NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

SUPPLEMENTAL TO THESIS
(1 OF 4: PRESENTATION OF HOODTECH RESEARCH RESULTS)

ASSESSMENT OF NIGHTTIME AIRBORNE VISUAL ASW CAPABILITY

by

Justin P. Goff

June 2023

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Second Reader: Fotis A. Papoulias

Approved for public release. Distribution is unlimited.

Shallow Search of a 10-Mile Swath with a Flight of Ship-Based UAVs

October 2022

Dr. Andreas von Flotow (Hood Technology)
Rear Admiral Tom Q. Donaldson (Ret US NAVY)
Dr. Shaju John (Hood Technology)

Hood Tech Vision Proprietary

PAISO Use and Development

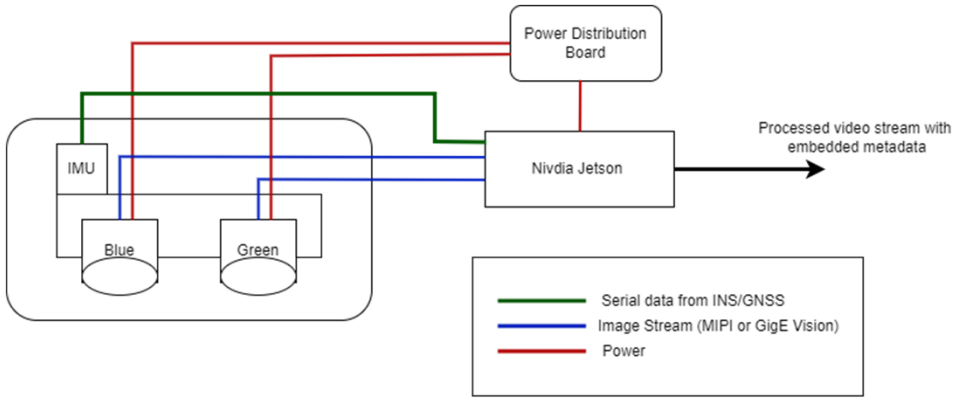
PAISO (Passive Airborne Imaging of Submerged Objects)

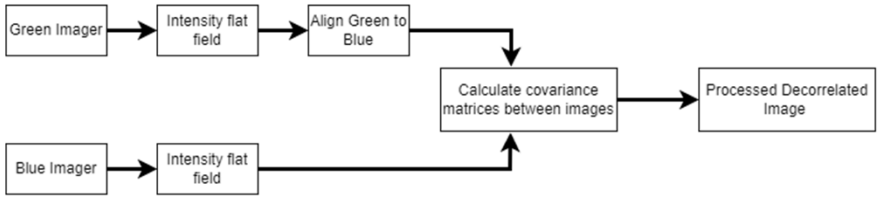
Intended Use - UAVs

Development Flying - Cessna

PAISO Development Hardware

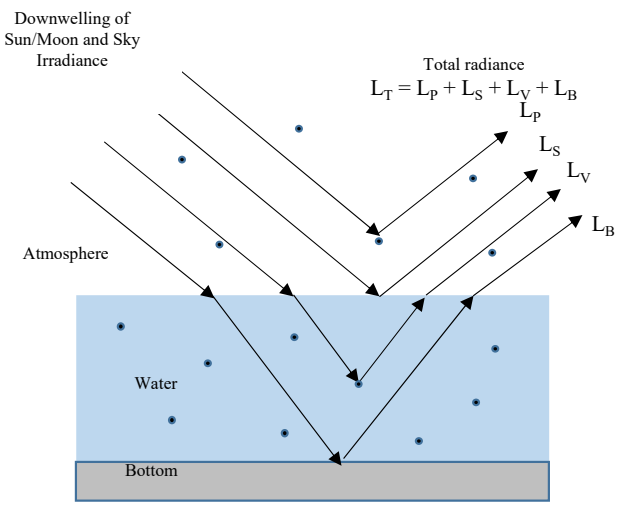
- Two Sensors: Low-light sCMOS with F/1.2 lens
- Coboresighted and synchronized
- Two Filters:
  - Blue: 475nm +/- 25nm
  - Green: 555nm +/- 25nm
- Gimbal: Alticam 09 outer stage with IMU
- Data Acquisition: laptop in aircraft
- Data Analysis: Post-flight

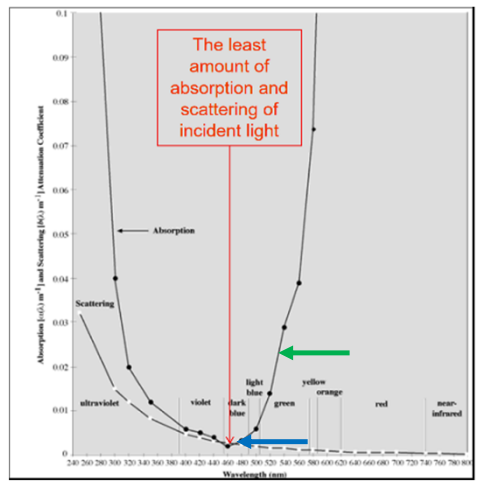


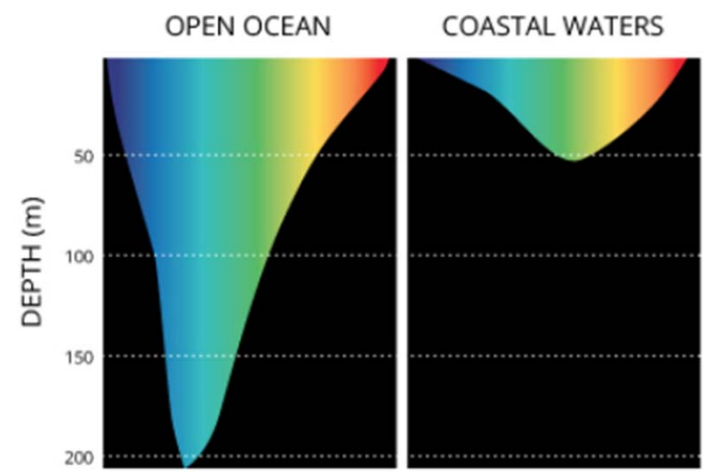


DAYTIME OPERATIONS : SUBMERGED OBJECT IMAGING

SUBMERGED OBJECT IMAGING (THEORY)

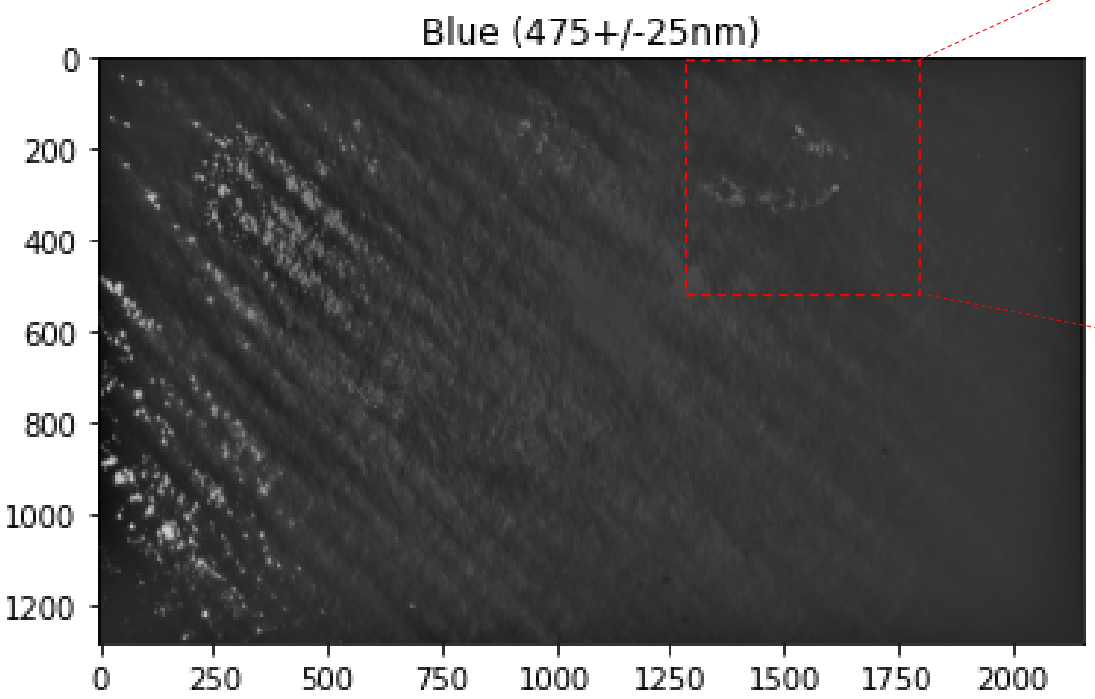


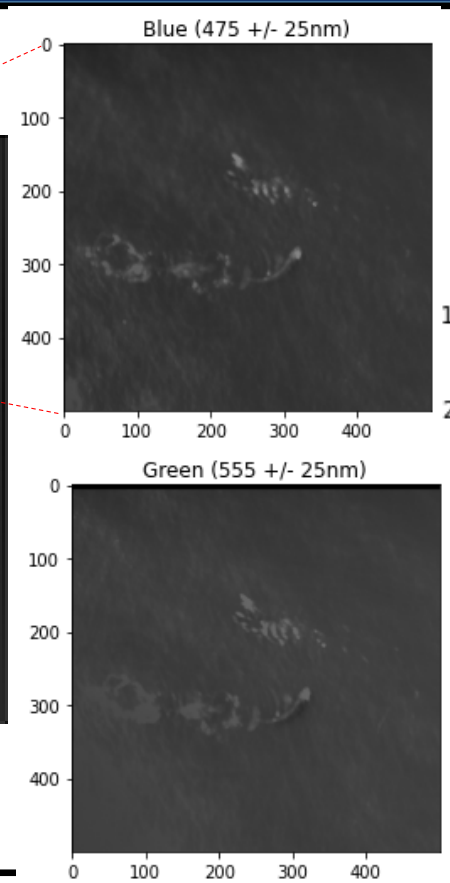


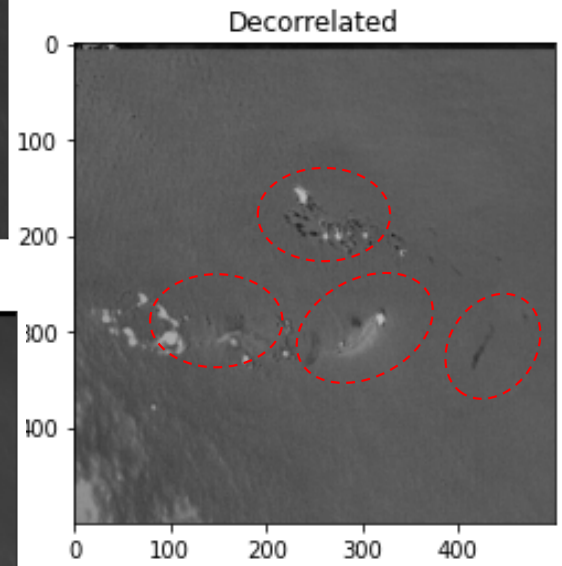


- Decorrelate blue and green to “cancel” the surface-reflected light
- Display the decorrelated intensity

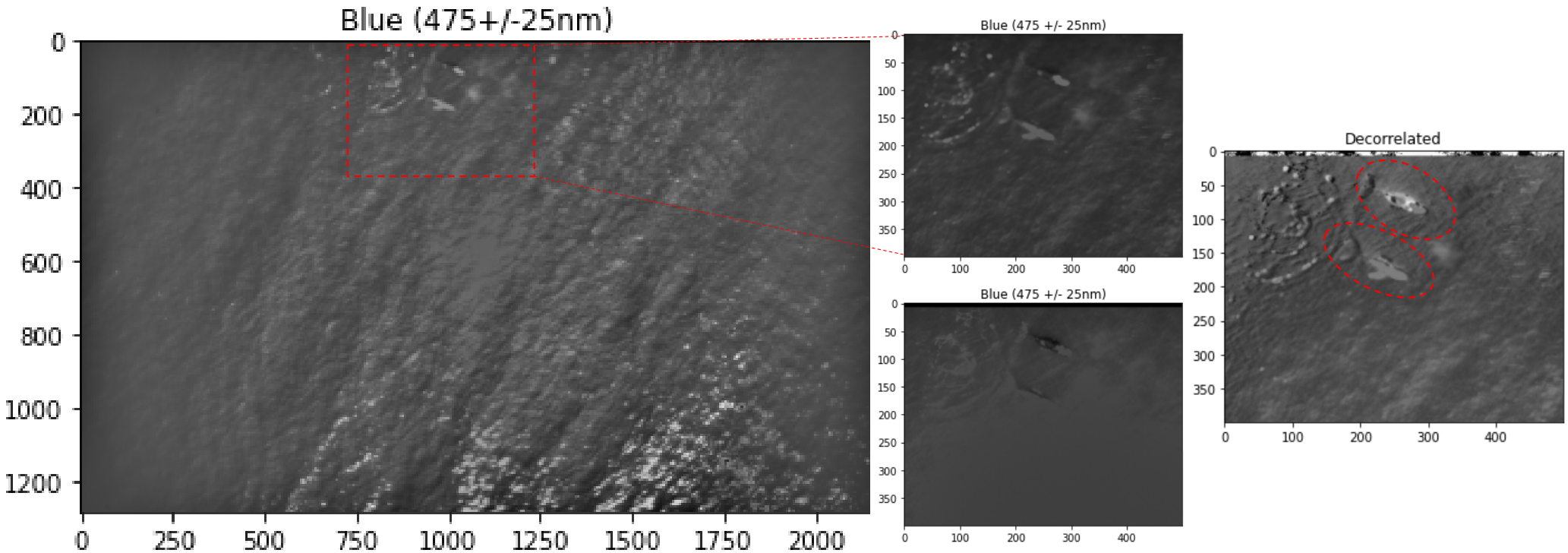
Submerged Object Imaging (Results 1)



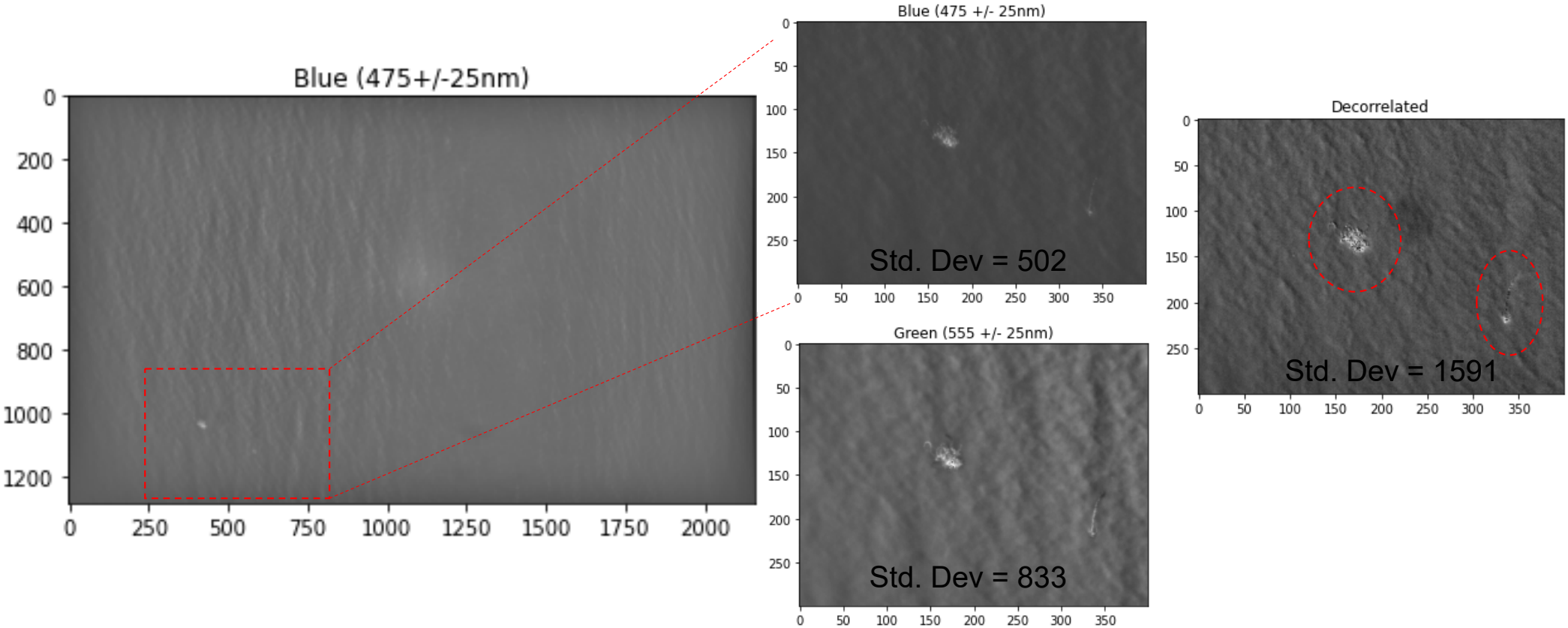




Submerged Object Imaging (Results 2)

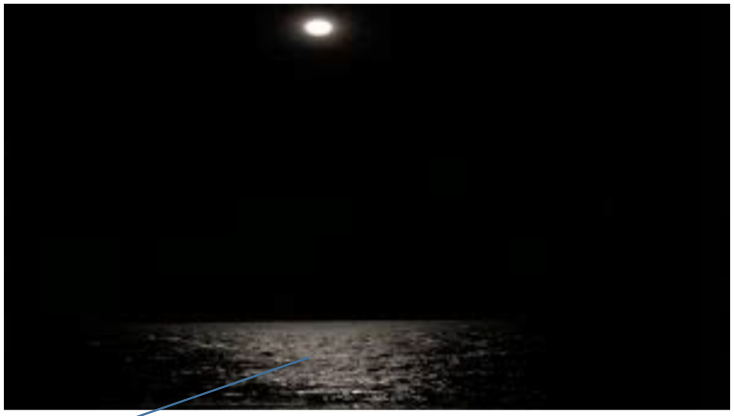


Submerged Object Imaging (Results 3)

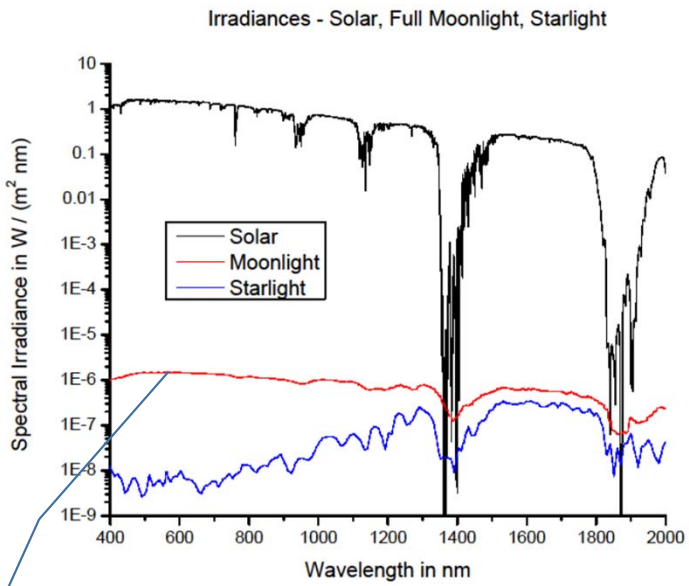


Night-time Operations : Bioluminescence Imaging

Bioluminescence Imaging (Theory)



Decorrelate blue and green images to reduce surface reflection

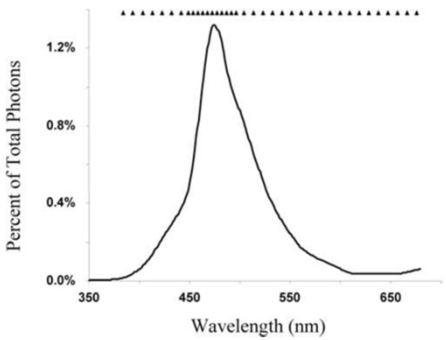


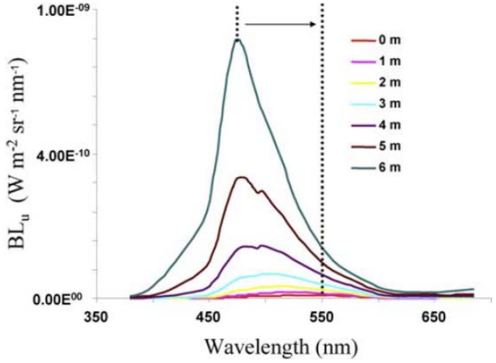
Over a 50nm band, full moon reflected radiance expected as-bright as best-case bioluminescence

BIOLUMINESCENCE IMAGING (THEORY)

Surface radiance depends on

- Type of organism causing the effect (dinoflagellates, zooplankton, bacterial+micro algae etc).
- Stratification of organism (tidal forces, surface wind, etc).
- Depth where these organism are prevalent
- Water clarity
- Water disturbance





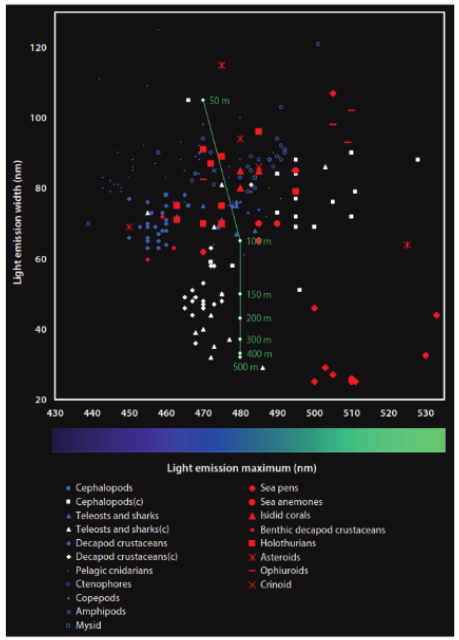
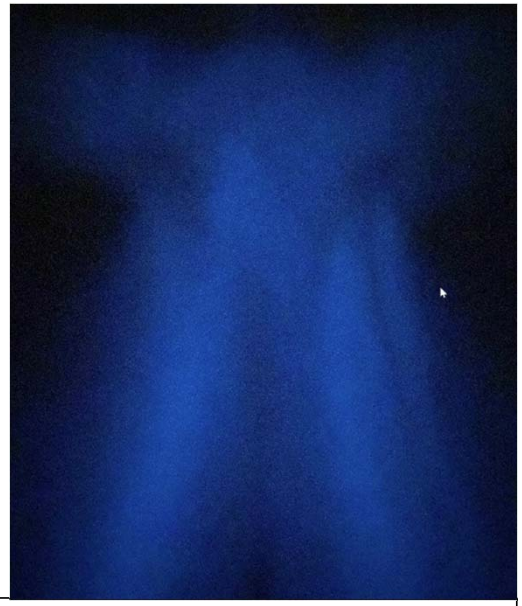


Figure 2.21 Peak wavelength versus emission width (full-width half-max) for the light emissions from deep-sea benthic and mesopelagic species. *White symbols* represent photophores used for counter-illumination (c). *Blue symbols* represent light emitted for other purposes in pelagic species. *Red symbols* represent light emitted by deep-sea benthic species. The *green line* gives the peak wavelength and spectral width of the downwelling irradiance in clear oceanic waters as a function of depth. All spectra are calibrated in energy units. (Modified from Johnsen et al., 2004, and Johnsen et al., 2012)

Bioluminescence Imaging – Test Setup

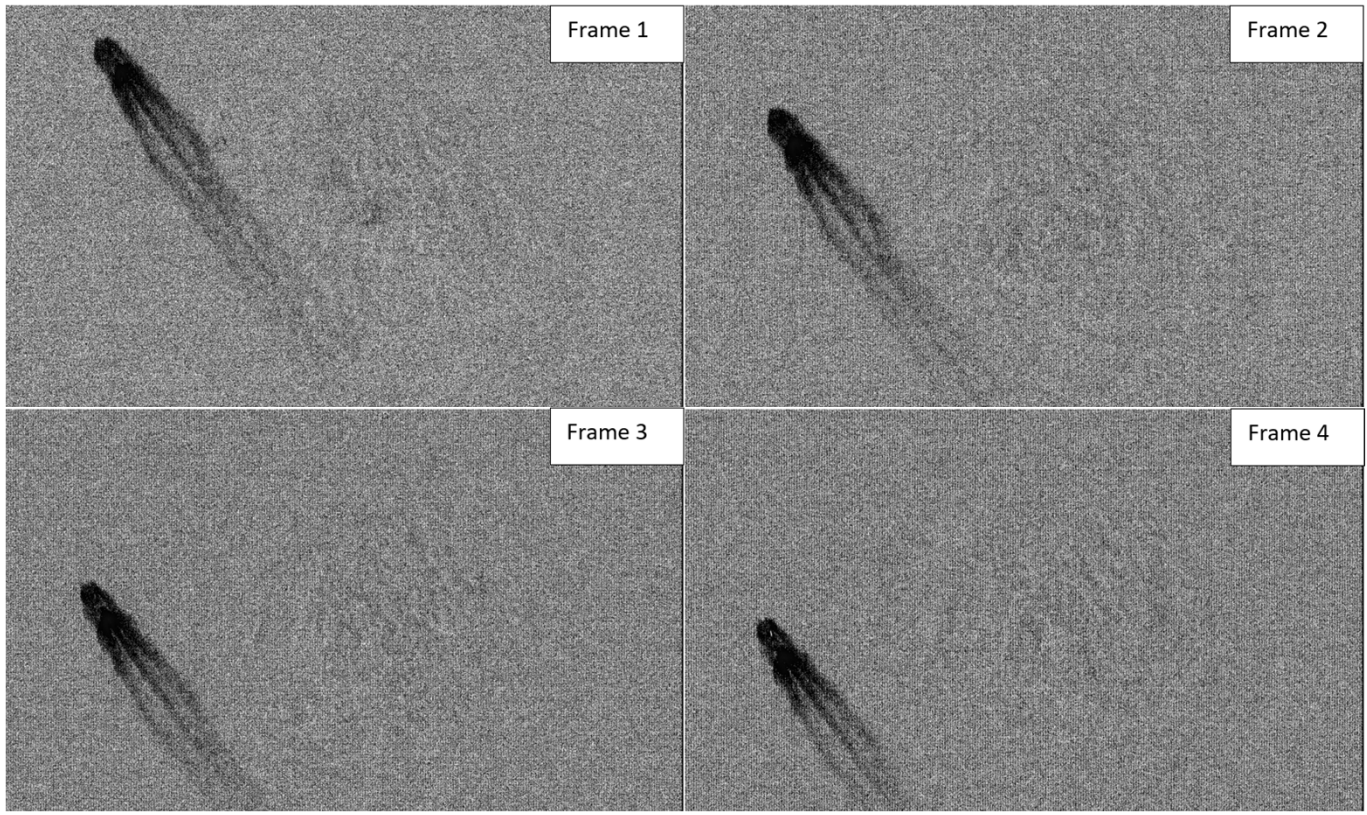
- Location: Santa Barbara
- Date: 28 Oct 2022
- Test conducted after moon set at 20:40.
- Boat location 5 nm from Santa Barbara and from nearby offshore oil rigs.
- No filters used.
- Bioluminescence not seen from airplane.
- Boat captain reported seeing bioluminescence. When boat lights are off, the boat looks “bluish”.
- Boat wake looks blue with no white break water – implying no illumination from external sources like city lights or oil rigs.



- Bioluminescence in the wake, as seen from the boat travelling at 8 knots.
- Exposure: ISO8000, f1.8, 1.1s exposure

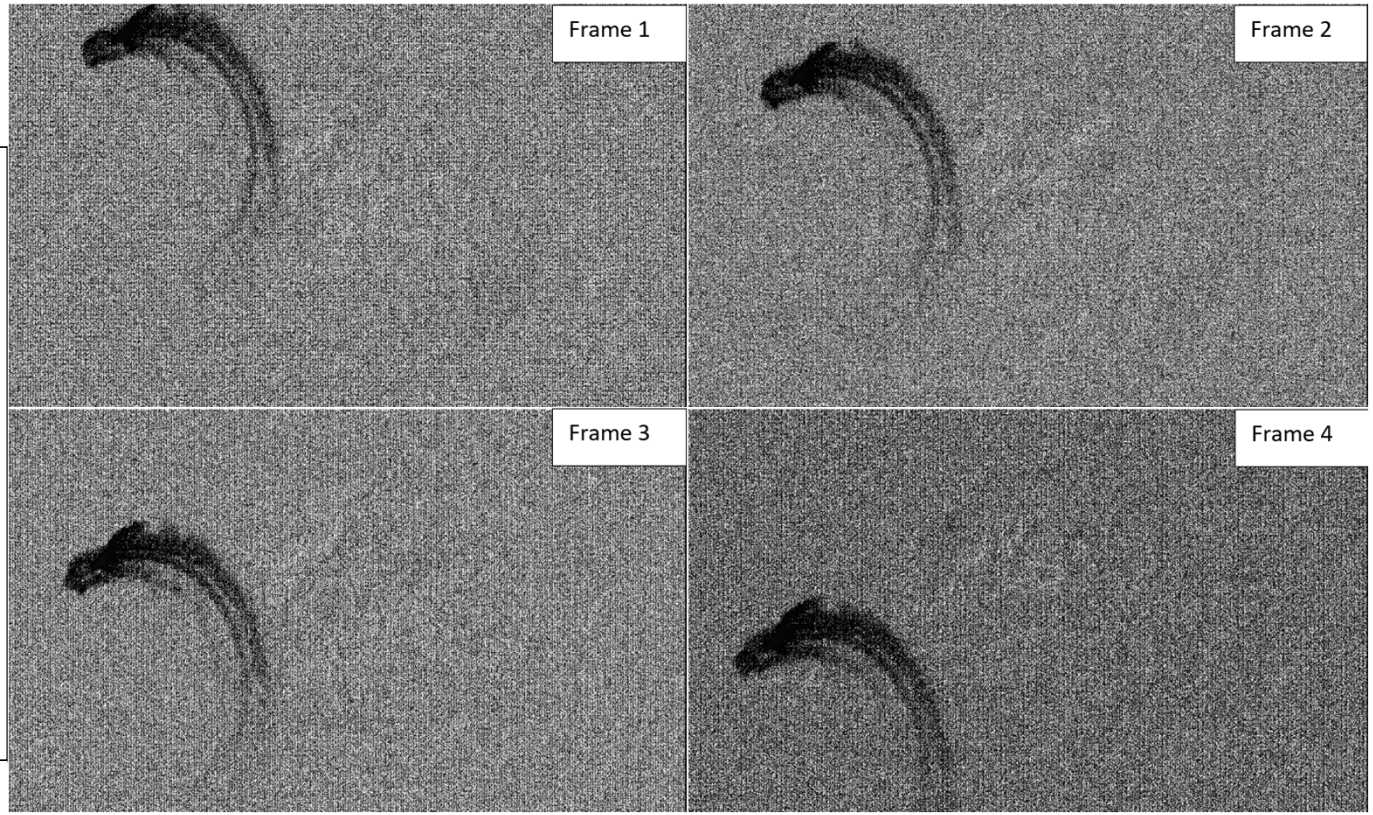
Bioluminescence Imaging (Results)

- Image of boat with lights OFF
- Boat travelling at 10 knots on a 2nm long racetrack.
- Wake and boat illuminated from bioluminescence.
- Altitude = 700ft
- Exposure = 30msec, f1.2
- Sensor gain = x16 Analog, x500 Digital



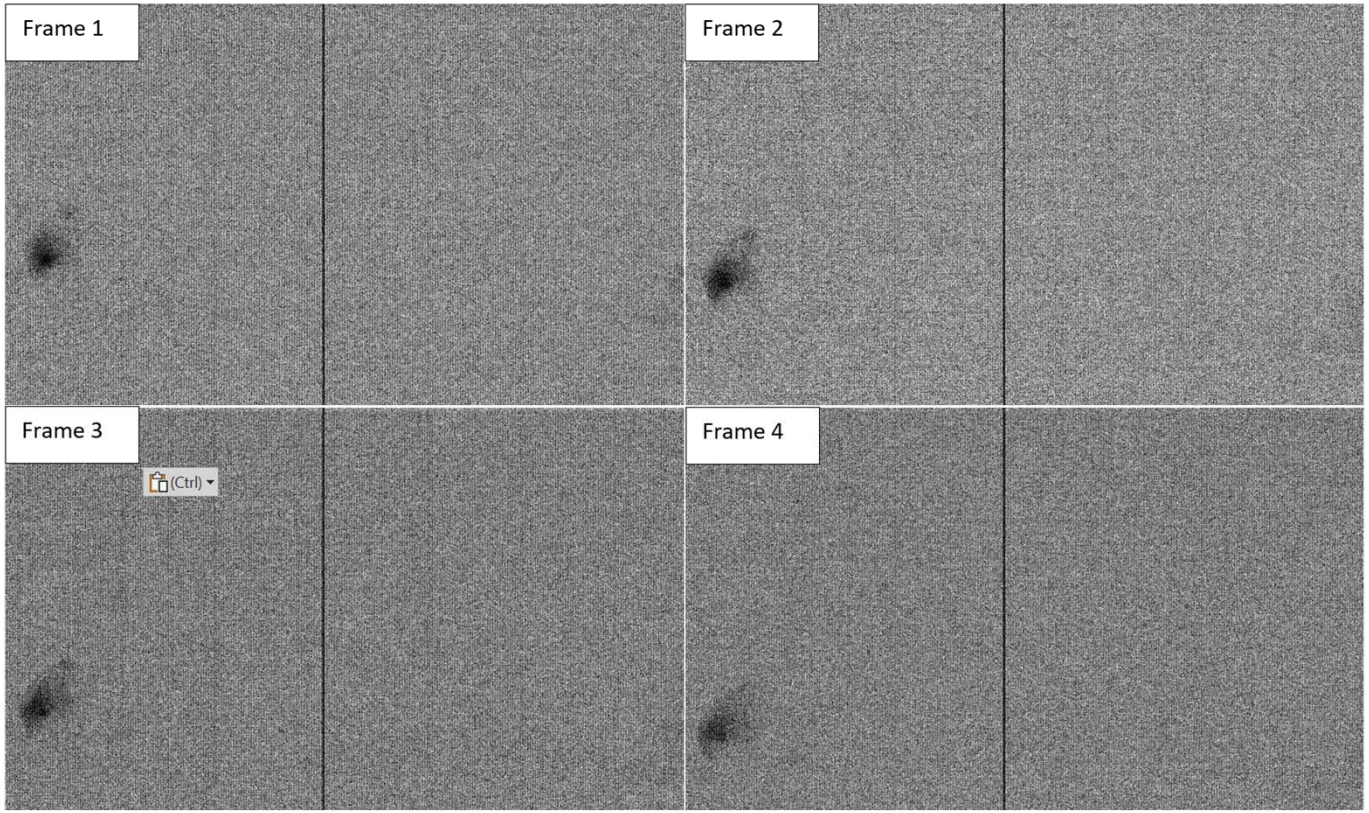
Bioluminescence Imaging (Results)

- Image of boat with lights OFF
- Boat traveling on a figure 8 track.
- Wake and boat illuminated from bioluminescence.
- Altitude = 700ft
- Exposure = 30msec, f1.2
- Sensor gain = x16 Analog, x500 Digital



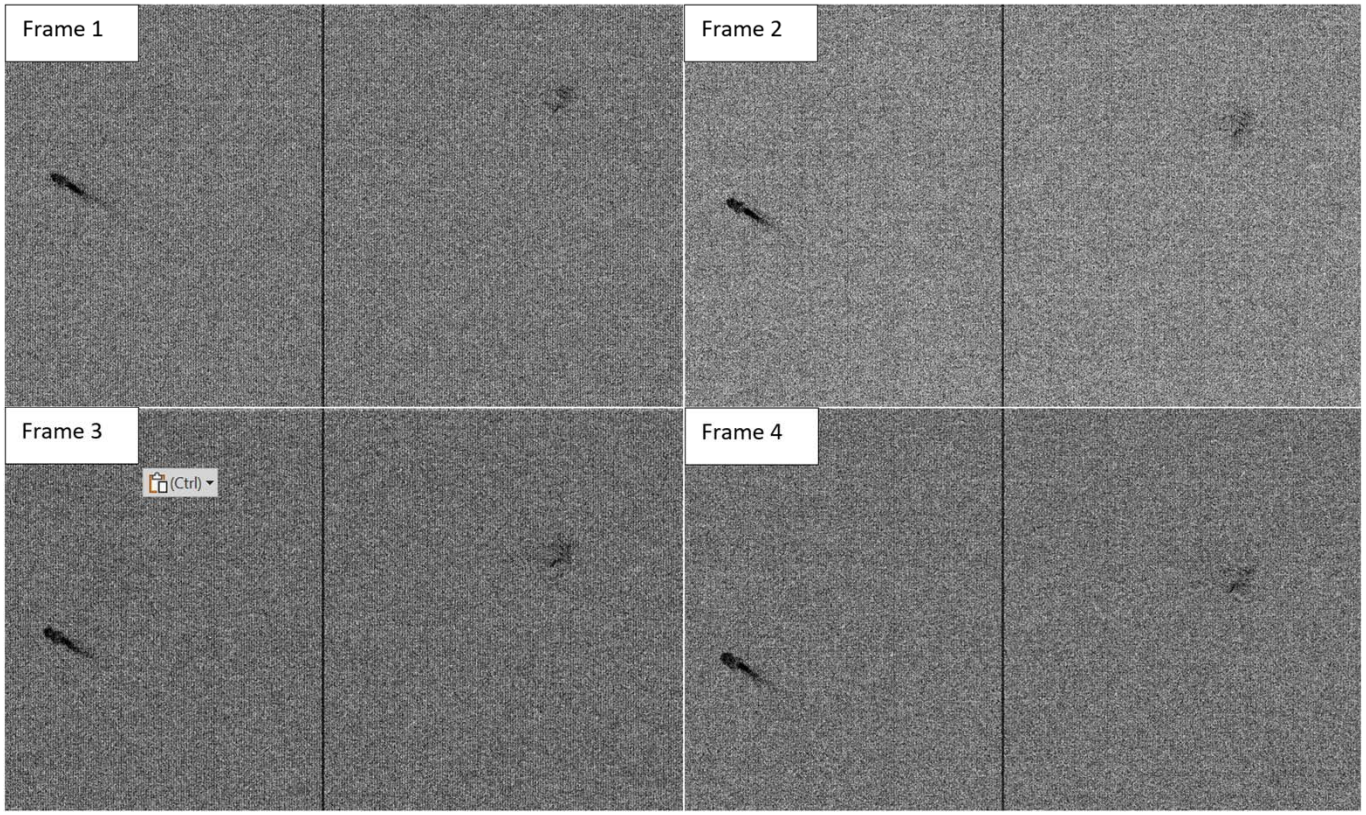
Bioluminescence Imaging (Results)

- Image of blob of excited bioluminescence in water.
- Water likely disturbed by large water mammal, thus exciting bioluminescence
- Altitude = 1000ft
- Exposure = 15 msec, f1.2
- Sensor gain = x16 Analog, x500 Digital
- Vertical line is an artifact of camera operation, now eliminated



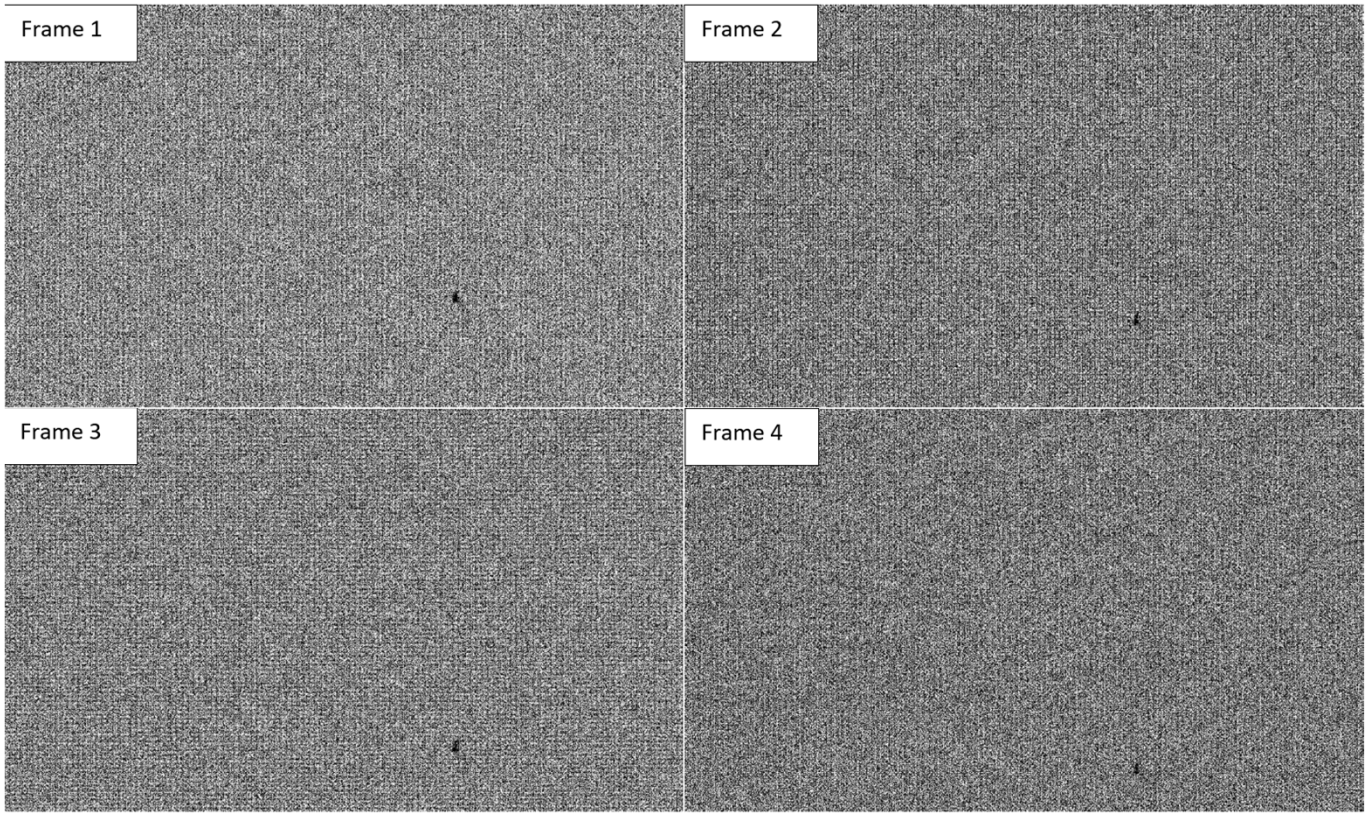
Bioluminescence Imaging (Results)

- Image of boat with no lights and a blob of excited bioluminescence in water.
- Water likely disturbed by large water mammal, thus exciting bioluminescence
- Altitude = 1100ft
- Exposure = 30 msec, f1.2
- Sensor gain = x16 Analog, x500 Digital
- Vertical line is an artifact of camera operation, now eliminated



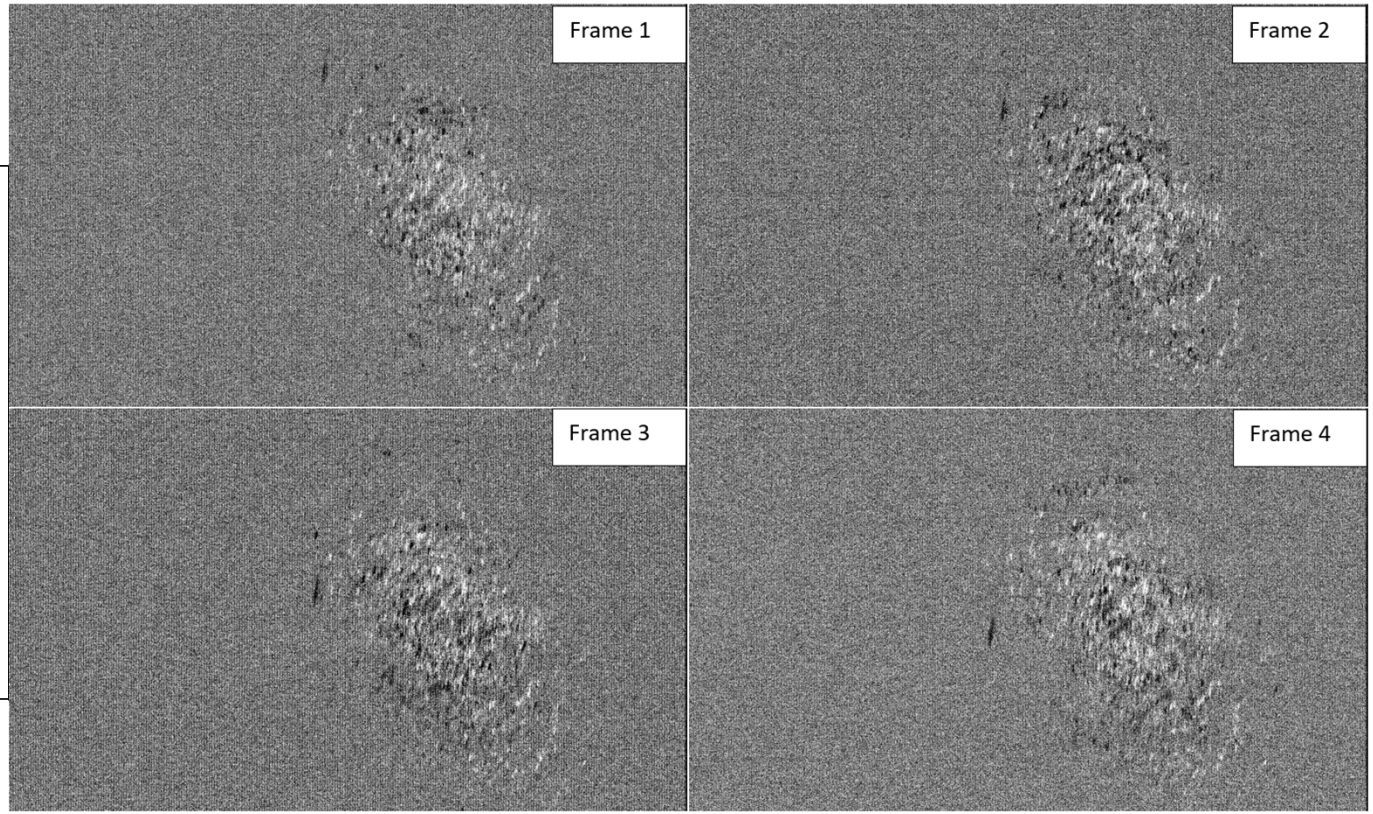
Bioluminescence Imaging (Results)

- Image of a blob of excited bioluminescence in water.
- Water likely disturbed by large water mammal, thus exciting bioluminescence
- Altitude = 1000ft
- Exposure = 30 msec, f1.2
- Sensor gain = x16 Analog, x500 Digital



Bioluminescence Imaging (Results)

- Image of one large marine mammal and several smaller marine mammals exciting bioluminenscence.
- Altitude = 1000ft
- Exposure = 30 msec, f1.2
- Sensor gain = x16 Analog, x500 Digital



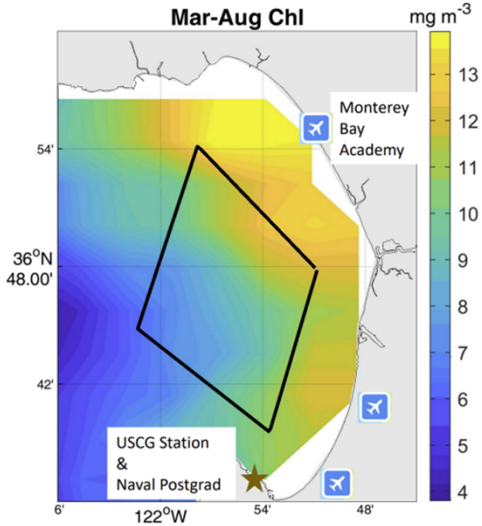
CONCLUSIONS

- Dual-band decorrelation adds value during sun-illuminated operation. Not yet evaluated during night-time bioluminescence imaging.
- Successfully demonstrated the ability to see objects disturbing bioluminescent waters under starlit conditions. (marine mammals and darkened motorboat.)
- Low-light imagers seem capable of detecting light more faint than detectable by human vision.
- Same hardware assembly is applicable to both sunlit imaging and bioluminescence imaging.
- Next steps: Refine methods and gather experience with varying conditions.

Extra Slides

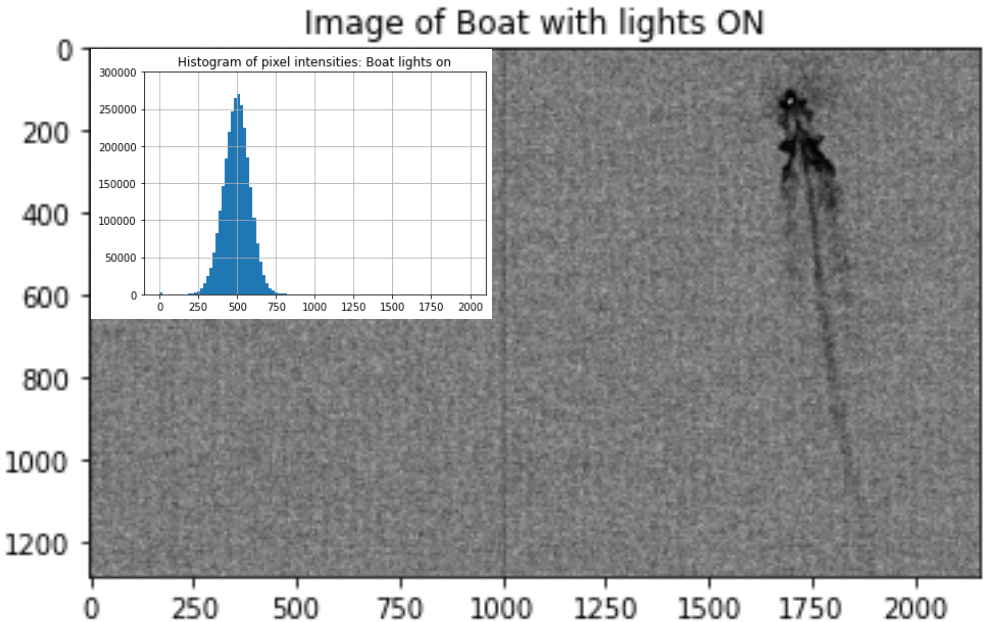
Bioluminescence Imaging – Test Setup

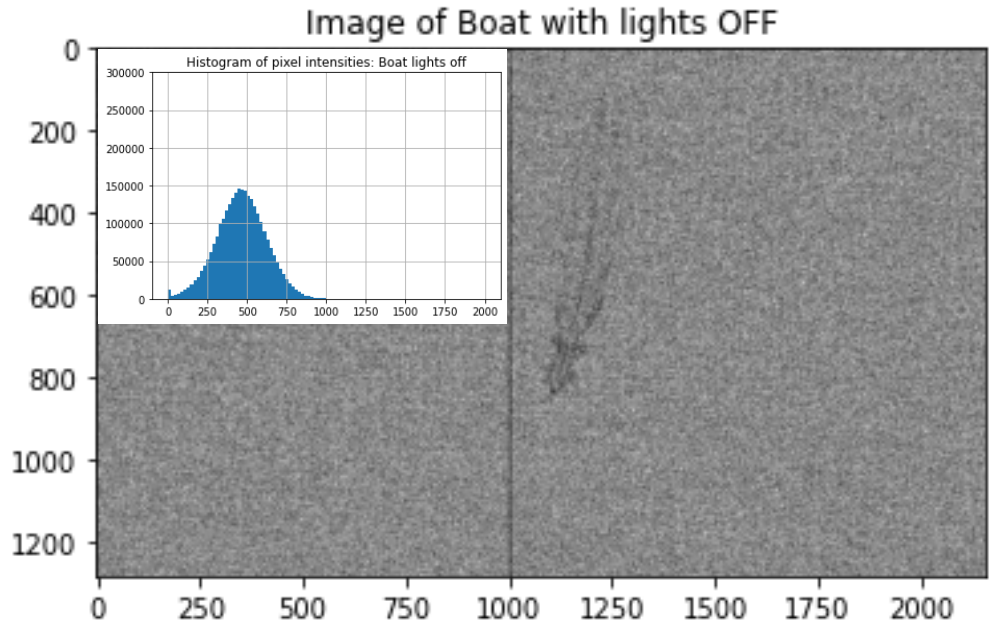
- 27-28 Sept 2022 (new moon)
- No filters used.
- Challenging flying weather
- Eyeballs detected no bioluminescence



Heatmap of likely bioluminescent activity in Monterey Bay.
(Courtesy: MBARI)

Bioluminescence Imaging (Results)



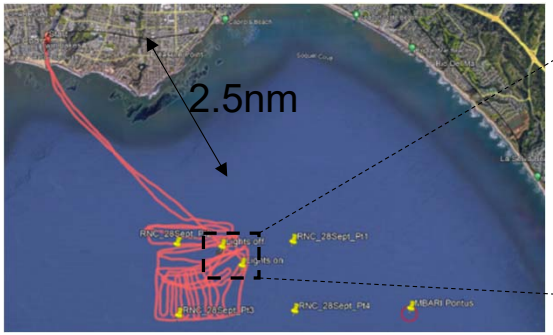


The histogram of both images are restricted approx. 1000 counts (out of 65536)

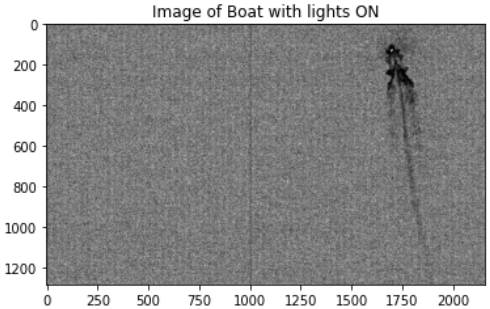
Images have been flat field corrected.

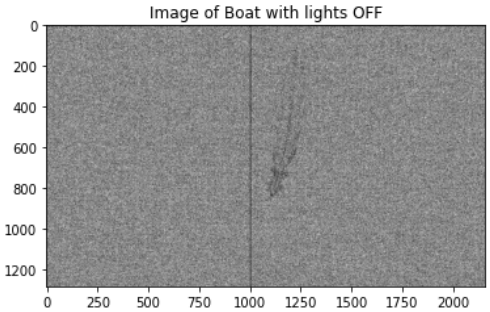
Bioluminescence Detection (Results)

- Difficult to visually spot the boat from aircraft even with boat lights on.
- Captain's log:
  - No blue glow in the wake.
  - Shoreline light from Santa Cruz is visible from the boat.
  - Cloudless night. City glow was not reflected back from clouds.



Use AttNav data from IMU to align images to earth





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