Monitoring coastal ocean color with low-cost CubeSats

Carl Schueler and Alan Holmes

Miniaturization of satellite remote sensing promises lower costs, and SeaHawk is a prime example, offering global coastal ocean color imagery comparable to previous larger and more expensive systems.

The National Research Council recently established the need to sustain and advance satellite ocean color research. Space observations have transformed biological oceanography, advancing knowledge of carbon and nitrogen cycling, showing how the ocean’s biological processes influence climate, and allowing assessment of changes in primary production (the basis of the marine food chain). Continuous ocean color observation is also essential for monitoring the health of the marine ecosystem and its ability to sustain fisheries. Interrupting the ocean color record would hamper the work of climate scientists, fisheries and coastal resource managers, and other users ranging from the military to oil spill responders.

Earth observing (EO) satellite missions have typically required large spacecraft with multiple payloads, resulting in high costs. For example, the 1997 SeaStar satellite (known later as OrbView-1) with its Sea-viewing Wide Field-of-View Sensor (SeaWiFS) cost more than $100M, including the sensor, spacecraft, and launch costs. A constellation of EO CubeSats could change this, providing daily or finer temporal resolution and better spatial resolution for dramatically reduced cost.

CubeSats are small, inexpensive satellites built on a concept created by Stanford University’s Space Systems Development Laboratory and California Polytechnic State University intended to provide less-expensive access to space. SeaHawk is a CubeSat fitted with a low-cost, miniature ocean color sensor known as HawkEye that will allow fine-spatial-resolution observations of the ocean. SeaHawk’s low cost, mass, and volume, and short development time should enable more similar EO missions in the future. SeaHawk (see Figure 1) will be 200 times smaller (10 x 10 x 30 cm³ vs. 50 x 50 x 200 cm³) and 100 times lighter (~3 kg vs. 309 kg) than OrbView-1, with eight times finer resolution (120 m vs. 1 km) and similar signal-to-noise ratio.

Two SeaHawk CubeSats are being built over a two-year period (2015–2017) to be launched in 2018, for a cost of $1.7M. SeaHawk has completed its Critical Design Review. There is no technology development involved because commercial subsystems are used throughout. SeaHawk is a 3U CubeSat composed of a 2U standard bus produced by Clyde Space of Glasgow, Scotland, and a 1U HawkEye multispectral ocean color sensor.

HawkEye uses eight spectral bands with ground sample distance of about 120 m from a nominal 540 km polar orbit. HawkEye’s specifications are summarized in Table 1. The red rectangle in Figure 2 shows HawkEye’s nominal field of view. The system engineering approach driving SeaHawk and HawkEye is based on fitting HawkEye within a 10 cm cube with SeaWiFS radiometry at 120 m nadir resolution from an orbit altitude of 540 km over a 350 km swath. HawkEye’s 120 m resolution dramatically improves imaging capabilities compared to the 1 km resolution of OrbView-1’s SeaWiFS.

Imagery from SeaHawk’s HawkEye sensor will improve the ability to monitor fjords, estuaries, coral reefs, and other nearshore environments where anthropogenic stresses are often most acute and where there are considerable security and commercial interests. HawkEye is in ground testing at Cloudland Instruments, with anticipated completion in 2017 for spacecraft.

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Table 1. HawkEye offers eight Sea-viewing Wide Field-of-View Sensor (SeaWiFS) spectral bands with 140µrad instantaneous field of view per band. SNR: Signal-to-noise ratio. Ltyp: Typical radiance level.

<table>
<thead>
<tr>
<th>Band #</th>
<th>HawkEye band center, nm</th>
<th>Ltyp, W/m² µm sr</th>
<th>HawkEye bandwidth (BW), nm</th>
<th>Predicted HawkEye BW SNR</th>
<th>SeaWiFS specified SNR</th>
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</table>

* 765nm SeaWiFS band modified per NASA request  
**SeaWiFS Ltyp = 2HawkEye Ltyp

Figure 2. HawkEye field of view illustrated with a MODIS image of the Santa Barbara channel. The field of view is approximately 350km cross-track from a 540km altitude via pushbroom scan of the 4080 pixel 120m spatial resolution linear arrays. MODIS: Moderate Resolution Imaging Spectroradiometer.

integration and launch in early 2018. The SeaHawk program, managed by John Morrison of the University of North Carolina-Wilmington (UNC-W), is overseen by members of the former SeaWiFS science team at NASA’s Goddard Space Flight Center. UNC-W is preparing for SeaHawk by developing algorithms to take advantage of the improved 120m spatial resolution compared to the SeaWiFS 1km spatial resolution.

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References


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