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# Assessment of Nighttime Airborne Visual ASW Capability

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# ASSESSMENT OF NIGHTTIME AIRBORNE VISUAL ASW CAPABILITY

# EXECUTIVE SUMMARY

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**Prepared for:**
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**Project Summary**
Rapid developments in small unmanned aircraft systems (sUAS) are accelerating their extensive deployment in the commercial and military communities. Combining low-light imaging sensors and advanced signal processing mounted on a sUAS can provide a fiscally responsible capability for nighttime subsurface object detection for the naval and merchant vessels and contribute to anti-submarine warfare (ASW). Low-light sensors mounted on sUAS systems can leverage marine bioluminescence as a naturally occurring object enhancement to detect, track, and potentially identify subsurface objects in the vicinity of vessel traffic. This report presents the results of initial attempts to collect and process imagery of relatively large moving objects in the shallow waters in Monterey Bay, California.

The preliminary tests with low-flying sUAS with affixed Sony UMC-R10C and 10-band MicaSense Blue/RedEdge-MX dual payload (20-megapixel and 1.2-megapixel per band sensors, respectively) showed concerns with the percentages of pixels per image based on the altitude of the aircraft, dictating a need to reduce experimental altitude based on the sensor specifications to improve the identification of a subsurface object at shallow depth. Imagery obtained using an affixed SBIG STC-428 photometric complementary metal-oxide semiconductor (CMOS) -based 7-megapixel sensor showed challenges with the exposure time creating elongated imagery and the need to use a filter to focus the sensor on the specific wavelength of light for bioluminescence detection. The lessons learned were reported to the sponsor. It is suggested to conduct some additional lab tests and low-altitude flights using a 40-megapixel sensor with a multirotor UAS launched from the ship.

**Keywords:** *anti-submarine warfare*, *bioluminescence, low-light and multispectral sensors, image processing, unmanned aircraft systems*

**Background**
In lieu of a submarine, this research attempted to detect a large marine mammal. If successful, the same methodology would then be applied to anti-submarine warfare. Subsurface collision by naval and merchant vessels is a growing safety, security, and environmental concern. In 2007, the International Whaling Commission (IWC) launched a long-term initiative to collect and analyze information about reported ship strikes, both historic and current, aiming at identifying "hot spots" where large numbers of whales coincide with busy shipping lanes. Satellite tracker data that were placed on 14 whales off the coast of northern Chilean Patagonia and publicly available shipping information indicates that whales feed in spaces subject to intense marine traffic. To date, IWC has identified 12 hot spots and has logged at least 1,200 collisions between ships and whales globally (Bedriñana-Romano et al., 2021).

Currently, technology such as radar is insufficient for subsurface object detection, and there is no other system in place for nighttime subsurface detection in real time. The use of sUAS leveraging bioluminescence for this application has been proposed after operational photography of a school of tuna was captured off the coast of California (Brodie & Donaldson, 2021). The use of aerial imagery for detecting subsurface marine mammals is not new and has been tested successfully many times in daylight operations (Schoonmaker et al., 2011). This research sought to determine the field feasibility of combining this naturally occurring image enhancement phenomena with advanced image processing to further the research in nighttime subsurface object avoidance.

To detect bioluminescence at night this research relied on using a range of small sensors that can be carried aboard a typical commercially available sUAS or tactical UAS of a RQ-21 class. Indeed, in the case of sUAS, the major constraint is the size of the sensor. The search for all feasible commercially-available sensors resulted in choosing the 10-band MicaSense Blue/RedEdge-MX dual camera system and combined Sony UMC-R10C and 5-band MicaSense RedEdge-MX. This research also involved building another sensor inhouse. To this end, a CMOS camera with a high light sensitivity and a fast readout was chosen and combined with a Nikon lens and a bandpass filter for blue light.

Data for the experiments was captured from the sensors onto secure digital (SD) memory cards. After completion of any experimental run, the SD cards were removed and the data was transferred to a computer for processing. A combination of Agisoft and MATLAB software suites were used to post-process the imagery. Agisoft photogrammetric processing allows for creation of orthomosaic overlays of sensor data by stitching together images from preprogrammed mapping patterns into a single orthographic image. MATLAB Image Processing Toolbox allowed for detailed analysis of the imagery—specifically, enhancement to bring out underlying or fine detail.

**Findings and Conclusions**

When flown at 120m mean sea level (MSL), the MicaSense RedEdge-MX sensor's image resolution of a gray whale of a typical length of about 14m and width of 3.5m occupies 7,666 pixels or 1% of the image. The assumption is that in the case of bioluminescence presence, the amount of light collected by 1% of the area of the sensor should suffice to detect or even identify a whale. The strength of bioluminescence emission would then define sensor exposure. At night, it may require extended time to capture enough emitted light, but this creates a problem. With a sUAS flying at low altitude at cruise speed of 17m/s, compatible with the speed of the ship, longer exposure (which would be required to capture weak bioluminescence emission) means image shift. For longer exposure times this shift can be relatively large, especially for the lower altitudes.

Like in the case of a commercial-off-the-shelf MicaSense RedEdge-MX sensor, when using an inhouse-built CMOS sensor, a 14m×3.5m whale would occupy 19.3% of the image if flown at 400m MSL and 5.5% when flown at 1,400m MSL. While this performance of the black-and-white low-light sensor is still acceptable, the image shift for a faster flying platform may become an issue. Obviously, with a much longer exposure, a whale would appear not as it would be seen during the daytime. The effect of the stretched image, caused from the movement combined with the exposure time, could be calculated and processed to produce a clear image. It would also be possible to combine a stack of images with lower exposure times. If the observed object changes its pose or shape, as may be the case if a whale moves, the result will not be a sharp image.

To ease the process of finding a subsurface object in the ocean at night (using the light from bioluminescence) it is necessary to avoid other light-emitting sources and reflections. Therefore, it is natural to use a narrow blue bandpass filter with a fitting bandwidth of 460 nm to 490 nm. Another practice is to focus on times when the moonlight is low, either at new moon times or after moon set when the moon has fallen below the horizon.

The conclusion is that developing a novel nighttime subsurface object detection capability is a very challenging task. The test results showed that even with applying a narrow blue bandpass filter and using long exposure time settings, getting a clear image of a moving subsurface object was almost impossible. Since the entire technology relies on unpredictable bioluminescence emission, which is typically very weak anyway, the current state-of-the-art miniaturized sensors that a typical sUAS can carry does not seem to facilitate a reliable detection capability to contribute to ASW.

## Recommendations for Further Research

At this point in the research there are no field-ready findings from this report. However, three topic areas are ripe for further research with a potential for field implementation. First, sensor specification and settings must be researched further for use at night. Specifically, further research should investigate the effect of analog and digital gain optimized with sensor aperture and exposure time to reduce image shift and create a clear image of a moving target while the aircraft is moving.

Secondly, once those sensor specifications are researched, more test trials could be conducted throughout the year to capture experimental data with different levels of bioluminescence. The use of both multirotor and fixed-wing small unmanned aircraft systems must be explored in conjunction with offshore stationary platforms to detect and track the bioluminescence.

Lastly, algorithms to scan and isolate images that may contain low levels of emitted bioluminescent light could be developed. This will further the research by helping to comb through the thousands of captured images during each flight, but it will also be a step toward real-time imagery processing once the sensor systems are matured.

## References

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## Acronyms

| | |
|---|---|
| ASW | anti-submarine warfare |
| CMOS | complementary metal-oxide semiconductor |
| IWC | International Whaling Commission |
| MSL | mean sea level |
| SD | secure digital |
| sUAS | small unmanned aircraft system |