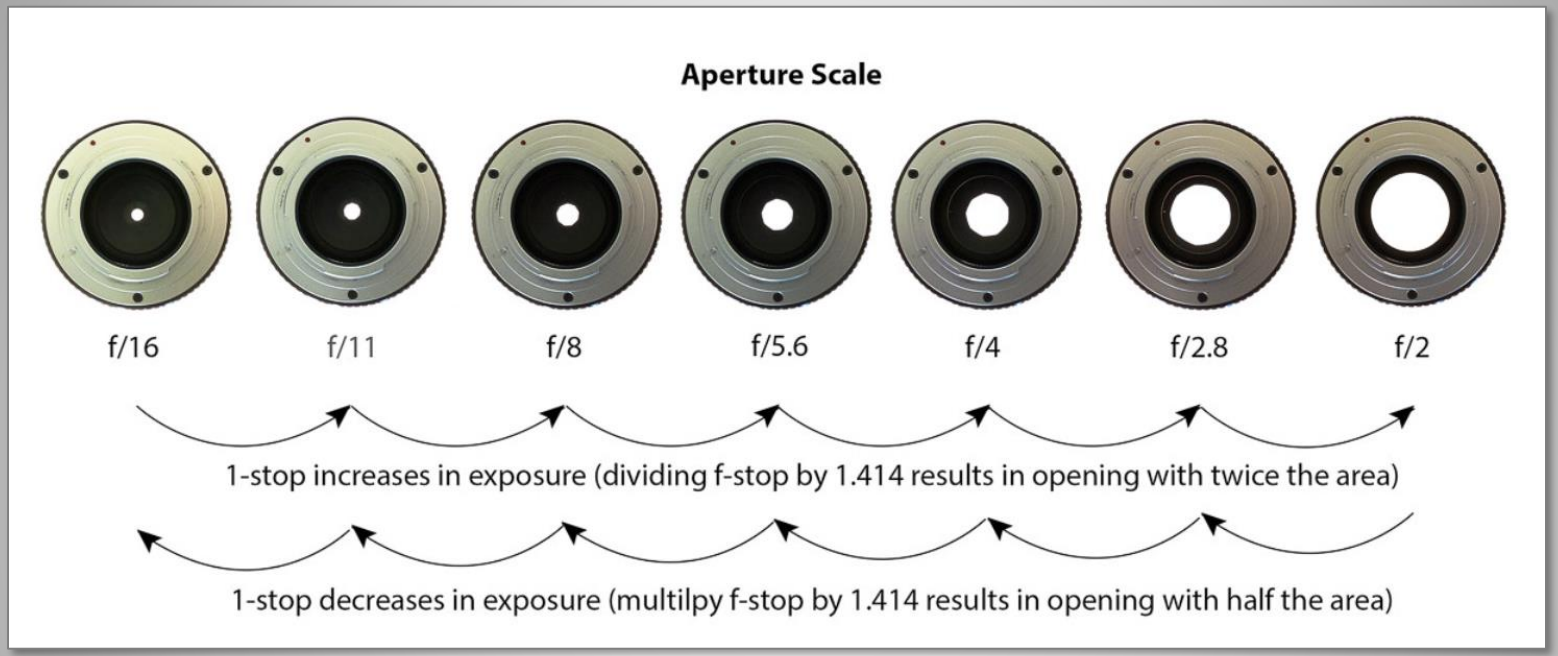


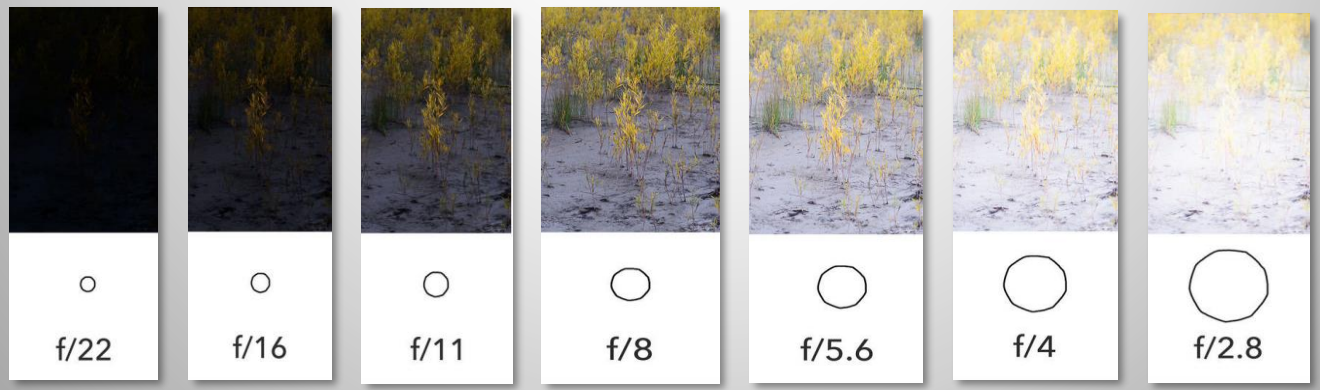
Range of Focus

Note: Digital cameras can be built to change to any aperture size, instead of doubling the size of the opening.

Photography & Camera Anatomy

Aperture – A space through which light passes an optical or photographic instrument. Measured in F-stops.

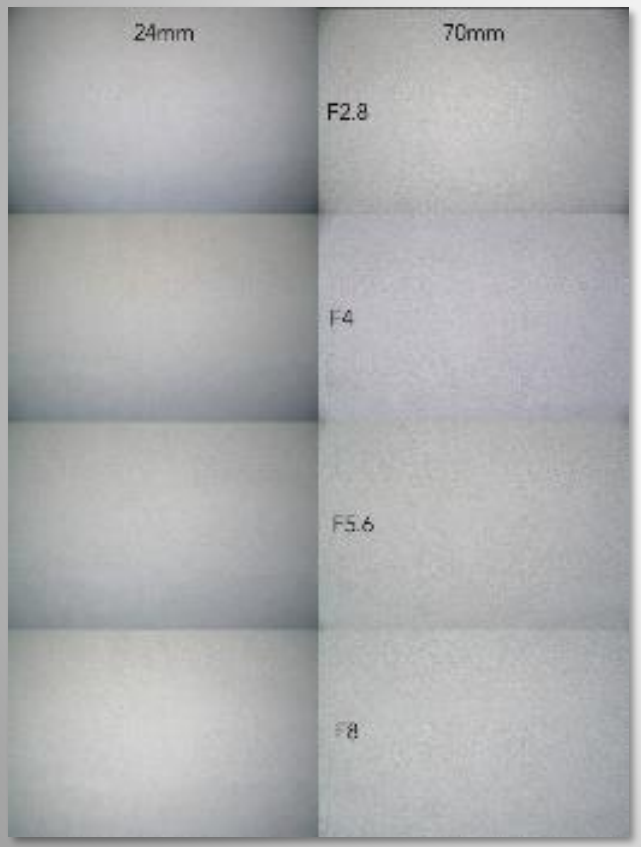




Photography & Camera Anatomy

Aperture – **A space through which light passes an optical or photographic instrument. Measured in F-stops.**

1.) Beware of optical vignette effects with changes of your aperture and lens focal length.



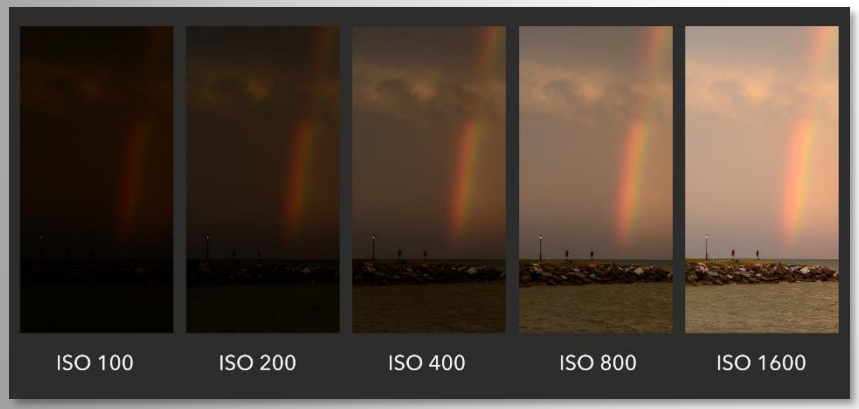
2.) Beware of image blur in the corners of your images due to your aperture.

Photography & Camera Anatomy

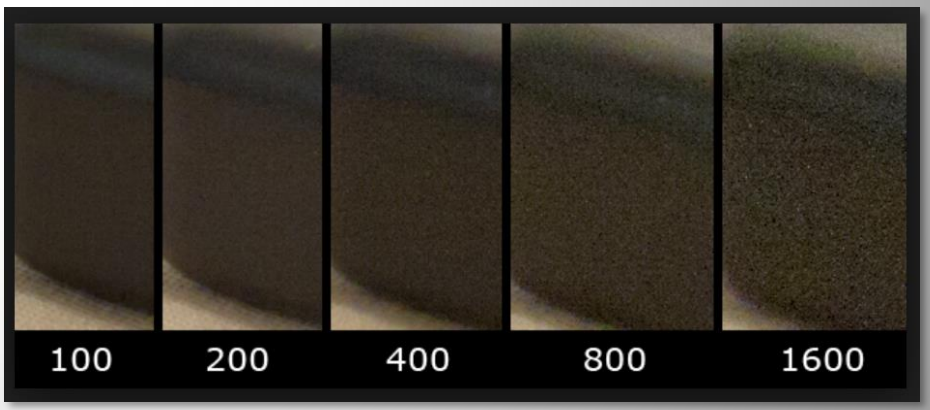
ISO

- The higher the ISO number, the faster the camera sensor absorbs light.
- In dim lighting situations, you can increase your ISO to achieve proper exposure
- Unfortunately, this benefit doesn't come without some consequences. The higher the ISO the more image noise (or grain) is created.

100 200 400 800 1600 3200 6400 12800



ISO Image Exposure Examples



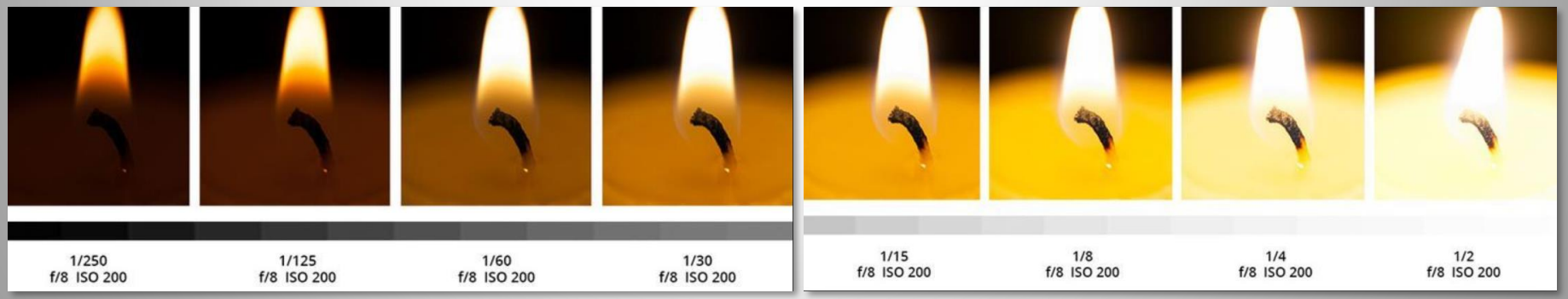
ISO Image Noise Examples

Photography & Camera Anatomy

Camera Shutter Speed / Exposure Time

- **Camera shutter speed or exposure time is the length of time the digital sensor inside the camera is exposed to light.**

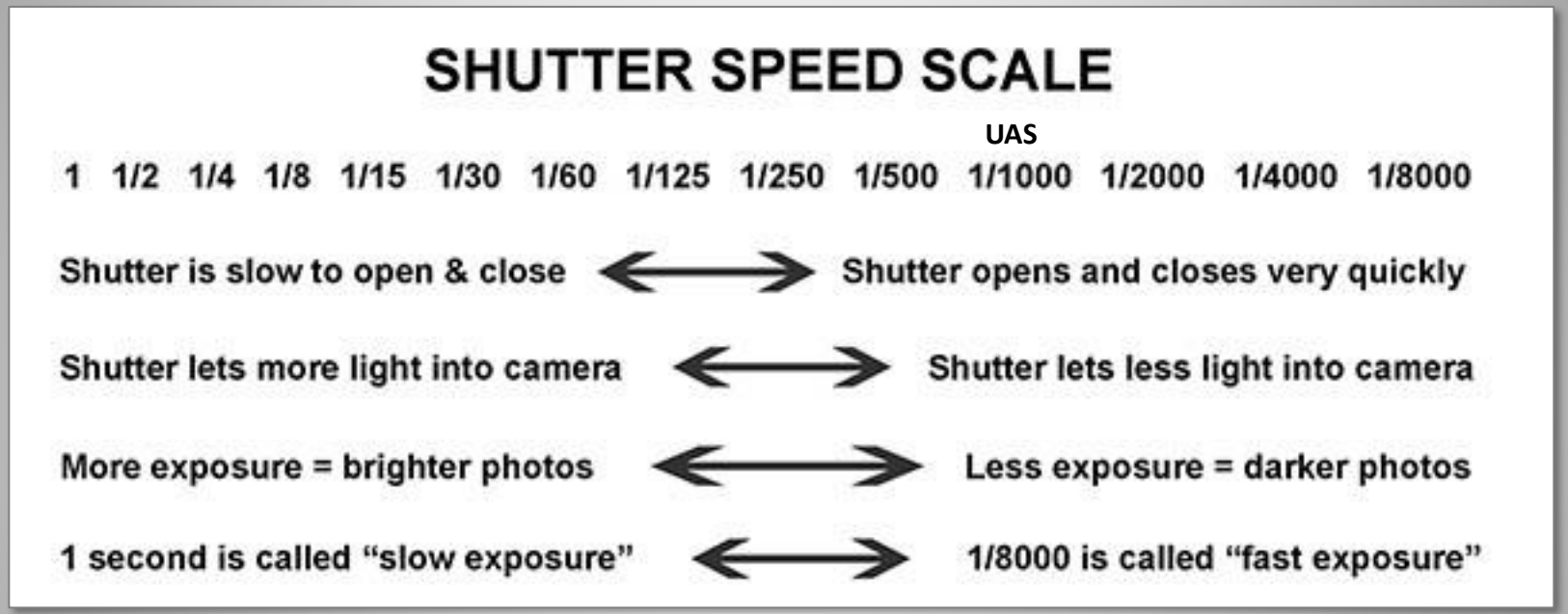
Shutter speed can cause blurring in the image.



Shutter Speed will affect your brightness of the image.

Photography & Camera Anatomy

Camera Shutter Speed / Exposure Time



- **Shutter speed or exposure time is the length of time the digital sensor inside the camera is exposed to light.**

Photography & Camera Anatomy

Camera Shutter Speed / Exposure Time

A good rule of thumb to reduce image blur is to set a camera shutter speed no lower than the time to move a half of pixel. (Source: Drone Mapper)

$$\text{Estimated Camera Shutter Speed} = \frac{(\text{GSD} / 2)}{\text{Speed}}$$

- Target our GSD size based on the flight height.
- Assume our flight speed

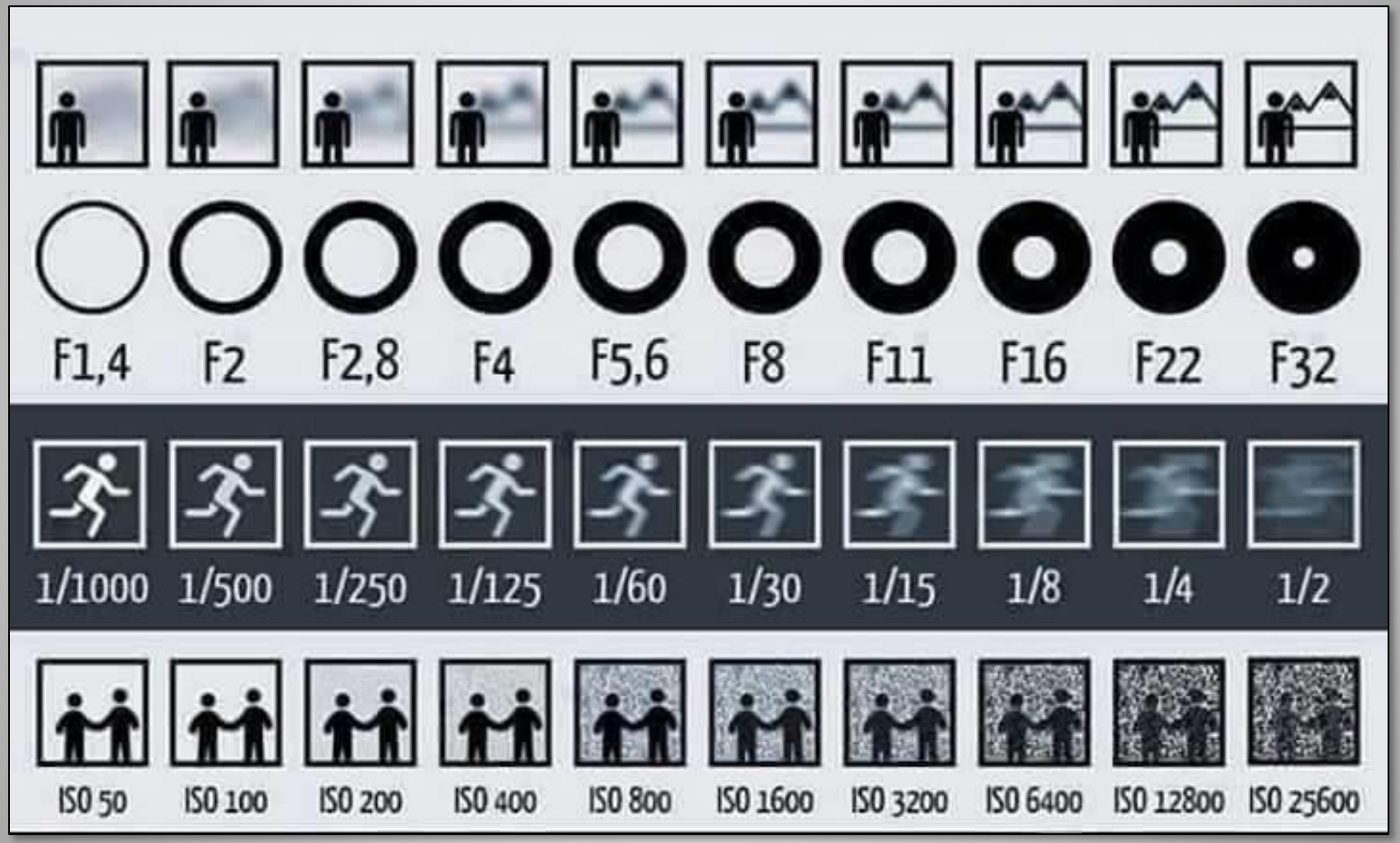
Examples

$$\frac{(3\text{ cm} / 2)}{(5\text{ m/s})} = 0.003\text{ sec or } 1/300\text{ sec}$$

$$\frac{(3\text{ cm} / 2)}{(10\text{ m/s})} = 0.0015\text{ sec or } 1/650\text{ sec}$$

Photography & Camera Anatomy

Recap of the Exposure Triangle

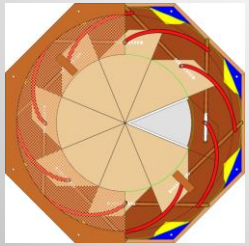


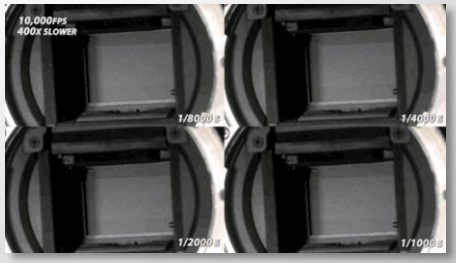
Mechanical Shutters and Electronic Shutters

Today, most digital cameras use combination of mechanical shutter and electronic shutter or mechanical shutter solely. Mechanical shutter can accommodate up to 1/16000 seconds (for example the Minolta Dynax/Maxxum/α-9 film camera had a maximum of 1/12000, a record in its era, and the later digital Nikon D1 series were capable of 1/16000), while electronic shutter can accommodate at least 1/32000 seconds, used for many superzoom cameras and currently many Fujifilm APS-C cameras (X-Pro2, X-T1, X100T and others).

Types of Mechanical Shutters: Focal plane Shutter, Simple Leaf Shutter, Diaphragm Shutter

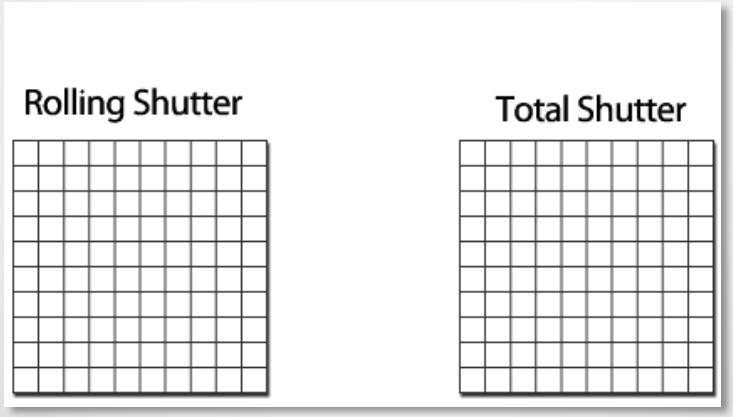
- **Most digital cameras employ mechanical shutters, though some small point and shoot cameras will use electronic shutters.**
- **Shutterless (electronic shutter) cameras tend to have more image noise in the image than their traditional shuttered counterparts. This is because shutterless cameras constantly send power to the sensor.**





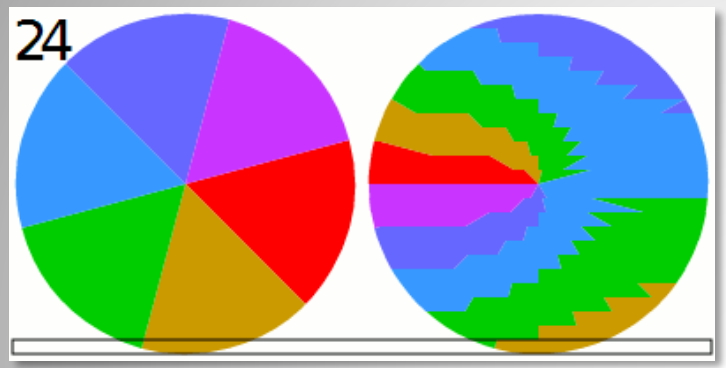
Rolling Shutters vs Global Shutters

- A rolling shutter exposes the image line by line, usually from top to bottom.
- A global shutter exposes the image across the entire sensor at the same time.

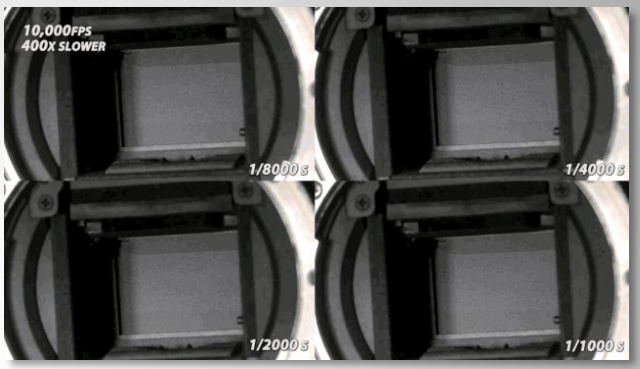


Photography & Camera Anatomy

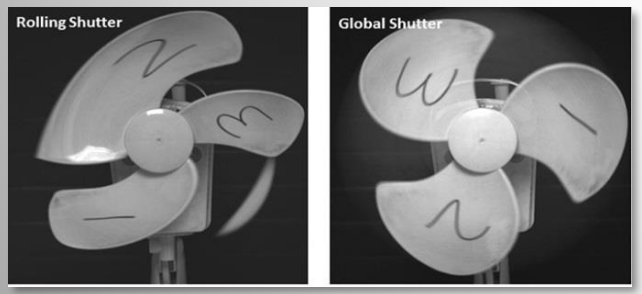
Rolling Shutters Examples and Issues



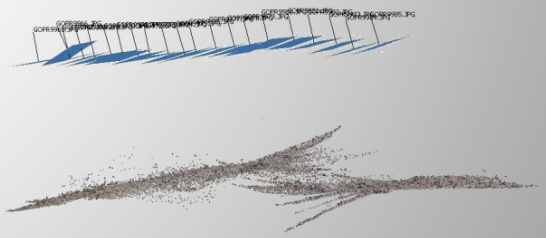
Moving Object Image



Mechanical Rolling Shutter example



Skew
Wobble
Partial Exposures
Smear



Most video cameras use a rolling shutter, but not all of them.

Photography & Camera Anatomy

Rolling Shutters vs Global Shutters

Rolling Shutter – Sony Action Cam

Photography & Camera Anatomy

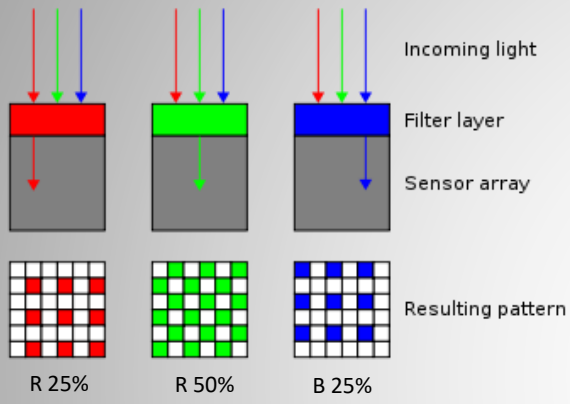
Rolling Shutters vs Global Shutters

Global Shutter – Ricoh GR

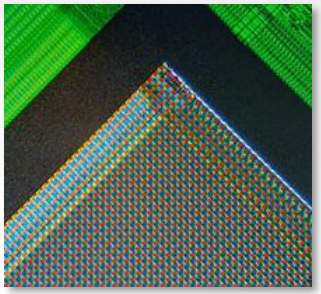
Photography & Camera Anatomy

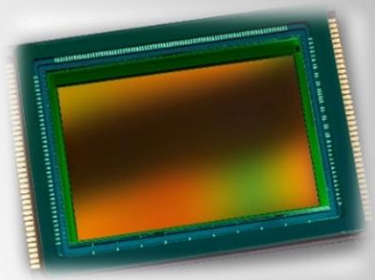
Image Sensor Filters / RGB Bands

Bayer Filter (Color Filter Array)

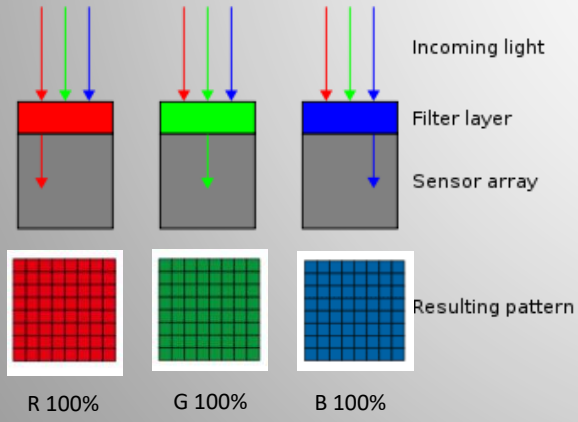


Most Commercial Off the Shelf Cameras

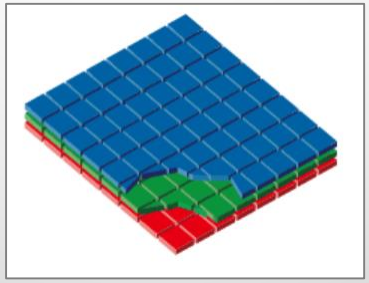


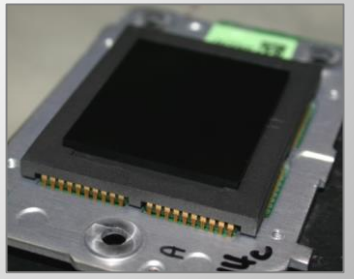


Direct Filter Array (dedicated sensors)



Specialized Cameras





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Commercial Off the Shelf (COTS) Cameras

- Having a higher quality camera build is more important than mega pixels.
- Collect in RAW, but typically processing is completed on .JPGs.

Compact Point and Shoot Cameras

- Typically Smaller Sensors
- Lightweight
- 8 and 12 Bit - Depth
- Contrast Based Auto Focus System

DSLR & MIL Cameras

- Typically Larger Sensors
- Heavier
- 12 and 14 Bit - Depth
- Phase Detection Auto Focus (Most Mirrorless cameras are a crossbreed)

	tones per channel per pixel	total possible tones
8 bit	256	16.78 million
10 bit	1,024	1.07 billion
12 bit	4,095	68.68 billion
14 bit	16,383	4.39 trillion
16 bit	65,532	281 trillion

Photography & Camera Anatomy

Current Cameras

	Camera	Sensor Size	MegaPixel	Bit Depth	Focusing Method	Anti-aliasing / Low Pass Filter
	MicaSense Rededge 3	4.8mm x 3.6mm	3.2 mp	12-bit	Contrast Adjust	None
	Sony a5100	23.5mm x 15.6mm	24.3 mp	12-bit	Contrast Adjust Phase Detect /Hybrid, Manual	On Fixed
	Pentax Ricoh GR II	23.7mm x 15.7mm	16 mp	12-bit	Contrast Adjust	None
	Sony a7R	35.9mm x 24.0mm	36 mp	14-bit	Contrast Adjust Phase Detect /Hybrid, Manual	None
	Sony RX1R II	35.9mm x 24.0mm	42 mp	14-bit	Contrast Adjust Phase Detect /Hybrid, Manual	On / Off
	Phase One IXU 150	43.8mm x 32.9 mm	50 mp	16-bit 14-bit	Manual	None

Photography & Camera Anatomy

Setting up the Ricoh GR II Camera for a UAS flight

In the Field Settings:

1.) Power On (battery 100%)
2.) Check SD Card
3.) Set Camera TAV
4.) Check Exposure Adjustment setting is set to 0
5.) Menu – Focus set to infinity
6.) Picture Format – Set to RAW + JPG
7.) Set ISO to Auto (as needed)
8.) Set Shutter Speed (as needed)
9.) Set Aperture (as needed)
10.) Meter Light / Make Adjustments
11.) Take Test Photo
12.) Set Intervalometer (as needed)

Shooting Tips:

- *Turn off auto rotate*
- *Turn off auto sensor cleaning*
- *Turn off Image Stabilization*
- *Focus to infinity and lock your AF*

Other Settings:

1.) Check your Time and Date Settings
2.) Auto Rotate - OFF
3.) Wi-Fi - Off
4.) Sleep Mode - OFF
5.) ND (Neutral Density) Filter - OFF
6.) Dynamic Range Comp - OFF
7.) Slow Shutter Speed - OFF
8.) Shutter / Aperture Auto Shift – Off
9.) Crop – Off
10.) Color Moire Correction – Cancel
11.) ISO Setting - Auto
12.) NR (Noise Reduction) – Off
13.) White Balance - Auto
14.) Image Setting – Standard

Photography & Camera Anatomy

A lot of information!

Source Credits:

Tom Noble, Neffra Mathews (BLM Photogrammetry Lab)
Mark Bauer, Jeff Sloan, Todd Burton, Joe Adams (USGS UAS Project Office)

National Unmanned Aircraft Systems (UAS) Project Office

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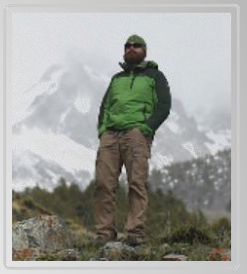

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