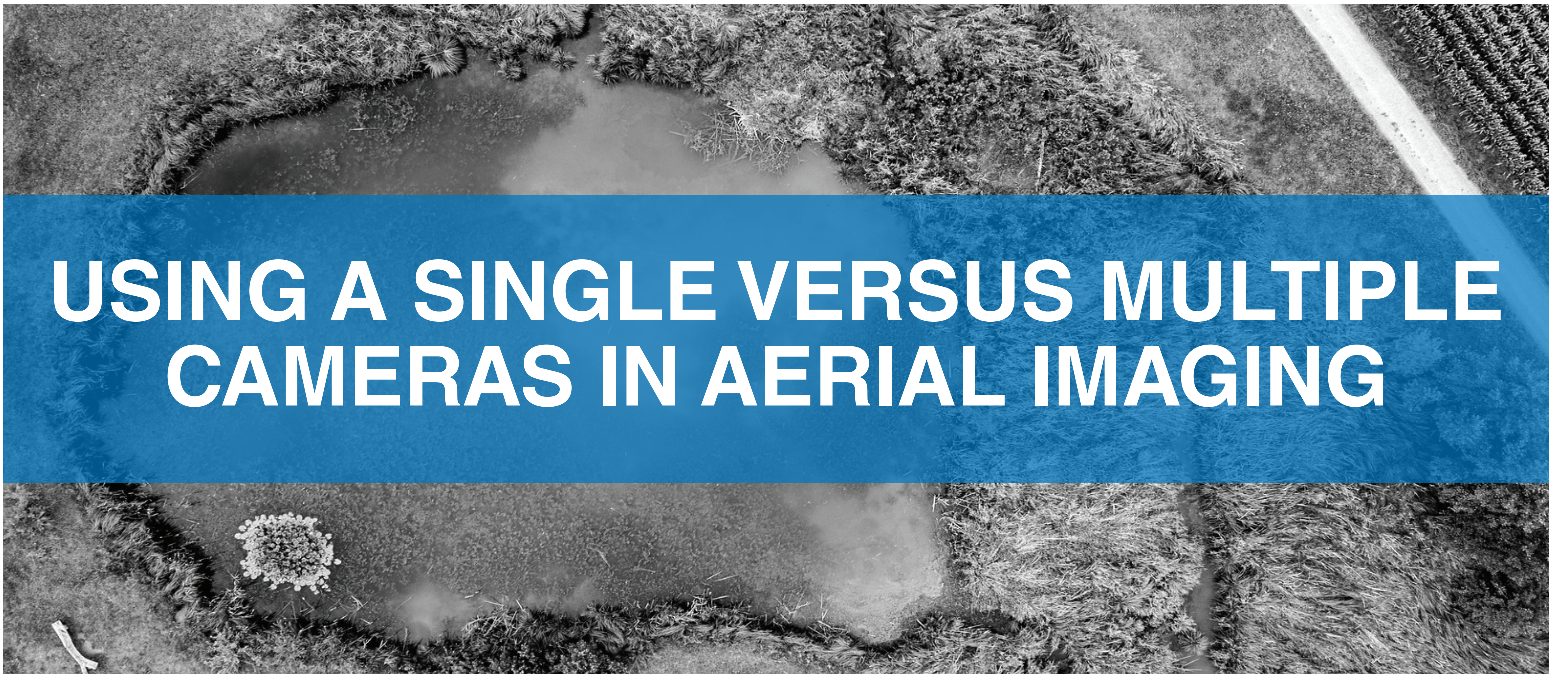
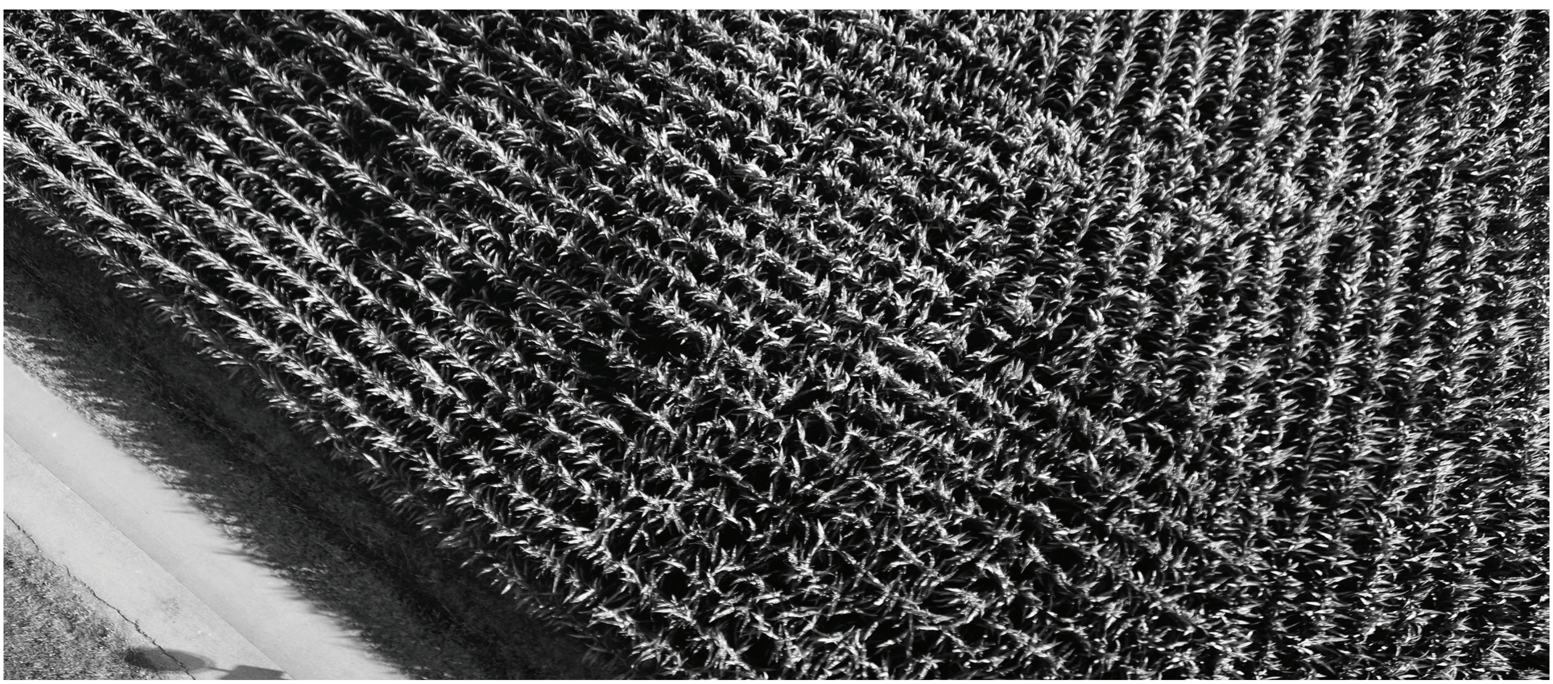


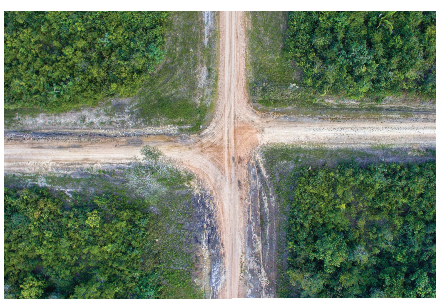
USING A SINGLE VERSUS MULTIPLE CAMERAS IN AERIAL IMAGING

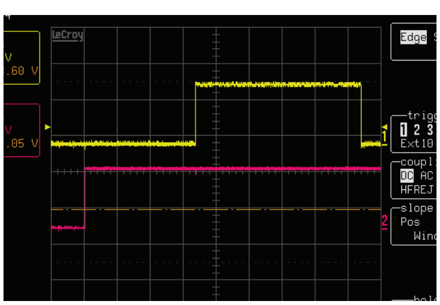
The Advantages of Using Mulitple Cameras For Aerial Imaging



TELEDYNE LUMENERA **WHITE PAPER**

USING A SINGLE VERSUS MULTIPLE CAMERAS IN AERIAL IMAGING





WHAT'S INSIDE

INTRODUCTION

When deciding on the right camera for an aerial imaging application, it might seem easier at first to simply look for the largest sensor or the most amount of megapixels (MPs) available. However, using multiple smaller cameras in place of a larger one can often outperform the single camera. The advantage of taking images with aerial vehicles comes from the wide landscape view the camera can capture. By combining multiple cameras side by side and putting those images together, a wider field of view (FoV), known as the image "swath" in Aerial Photogrammetry, can collect far more data and result in a more effective aerial vision system. Of course, the use case for multiple cameras varies and may require more planning.

MOSAICS

Pixel Height

The camera choice for aerial imaging should not be based just on the resolution of the camera. Images taken by an aerial vehicle are a mosaic that is stitched together, increasing the pixel height with ever additional image to the mosaic. Therefore, the pixel height of an image can be compensated for by stitching more images together. The cameras used for aerial imaging generally take images relatively slowly at a rate of one image every two seconds. By contrast, modern sensor technology can take dozens or even hundreds of images per second. To create a mosaic of a larger height with a smaller sensor, the camera needs to increase how frequently images are taken. As illustrated in Figures 1 to 3, the larger sensor will have a higher pixel height for every image, but the shorter and wider dual-camera setup can stitch images together to result in a much higher resolution mosaic, increasing the coverage area being imaged. Therefore, for a mosaic application, higher pixel height per image does not result in any net gain.

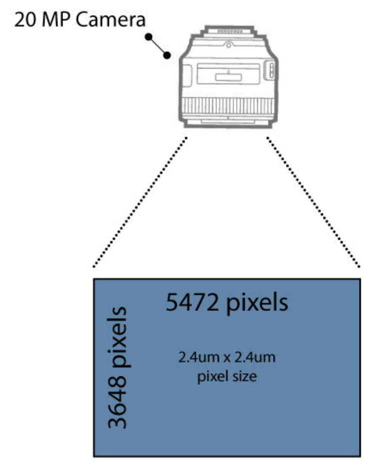


Figure 1 – Image Taken by a 20MP Camera

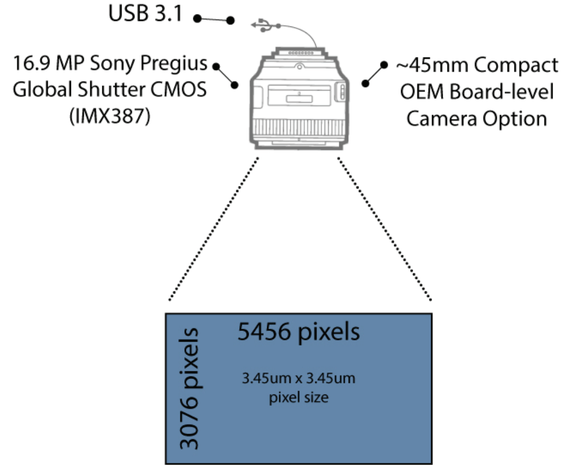


Figure 2 – Image Taken by 16MP Camera

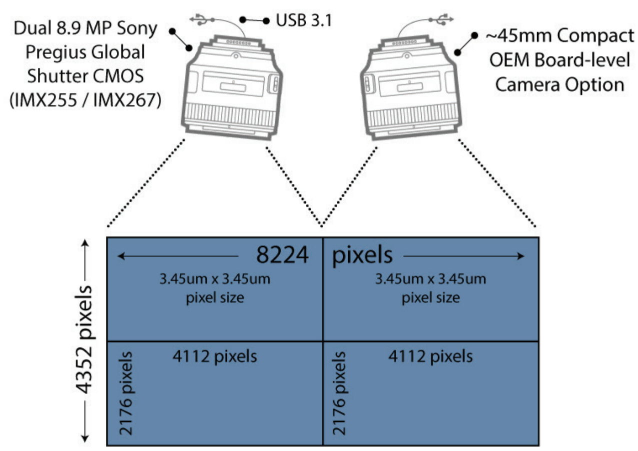


Figure 3 – Mosaic Taken by Two 9MP Cameras

Pixel Width

The pixel width identifies how much area can be surveyed at once. A larger megapixel size can help, but by putting two cameras together, as seen in Figure 3 and 4, the smaller 9MP or 5MP camera pair can substitute or even surpass the pixel width of larger sensors. Therefore, the difference in megapixels between Figure 1 and 2 is mostly due to the vertical pixels. As mentioned before, the pixel height can be compensated for in a mosaic by taking more images. So, it should also be noted that the actual megapixel value is not a good parameter for aerial imaging but when choosing a camera there are several other factors that should be considered such as: ground sampling distance (GSD), dynamic range, sensitivity, and noise.

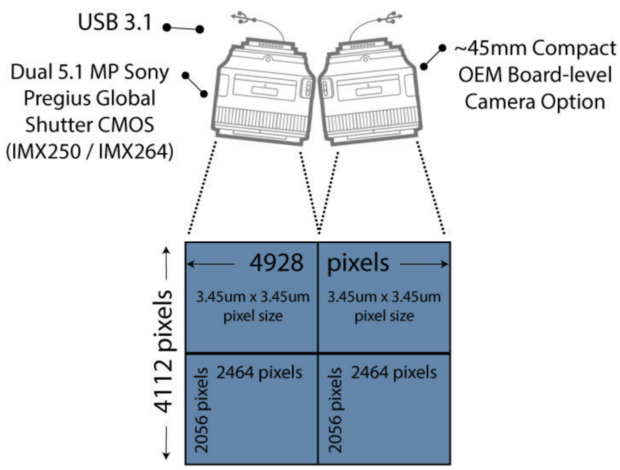


Figure 4 – Mosaic Taken By Two 5MP Cameras

STITCHING IMAGES

Doubling Pixel Width

Due to the significance of the pixel width, it can be advantageous to combine cameras together and effectively double the pixel width. When mounting two cameras side by side, a high level of accuracy is required to minimize the overlap of the images that make up the mosaic. The difference between a 20MP camera and a properly synchronized set of 9MP cameras can be seen in Figure 5.

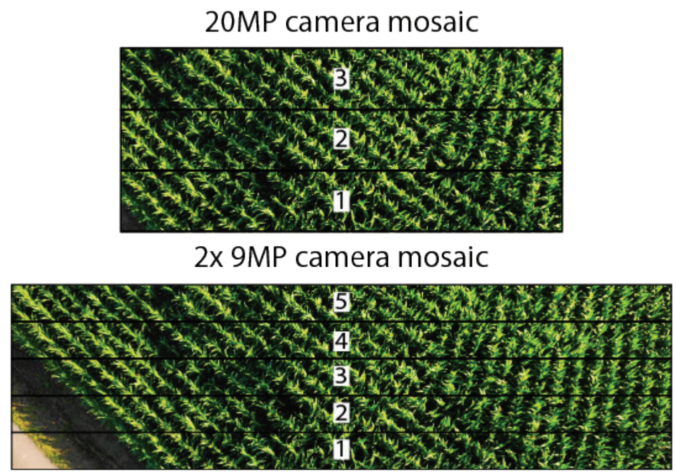


Figure 5 – Comparison of Single and Multiple Camera Setup to Optimize Pixel Width

Overlap

Overlap refers to the amount of pixels in each image that match each other. This means that each image will have a certain area that overlaps with another image and reduces the unique pixels within each image. In older solutions up to 80% of images need to be overlapped to achieve usable results. In Figure 6 the three stacked images have some overlap with part of the landscape that was imaged. The three images are stitched together and there is a clear indication of what areas do not contain unique information. This illustrates the issues that can come from improper calibration. Using real-time sensor data combined with deterministic triggering ensures minimal overlap can augment the maximum amount of unique data that can be collected from each image within the mosaic.

Figure 6 – Overlap of Three Images Illustrating Loss of Unique Data from Each Image

TRIGGERING SOLUTIONS

Software Triggering

Software triggering can be one of the ways in which cameras can take images simultaneously. A typical camera trigger might be thought of as a physical button that would be pressed down to take an image. Instead, for an aerial imaging camera there needs to be another option that can be used to trigger the camera automatically. With a software trigger the camera internally runs software than can take images on a timed loop.

However, this type of solution usually results in an asynchronous system due to the limited accuracy of software triggers taking images at slightly different times. The reason for the inconsistency in timing has to do the processing overhead within the operating system where the API will call the camera. Other tasks or priorities may need to be completed beforehand. This inconsistency with trigger timings results in a misaligned stitching such as the example in Figure 7 that is exaggerated to visualize this effect. It might be necessary, based on size and weight restrictions, to not have a physical trigger, although modern triggers have become increasingly more compact and lightweight. The cameras can also be timed to a clock, but can still result in taking images at slightly different times based on the accuracy of the clocks within each camera.

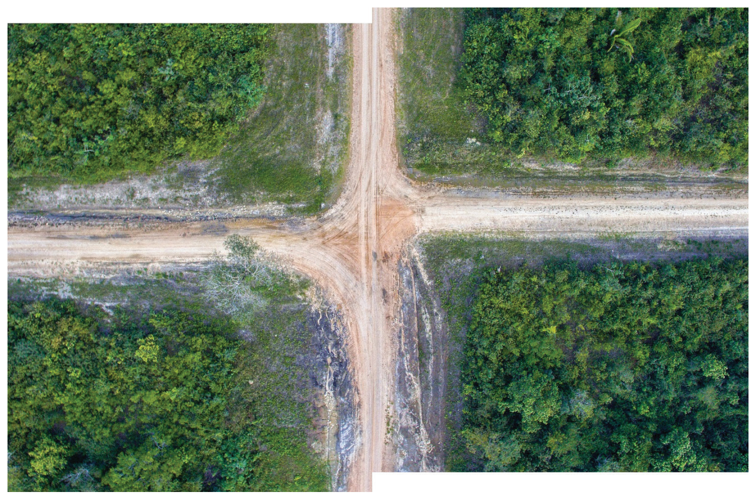


Figure 7 – Misalignment of Two Side-By-Side Images Taken From a Dual-Camera Setup

Hardware Triggering

Instead of using a software trigger, the cameras can be activated using a hardware trigger. Each camera can be connected to their own trigger that is calibrated to try and compensate for the difference in timing. Alternatively, both cameras can be connected to the same trigger which then sends the signal to both cameras at the same time, activating both to take an image simultaneously. For another accurate trigger, a camera can be chosen to be the primary camera which is referred to as the master. This means it controls what the other camera does by having a physical connection to the secondary camera (known as the slave).

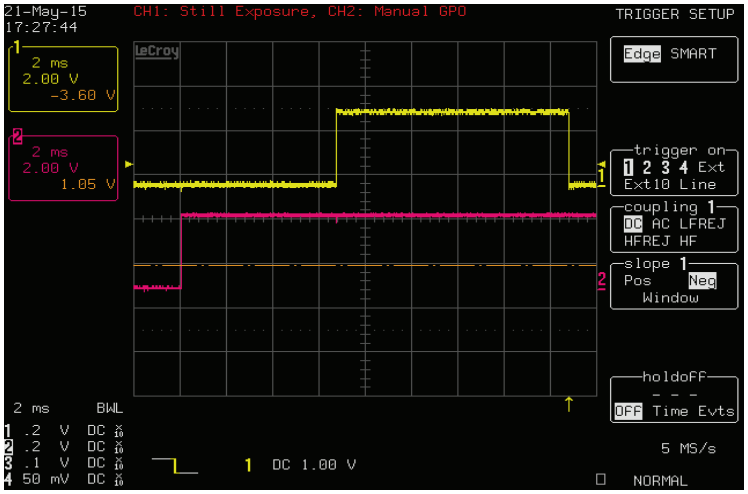


Figure 8 – Real-time Comparison of Software Triggering a Camera and Activating the Camera

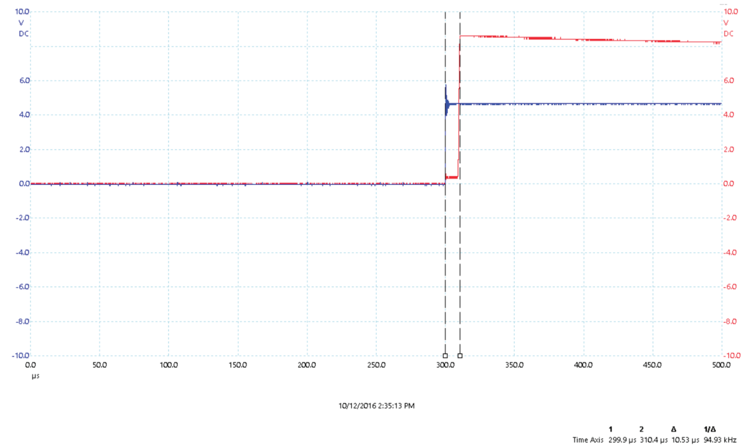


Figure 9 – Real-time Comparison of Hardware Trigger Sending a Signal to the Camera and Activating the Camera

The process starts with the hardware or software trigger sending a signal to the master. The master then sends a signal to the slave and both cameras capture an image together. This process is deterministic unlike a pure software solution because the time for which it takes the slave to take an image after receiving the master's signal can be accounted for (as seen in Figure 9). There is a measureable difference between when the signal was sent and when the slave actually activates. The difference in the amount of delay between the software and hardware triggers activating the camera can be compared in Figures 8 and 9 respectively. The amount of time in between the master sending a signal to the slave and the slave actually triggering can be measured precisely and then used to delay the master's own internal trigger which results in a sequence of events shown in Figure 10. By accounting for this precise timing the master and slave method will ensure both cameras can take an image at the exact same time.

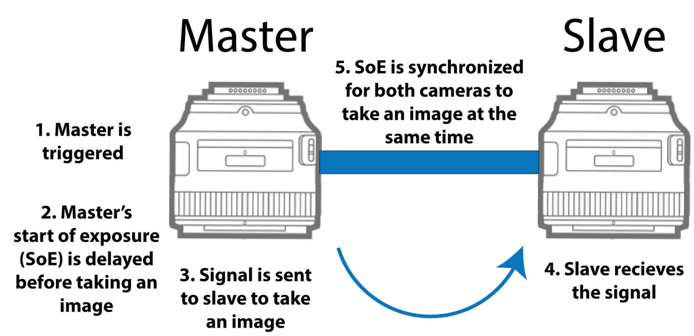


Figure 10 – Master and Slave Camera Triggering Configuration

CHALLENGES

On-Board Image Processing

In the case of real-time image stitching for creating a mosaic, one challenge may be developing a system that can processes both the image and flight data quick enough in a small package. Many solutions exist that can process aerial images on a computer or on the cloud. However, to make the most of an aerial vision system, having an aircraft capture images takes time which could be spent processing those same images.

SWaP Restrictions

When adding the necessary processing power to a UAV capable of on-board image processing, the size, weight, and power (SWaP) restrictions need be considered as well. This is why more lightweight UAVs tend to save images directly to a storage device (i.e. an SD card). There needs to be a compromise between the convenience of having the images processed in the air or waiting until the aircraft lands to process the images.

Having additional cameras can also cause added weight. The more weight added to a UAV system the more power required to lift the UAV. Even with a board level camera that has the heavy chassis removed, adding additional optics for each camera on the aircraft will weigh it down significantly. The added weight will increase the power consumption and will limit the possible airtime for the aircraft.

However, depending on the specific cameras and lenses, they can potentially weigh less than a single larger resolution camera. It should be noted that multiple cameras typically covers a wider imaging area, or offers better GSD, and second camera even provides some redundancies. Therefore, the pros and cons needed to be considered carefully.

TYPES OF AIRCRAFT

Unmanned Aircraft

Gas powered UAVs are often much larger and are not usually constrained by the same power limitations as their smaller counterparts, the battery powered UAV. The ideal form factor for UAV cameras involves having wider versus taller chassis or no chassis at all because for many UAVs the length of the legs limits what can be mounted on the underside of the drone. With lenses also being taken into account, the result is that a flatter form factor is better suited for UAV cameras. On the other hand, for much taller and powerful aircraft, there is less focus on these issues as performance is the number one concern.

Manned Aircraft

Manned aircraft use a lot of power and are so heavy / large that the addition of several cameras may not have the same downsides as it may with smaller aircraft. Therefore, these aircraft can likely handle several cameras together that allow a more powerful setup containing many large format cameras.

PRICING

From a cost saving perspective when the price per megapixel is compared, two 9MP cameras are a far better return on investment when compared to a 16MP camera. The two 9MP cameras are slightly more expensive but with over 65% more pixel width the cost is actually less relative to the performance. As seen in Figure 11, the cost per megapixel for each setup shows that when combining cameras the overall benefit is not just in performance but is financially beneficial as well.

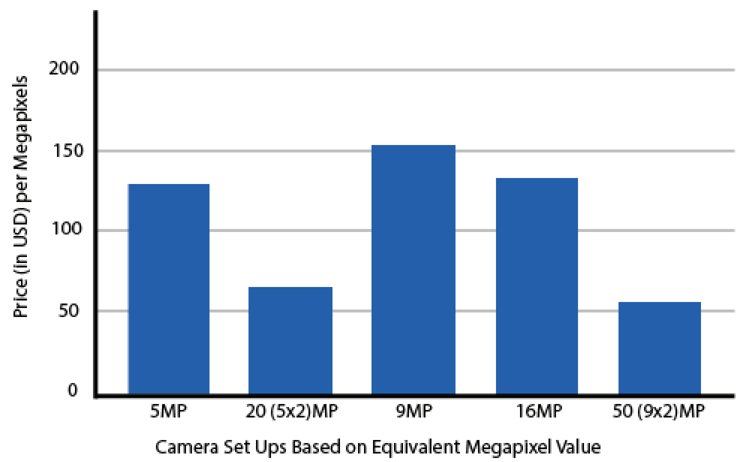


Figure 11 – Cost per Megapixel for Single and Multiple Camera Setups (Lower is Better)

CONCLUSION

Considering the strengths associated for aerial imaging, using multiple cameras can be an ideal choice, but the type of aircraft is what ultimately decides what solution is best. Some compromises must be made for battery powered aircraft, but for larger gas powered vehicles such as military grade UAVs and manned aircraft, the optimal solution often comes down to pure performance.